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ASSESSMENT OF THE SUITABILITY
OF AGRICULTURAL WASTE WATER
FOR GEOTHERMAL POWER PLANT COOLING
IN THE IMPERIAL VALLEY
I. WATER QUALITY

W. F. Morris
L.P. Rigdon

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ABSTRACT

Evaluation of the quality of agricultural waste water is the first step in assessing the suitability of agricultural waste water for geothermal power plant cooling. In this study samples of agricultural waste water from the New and Alamo rivers located in the Imperial Valley of California are analyzed. Determinations of standard water quality parameters, solids content, and inorganic compositions of the solids are made. The results are compared with data on samples of irrigation water and steam condensate also obtained from sites in the Imperial Valley. The data are evaluated in relation to cooling tower operation, waste generation, and waste disposal.

COOLING WATER REQUIREMENTS FOR GEOTHERMAL POWER PLANTS

Geothermal power plant technologies being developed and tested for utilization in the Imperial Valley geothermal resource area are of two types: the flashed-steam cycle and the binary-fluid cycle. In the flashed-steam cycle (Figure 1) a fraction of the geothermal hot water (20-35%) is flashed to steam and used to drive a turbogenerator to produce electricity. Efficient operation of the turbogenerator is directly related to condensation of steam and reduction of pressure on the downstream side of the turbine. This is achieved in the steam condenser and is affected by the design of the condenser and the cooling tower, the temperature of the cooling water, and the quality of the water supplied to the cooling tower.

In the binary-fluid cycle (Figure 2) hot water from geothermal production wells is pumped through a heat exchanger where the heat is absorbed by a

Fig. 1 Flashed steam cycle power plant (Layton and Morris, 1981)

Fig. 2 Binary fluid cycle power plant (Layton and Morris, 1981)

low-boiling fluid. The low-boiling fluid is vaporized and used to drive a low pressure turbine while the geothermal hot water from which energy has been extracted is injected back into the reservoir. The vapor on the downstream side of the turbine is condensed and returned to the heat exchanger where the cycle is repeated. The efficiency of the binary-fluid cycle power plant is also dependent upon cooling water and the effective operation of the condenser and cooling tower system.

Wet mechanical-draft cross-flow cooling towers are deemed to be best suited for operation in the hot, dry climate typical of the Imperial Valley (Robertson et al., 1981). More than $1.2 \times 10^8 \text{ m}^3$ per year of cooling water can be expected to circulate through the condensers of a 50 MW geothermal power plant utilizing 250°C geothermal fluid. Makeup water required to replace evaporation and blowdown losses is expected to be at least 7 m^3 per MW-h depending on the type of power plant, the heat content of the geothermal fluid used in the plant, the quality of the makeup water, and the design of the tower. This relatively large volume of makeup water for geothermal power plants contrasts with the 2 m^3 per MW-h requirements of a comparable fossil-fuel power plant (Layton, 1978). The difference is directly related to the low heat content of the geothermal fluids, 350 to 450 Btu/lb compared to >1500 Btu/lb for steam produced in a fossil fueled power plant.

AVAILABILITY OF COOLING WATER SUPPLIES

The principal sources of cooling water for potential use in geothermal power plants in the Imperial Valley are: irrigation water imported from the Colorado River in the All American Canal, steam condensate from flashed-steam power plants, Salton Sea water, and waste water discharged from agricultural

lands into the New and Alamo rivers. The relative locations of the surface water sources and the known geothermal resource areas in the Imperial Valley are shown in Figure 3. The availability of any one of these sources or mixtures thereof is not certain at this time due to complications in irrigation priorities, seasonal and yearly variations in supplies, regulatory and technical problems stemming from the qualities of both the supply and receiving water bodies, and the enactment of local, state, and federal requirements, policies, and agreements. Two crucial policies written into the Geothermal Element of the Imperial County General Plan (Imperial County, 1977) potentially limit and possibly exclude the use of irrigation water and steam condensate for power plant cooling. The policies protect water resources in order to allow maximum development of agriculture and at the same time recommend that geothermal developers use sources "other than irrigation water." Furthermore, county policy requires "reinjection of all geothermal fluids extracted from irrigated areas of the county or from any area that could directly impact those irrigated lands."

Of the two remaining sources of water, Salton Sea water is the less desirable. It is a high salinity water approaching 39,000 ppm total dissolved solids (TDS) and, if utilized, would require specialized salt-water cooling tower technology. Concomitant problems include: the need for chemical treatment systems to inhibit scaling and corrosion and relatively frequent discharge of salt-laden blowdown from the cooling tower basin.

Waste waters from agricultural lands in the Imperial Valley drain into the New and Alamo rivers at numerous locations as they flow northward along the length of the Imperial Valley before emptying into the Salton Sea. Setmire (1979) reports that discharge records show that 300,000 Acre feet of agricultural drainage water was discharged into the New river during 1975. This is 3 times the volume that flowed across the international border at

Fig. 3 Surface water sources Imperial Valley California (Layton and Ermak, 1976)

Calexico. The water in both rivers is of relatively poor quality, ranging from 2000 to 4000 mg/l TDS and containing undissolved solids approaching 500 mg/l. Imperial Irrigation District and the California State Water Resources Control Board favor the use of agricultural waste water for geothermal power plant cooling. On the other hand, the California Department of Fish and Game is opposed to its diversion to geothermal use because the flow of water to the Salton Sea would be reduced leading to a potential increase in the salinity of the sea.

Layton (1978) studied all of these factors and determined that certain future water policy combinations and water usage practices could provide sufficient cooling water for substantial geothermal development in the Imperial Valley. The determination is based on the use of a mix of cooling water sources including agricultural waste water, steam condensate and irrigation water, seasonal changes in the mixtures, and possible substitution of agricultural waste water as injection fluid if condensate is used for cooling.

QUALITY OF WATER IN THE NEW AND ALAMO RIVERS

SOLIDS CONTENT

The water in the New and Alamo rivers is made up almost entirely from waste sources. Industrial and domestic wastes apparently are discharged into the New river at Mexicali, before it enters the United States. Setmire (1979) reported high organic-carbon content, the presence of coliform bacteria, and dissolved solids in excess of those subsequently discharged from agricultural fields in the Imperial Valley. Alamo river water entering the United States is not as heavily polluted as the New river; however, like the New river, it

is unsafe for human use. Because agricultural waste water is discharged at numerous points into both rivers and contains lower levels of dissolved solids than that flowing across the border, the quality of the river water, as measured by dissolved solids and organics content, is gradually improved as it approaches the Salton Sea.

Data gathered quarterly by the Imperial Irrigation District from 1975 through 1979 at both river outlets to the Salton Sea show wide seasonal variations in TDS and suspended solids (IID, 1981). The minimum and maximum concentrations and the mean values are given in Table 1. Water quality data have also been obtained by the U.S. Geological Survey (USGS, 1977 and 1978), the U.S. Department of Agriculture (Hermsmeier, 1981), the California State Regional Water Quality Control Board (Morris, 1981), and Pimentel et al., (1978). The preponderance of these data are concerned with dissolved and suspended solids contents while relatively little data were obtained regarding the constituents present in the dissolved and suspended solids. The latter information is essential to make a proper assessment of the suitability of agricultural drainage water for geothermal power plant cooling.

PESTICIDES

Large quantities and a wide variety of pesticides are used by agriculture in the Imperial Valley. Data on file in the Imperial County Agricultural Commissioner's office indicate that application of insecticides is three times greater than herbicides. More than 50% of the insecticides are organic phosphates, 25% carbamates, and 10% chlorinated hydrocarbons. Eccles (1979) conducted an investigation to determine the concentrations, distributions, and sources of pesticide residues in various types of drains and surface runoffs from agricultural fields. The study included 33 of the most widely used

TABLE 1. Total dissolved solids and sediment solids in the New and Alamo rivers during the period 1975 through 1979.¹

	New River		Alamo River	
	Min. - Max.	Mean	Min. - Max.	Mean
Sediment Solids	255-865	543	170-855	510
Total Dissolved Solids	2778-4388	3541	2308-3785	2701

¹ Numbers = milligrams per liter
Data supplied by Imperial Irrigation District, El Centro, CA.

pesticides for which reliable analytical methods were available. Widely fluctuating concentrations were found for virtually all of the pesticides included in the study. Those most frequently detected were DDE, 2,4-D, diazinon, endosulfan, ethyl parathion, and methyl parathion. The report concluded that irrigation runoff and drift from aerial applications were the major sources of pesticide residues.

The determination of the amounts of pesticides and their alteration products in surface runoff and ground waters and the relationship to pesticide application and irrigation management practices are subjects of continuing interest to the U.S. Environmental Protection Agency and the U.S. Department of Agriculture. Spencer (1981) has found considerable variation in the amounts of pesticides in irrigation runoff water. In general, higher amounts of pesticides were found in runoff water following "first irrigations." Herbicides were found in higher concentrations and persisted longer than insecticides. The latter were detected in high concentrations only when aerial application took place during irrigation.

The data from these two studies pertain to agricultural drainage water in the immediate vicinity of agricultural fields. Considerably lower levels of pesticides are predictable in the mixture of various agricultural drainage waters, runoff, and waste waters that make up the flow in the New and Alamo rivers. Data published by Setmire (1979) bears out this conclusion and the U.S. Geological Survey intends to continue the monitoring of pesticides in the two rivers.

COOLING TOWER OPERATION AND ENVIRONMENTAL CONCERNS

Wet mechanical-draft, cross-flow cooling towers are used almost exclusively in The Geysers geothermal power plants and it is expected that this type of technology will be used widely in geothermal power plants in the Imperial Valley. A typical cooling tower facility for a 50 MW power plant incorporates 10 mechanical-draft, cross-flow cells (Figure 4) arranged in a row. Air flowing in through the sides of the cells is drawn out through the top by large fans mounted on each cell. Hot water to be cooled enters at the top of each cell, descends through the fill material, and is broken up into droplets from which heat is removed by evaporative cooling and sensible heat exchange with air. The cooled water is then withdrawn from the base of the tower by means of pumps. Water is lost from the cooling tower mainly by evaporation and periodic discharge of blowdown fluid from the tower basin. The latter fluid discharge and replacement with higher quality makeup water is necessary to minimize salt buildup in the water circulating in the tower. Makeup water is also required to replace the losses due to evaporation. The amount of agricultural drainage water that would be needed to replace water losses in a 50 MW geothermal power plant is estimated by Layton and Morris (1981) to range between $440 \text{ m}^3/\text{h}$ to $660 \text{ m}^3/\text{h}$ depending upon the geothermal resource temperature.

There are several potential environmental problems related to cooling tower operations that must be considered especially if poor quality water such as that from the New and Alamo rivers is contemplated for use in the towers. The concerns, illustrated in Figure 5, have to do with the generation of liquid wastes, the potential generation of solid wastes, and the potential release of toxic substances into the atmosphere from tower emissions. This

Fig. 4 Mechanical draft cross-flow cooling tower cell
(Holmberg and Kinney, 1973)

Fig. 5 Cooling tower waste effluents

study is concerned primarily with the generation of wastes as a result of treatment of makeup water prior to its use in the tower and treatment of blowdown fluids. Whether or not sidestream treatment will be required for geothermal power plants is not known at this time. In any case, the accumulation of wastes from sidestream processes is not considered significant. The impact of emissions resulting from cooling tower drift will depend upon the quality of the water supply (toxic metals, pesticides, etc.), chemicals that are added to control conditions in the towers, and the design and function of drift eliminators. Assessment of this potential environmental problem will be undertaken in a separate study.

Suspended solids (e.g. sediment, organic matter, etc.) contained in the New and Alamo river waters must be removed before circulation of the water in cooling tower systems. Layton and Morris (1981) estimate that between 4.4×10^5 and 6.5×10^5 kg of solids could be accumulated in one year by lowering the solids content in the incoming river water from 200 mg/l to 50 mg/l. They also estimate that greater than 1×10^7 kg of solids could be generated annually if it is found necessary to discharge blowdown fluid to an evaporation pond yielding a final waste product composed of solid salt residue.

These accumulated levels of solid wastes could be reduced to some extent if mixed water supplies combining agricultural waste water and purer sources such as irrigation water and steam condensate were to be utilized. The extent to which waste generation may be alleviated by this recourse can be assessed only if more details are known concerning constituents present in all three water sources.

REGULATIONS

Handling and disposal of wastes associated with the use of agricultural waste water for geothermal power plant cooling will be regulated for the most part under state and federal standards. At the federal level three congressional actions are more or less directly applicable: the Federal Water Pollution Control Act (FWPCA), the Safe Drinking Water Act (SDWA), and the Resource Conservation and Recovery Act (RCRA). In California, virtually all aspects of these federal actions are being implemented by state laws and regulations.

Discharge of effluent is regulated by the California State Water Resources Control Board established by the state legislature under the Porter-Cologne Water Quality Control Act. This act essentially implements the National Pollution Discharge Elimination System (NPDES) permit program required under FWPCA.

The Division of Oil and Gas of the California State Department of conservation is responsible for controlling activities associated with the disposal of waste fluids by injection. These controls are delineated under various subsections of Title 14 of the California Administrative Code pertaining to Natural Resources. The state regulations parallel the Underground Injection Control (UIC) programs promulgated by EPA under the SDWA and are designed to protect underground drinking water sources.

The California State Water Resources Control Board regulates the disposal of solid wastes to land-surface disposal sites under provisions set down in Title 23, Chapter 3 of the California Administrative Code. Wastes are classified into groups according to their impact on the quality of usable waters. Saline fluid from water treatment processes and brines from geothermal plants are considered toxic and capable of significantly impairing

the quality of usable waters. Accordingly, they must be disposed of in a Class I disposal site as defined in Section 2510 of Title 23 of the state code.

At the federal level regulations under RCRA have been promulgated by EPA with the intention of providing a management system for hazardous and non-hazardous wastes. At the present time "drilling fluids, produced waters, and other wastes associated with the exploration, development, and production of geothermal energy" are excluded from regulation and are deemed not to be hazardous under Subtitle C, Part III, Subpart A, Section 261.4(b) of the Hazardous Waste and Consolidated Permit Regulations. However, in spite of this, the wastes are subject to control under Subtitle D which assigns management of solid waste to state and local control.

STUDY OBJECTIVES

The overall objective of this study is to determine from an environmental point of view if it is feasible to use agricultural waste water or mixtures of agricultural waste water, irrigation water and steam condensate for geothermal power plant cooling. The feasibility of using these water sources is affected to a large extent by constituents present in the water. Major concerns have to do with identifying whether hazardous constituents are present in wastes derived from water pretreatment processes and periodic discharge of blowdown from the cooling towers especially in the event the latter is handled by ponding and evaporation techniques. Knowledge of constituents present in the water is also necessary to assess the potential for fouling and scaling of components in the cooling towers such as the drift eliminators intended to minimize the amount of water entrained in air exiting the towers. Constituents present in this entrained water must be known to evaluate the impact of drift on nearby agricultural lands.

The specific objectives of this first phase of the study are:

- To obtain samples of agricultural waste water from the New and Alamo rivers in the Imperial Valley, irrigation water from the All American Canal, and steam condensate from an operating geothermal facility in the Imperial Valley.
- To analyze the samples for the following parameters and specific metals:
 - total dissolved solids (TDS)
 - total undissolved solids (suspended and settleable solids), (TUS)
 - standard water quality parameters, pH, HCO_3^{-1} , CO_3^{-2} , SO_4^{-2} , Cl^{-1} , Mg, Ca, Na, K
 - elemental composition of TDS
 - elemental composition of TUS
 - toxic metals (RCRA), Ag, As, Ba, Cd, Cr, Pb, Hg
 - other metal contaminants, B, Be, Cu, Ni, Sb, Sr, Zn
- To evaluate the data with respect to overall study objectives
- To determine future work.

SAMPLING AND ANALYSIS METHODS

SAMPLING

Water samples were taken at four locations on both the New and Alamo rivers on February 26, 1981 and June 2, 1981. The sampling locations were nearly equally spaced along the lengths of the two rivers from the Salton Sea to the Mexican border. Samples of Colorado river irrigation water were taken from the All American Canal on June 3, 1981 at a point just below the Imperial Dam where the water enters the Canal and at a point 4 miles east of Calexico where the canal turns northwestward into the Imperial Valley. Steam

condensate was provided by the Union Geothermal Division of Union Oil Company and was sampled from the steam handling facilities of Southern California Edison's 10 MW geothermal electric project at Brawley, California.

All of the river and canal sampling locations were spanned by bridges where it was possible to lower a weighted one liter wide-mouth polypropylene sample bottle into the water at midstream. The weighted bottle, secured to a line, was held a few inches above the water, then dropped so that it would sink rapidly and fill within a descent of 1.5 to 2 feet. Duplicate samples were transferred to polypropylene bottles and sealed with plastic tape for transportation to Lawrence Livermore National Laboratory (LLNL) for analysis. On the June field trip, silica and pH measurements were made when the samples were taken.

ANALYSIS

Undissolved Solids

One each of the duplicate water samples was shaken vigorously and the solids were allowed to settle for one hour. Most of the water containing suspended solids was then decanted into a graduated cylinder. The settled and the suspended solids fractions were filtered separately through tared 0.45 μm polycarbonate membranes then dried at 90°C, allowed to cool in a dessicator, and weighed. The separately determined weights for the settled and suspended solids were combined to give the total undissolved solids values. The solids on the filter membranes were then stored in covered petri dishes for subsequent compositional analysis by optical spectrography. The filtrates were retained for determination of total dissolved solids and other standard water quality parameters.

Total Dissolved Solids

Either 50 or 100 ml aliquots of the filtrates retained from the undissolved solids determination were transferred to tared 150 ml platinum dishes and evaporated to dryness on a steam bath. The residues were then heated in an oven at 103°C for two hours, allowed to cool in a dessicator and weighed. Subsequently, the residues were heated at 600°C for two hours so that fixed and volatile TDS could be determined in accordance with the American Society for Testing and Materials (ASTM) procedure D1888.

Determination of pH

The pH of all samples was measured at LLNL using a conventional laboratory pH meter. Field measurements of pH were performed only on the June field trip by a colorimetric method using a portable test kit. There were no significant differences between the field and laboraotry pH measurements.

Determination of Standard Water Quality Parameters

The water quality parameters Ca, Mg, Cl^{-1} , CO_3^{-2} , HCO_3^{-1} , Na, K, SO_4^{-2} , and SiO_2 were determined by standard assay or commonly accepted methods. The Ca and Mg were determined by titration with EDTA, Cl^{-1} by titration with Hg^{+2} , CO_3^{-2} and HCO_3^{-1} by titration with H_2SO_4 , and Na and K by plasma spectroscopy. The SO_4^{-2} was determined by nephelometric and colorimetric methods and SiO_2 was determined colorimetrically. Only two determinations of SiO_2 were made in the field; these were in agreement with the laboratory determinations.

Solids Composition and Trace Constituent Determinations

Major elements, metal contaminants, and the RCRA designated toxic metals were estimated in residues of the total dissolved solids and undissolved

solids by optical emission spectroscopy. The spectra of the residues were compared with spectra of standard silicate rocks obtained from the U.S. Geological Survey and mixed-base standards synthesized in the laboratory.

ANALYTICAL RESULTS

The concentrations of total undissolved solids, total dissolved solids, and values determined for the standard water quality parameters in New and Alamo river waters, All American Canal water, and steam condensate are given in Tables 2, 3, 4, and 5*.

Constituents present in the residues of total dissolved solids and total undissolved solids (settleable and suspended solids) for the New and Alamo river water samples are summarized in Tables 6 and 7*. The values listed represent the range of concentrations obtained for four samples from four sites on each of the two rivers.

Constituents present in the residues of total dissolved solids for the samples of All American Canal water and steam condensate are given in Tables 8 and 9*. Because undissolved solids in these two types of waters were very low and the recoverable residues were small, spectrographic analyses were not performed on total undissolved solids.

* Table 2 through 9 are attached at the end of the text.

EVALUATION OF THE ANALYTICAL DATA

NEW AND ALAMO RIVER WATERS

Relatively high levels of undissolved solids are present in the New and Alamo river waters (Tables 2 and 3). These solids can adversely affect heat exchange surfaces, pumps, and other components in a cooling tower. Therefore, separation of the readily settleable and suspended solids from the water prior to circulation in cooling towers will be necessary. Since the solids are composed of elements commonly found in silicate-base soils (Tables 6 and 7) and do not appear to contain toxic elements, special handling and disposal of the separated solid waste should not be required.

Total dissolved solids in the New and Alamo river waters were found at high levels as expected. The values shown in Tables 2 and 3 along with the concentrations of Ca, Na, CL, SO_4 , and other parameters indicate that scaling and other adverse effects are possible after only a few cycles of concentration in a cooling timer unless counter-measures are taken. The presence of relatively high levels of the scale-producing constituents Ca and SO_4 should be a matter of some concern not only because of the potential for fouling of cooling tower components but also because of scaling that could take place in injection wells utilized for disposal of salt-laden blowdown fluid. As shown in Tables 2 and 3, Na and CL compose about 60 percent of the total dissolved solids in New river water and approximately 40 percent in water from the Alamo river. Other than these salt components, no other toxic constituents were detected (Tables 6 and 7) that would classify the solids as hazardous. However, if injection of blowdown is not successful and if it is found necessary to dispose of blowdown fluid by ponding and evaporation, then the presence of high levels of NaCl in the residual waste will very likely require disposal in accordance with state hazardous waste regulations.

All American Canal Water

As expected the chemical analysis of All American Canal water (Table 4) indicates water of relatively high quality. Undissolved solids are very low and total dissolved solids are only 900 mg/l. Also the data in Table 8 show that toxic elements are not present in the residues of dissolved solids. The low concentrations of scale forming constituents in the canal water suggest that many cycles of concentration of the water circulating in a cooling tower are possible.

Existing restrictive-use policies provide only limited use of irrigation water for geothermal power plant cooling. The data presented here indicate that the water is of relatively high purity and may be used effectively as a diluent in making up cooling water from less-pure agricultural waste water sources or as a diluent of waste fluids to facilitate effective injection.

Steam Condensate

Table 5 shows that steam condensate is essentially free of undissolved solids and contains only 56 mg/l of total dissolved solids composed mainly of Na, B, CL and SO_4 . The presence of B in the condensate gives cause for some concern specifically with regard to cooling tower drift. If drift eliminators in cooling towers using condensate makeup water do not operate efficiently, then it is possible that B dissolved in the water droplets blown from the tower as drift, could deposit on nearby farmlands and damage crops.

Based on the analysis of condensate performed in this study B appears to be the element of major concern. The detailed list of elements in the total dissolved solids (Table 9) does not show the presence of any other toxic constituents that would adversely affect cooling tower operations or disposal of waste discharges.

CONCLUSIONS

The inorganic composition of agricultural waste water samples taken from the New and Alamo rivers in February and June of 1981 has been determined. The data have been compared with compositions of All American Canal irrigation water and steam condensate. The findings of the study are summarized as follows:

- Undissolved solids in the New and Alamo rivers are composed of readily settleable and suspended solids. These solids are present in the water at levels sufficiently high to require separation prior to circulation in cooling towers.
- The undissolved solids in the New and Alamo river waters are composed of elements typically found in silicate soils. Toxic elements were not detected in the solids. Therefore from the standpoint of inorganic constituency, determined by this study, wastes generated by separation of these solids are not deemed to be hazardous.
- The total dissolved solids in the New and Alamo river waters range between 2100 and 4900 mg/l. Scale-forming constituents, especially Ca and SO_4 are present in the water at levels that will produce scale after only a few cycles of concentration unless water treatment measures are taken either to retain the scale-producers in solution or to remove them prior to circulation of the water in a cooling tower. NaCl in the dissolved solids ranges from approximately 40 to 60 percent; however other toxic elements were not detected in the solid residues. Based on the compositional and trace element determinations of this study, solid wastes from ponding and evaporation of blowdown fluid are not likely to contain toxic metals

but will contain sufficient NaCl to classify the wastes as hazardous according to California state regulations.

- All American Canal irrigation water and steam condensate from the Brawley demonstration plant are of relatively high quality. No toxic elements were detected in concentrated solids from the irrigation water. However, B is present in steam condensate at a sufficiently high level to cause some concern in connection with cooling tower drift if condensate is used for make-up water.

The chemical analyses performed in this study have focused on the determination of inorganic constituents. Other chemical analysis studies must be undertaken before the suitability of agricultural waste water for geothermal power plant cooling can be thoroughly assessed. The studies include:

- Identification of pesticide compounds and determination of their concentrations in New and Alamo river waters.
- Identification and quantitation of other organic species, bacteria, and living organisms in the waters.
- Evaluation of the water treatment required to deal with cooling tower operational problems imposed by the use of agricultural waste water.
- Evaluation of the secondary effects caused by the use of water treatment chemicals.

TABLE 2. Chemical Analysis of New River Water.¹

Parameter	Gentry Road		Western Avenue		Route S28		La Brucherie Road	
	2/81	6/81	2/81	6/81	2/81	6/81	2/81	6/81
pH	7.7	7.8	7.6	7.8	7.7	8.0	7.2	8.0
TDS	4180	3856	4676	3873	4372	4140	4916	4427
TUS	269	313	241	367	201	312	54	67
Na	1008	911	1200	934	1090	992	1260	1062
K	33	44	41	47	41	51	64	68
Ca	247	223	340	213	250	230	266	238
Mg	116	101	77	99	117	98	129	107
Cl	1510	1404	1772	1427	1635	1561	1929	1729
SO ₄	920	675	972	712	927	775	854	687
CO ₃	<15	<15	<15	<15	<15	<15	<15	<15
HCO ₃	271	270	290	275	270	292	282	298
SiO ₂	NA	20	NA	22	NA	24	NA	29

¹ Numbers = milligrams per liter (except for pH)

NA = Not analyzed

TDS = Total dissolved Solids

TUS = Total undissolved solids (settleable and suspended solids)

Na through SiO₂ were determined in the filtrates after removal of settled and suspended solids.

Samples taken on February 26, 1981 and June 3, 1981.

TABLE 3. Chemical analysis of Alamo River Water.¹

Parameter	Sinclair Road		Shank Road		Route S28		Heber Road	
	2/81	6/81	2/81	6/81	2/81	6/81	2/81	6/81
PH	7.6	7.8	7.5	8.0	7.4	7.7	7.7	8.0
TDS	2181	2845	2352	2918	2342	2696	2120	2298
TUS	534	495	687	349	553	349	71	132
Na	444	551	455	550	453	505	416	432
K	10	12	10	12	10	10	10	11
Ca	176	202	178	216	198	218	178	196
Mg	78	107	88	108	79	92	72	76
Cl	503	681	525	710	500	622	464	516
SO ₄	790	958	838	900	858	888	764	712
CO ₃	<15	<15	<15	<15	<15	<15	<15	<15
HCO ₃	189	263	220	273	216	277	240	314
SiO ₂	NA	12	NA	13	NA	11	NA	15

¹ Numbers = milligrams per liter (except for pH)

NA = Not analyzed

TDS = Total dissolved Solids

TUS = Total undissolved solids (settleable and suspended solids)

Na through SiO₂ were determined in the filtrates after removal of settled and suspended solids.

Samples taken on February 26, 1981 and June 3, 1981.

TABLE 4. Chemical Analysis of All American Canal Water.¹

Parameter	Imperial Dam ²	Imperial Valley ³
pH	8.2	8.2
TDS	897	907
TUS	1	8
Na	145	148
K	5	5
Ca	93	97
Mg	32	33
CL	127	129
SO ₄	300	330
CO ₃	<15	<15
HCO ₃	182	188
SiO ₂	2	10

¹ Numbers = milligrams per liter (except for pH)

² Sample taken at McKinley Road, just below the Imperial Dam, June 3, 1981.

³ Sample taken at Anza Road, 4 miles east of Calexico, Imperial Valley, June 3, 1981.

TABLE 5. Chemical analysis of steam condensate.¹

Parameter	Value
pH	9.2
TDS	56
TUS	<1
B	8
Na	5
K	<.2
Ca	.05
Mg	.01
Cl	17
SO ₄	22
CO ₃	>660 ²
NH ₄	>383 ³
HCO ₃	≤ 60
SiO ₂	.1

- ¹ Numbers = milligrams per liter (except for pH)
Sample supplied by Union Geothermal Division, Union Oil Company, 10 MW power plant, Brawley, CA.
- ² Milliequivalents of acid titratable species calculated as CaCO₃. Sample not stabilized, therefore, value is probably low.
- ³ Milliequivalents of ammonia nitrogen (kjeldahl) calculated as NH₄. Sample not stabilized, therefore, value is probably low.

TABLE 6. Constituents determined in solids from the New river.¹

	Total Undissolved Solids				Total Dissolved Solids	
	February 1981		June 1981		February 1981	June 1981
	Settleable	Suspended	Settleable	Suspended		
Major Constituents, weight %						
Al	5-6	5-6	4-5	4-5	.002-.01	<.001-.002
Ca	3.5-4	2.5-3.5	2-3	3-3.5	see Table 2	see Table 2
Fe	2.5-3	2.5-3.5	2-3	1.5-4	.001-.01	<.001-.002
K	2-2.5	.5-2	.5-1	.8-1	see Table 2	see Table 2
Mg	2-2.5	1.5-2	.8-1	.5-1.5	see Table 2	see Table 2
Na	.5-1	.5	.2-.5	.5	see Table 2	see Table 2
Si	15-20	15-20	12-18	12-18	NA	see Table 2
Minor and Trace Constituents, µg/gm						
Ag	<1-2	1-2	<.3	<.3-.3	<.3	.3-1
As	<30	<30	<30	<30	<30	<30
B	60-100	40-100	40-50	50	250-350	200-300
Ba	500-700	250-500	250-300	250-300	80-100	40-70
Be	0.5-1	0.5-1	0.3-1	.3-1	<.3	<.3
Bi	<10	<10	<10	<10	<3	<3
Cd	<10	<10	<10	<10	<10	<10
Co	10-15	10-15	5-15	5-10	<3	<3
Cr	50-75	30-60	20-25	25-40	<1	<1
Cu	40-60	40-60	10-20	25-30	3-4	2-5
Hg	<20	<20	<20	<20	<20	<20
Mn	700-800	700-1200	500-800	500-900	<3	<3
Mo	<10	<10	<10	<10	5-15	5-15
Ni	40-50	40-60	20-30	20-40	<3	<3
P	1000-2500	700-2500	800-1200	800-1200	<400	<400
Pb	<10	<10-20	<10	<10	<3	<3
Sb	<30	<30	<30	<30	<30	<30
Sn	<3	<3	<3	<3	<3	<3
Sr	200-300	200-250	100-150	150-200	800-1000	700-800
Ti	2500-3500	2500-3500	2000-3000	2000-3000	<3-10	<3
V	80-120	80-120	20-60	30-80	<10	<10
Zn	30-40	20-40	20-40	40-60	<10	<10
Zr	200-250	100-200	150-250	150-200	<3	<3

¹ Range of concentrations for four samples from four sites on the New river
 NA = Not analyzed

TABLE 7. Constituents Determined in Solids from the Alamo River.¹

	Total Undissolved Solids				Total Dissolved Solids	
	February 1981		June 1981		February 1981	June 1981
	Settleable	Suspended	Settleable	Suspended		
Major Constituents, weight %						
Al	5-6	4.5-6	4-5	4-5	.002-.004	.003-.006
Ca	3.5-4	3-3.5	2-4	2.5-3	see Table 3	see Table 3
Fe	3-4	3-4	2-3	1.5-4	.001-.002	.0015-.0025
K	1.4-2.5	2-2.5	1-2	.8-1.5	see Table 3	see Table 3
Mg	1.5-2	1.5-2	1-1.5	1-1.5	see Table 3	see Table 3
Na	.3-1	.3-.7	.3-.5	.2-.5	see Table 3	see Table 3
Si	15-20	15-20	12-18	12-18	NA	see Table 3
Minor and Trace Constituents, µg/g						
Ag	<.3	<.3	<.3-3	<.3	<.3	<.3
As	<30	<30	<30	<30	<30	<30
B	60-70	50-100	50-70	40-60	200-250	200-250
Ba	400-600	300-500	200-300	250-300	80-100	30-40
Be	.5-1.5	.5-2	.3-1	.3-1	<.3	<.3
Bi	<10	<10	<10	<10	<3	<3
Cd	<10	<10	<10	<10	<10	<10
Co	10-15	10-15	10-15	5-10	<3	<3
Cr	40-50	40-50	25-40	25-40	<1	<1
Cu	30-50	25-45	10-15	15-25	3-5	2-4
Hg	<20	<20	<20	<20	<20	<20
Mn	800-2000	500-1200	300-1500	800-1100	<3	<3
Mo	<10	<10	<10	<10	10-20	20-30
Ni	20-30	20-30	25-40	20-40	<3	<3
P	1200-2000	800-1500	800-1200	800-1200	<400	<400
Pb	<10	<10	<10	<10	<3	<3
Sb	<30	<30	<30	<30	<30	<30
Sn	<3	<3	<3	<3	<3	<3
Sr	250-350	200-300	150-200	150-200	900-1100	700-900
Ti	2500-3500	2500-3500	2000-3000	2000-3000	<3-3	<3-3
V	80-120	80-120	60-90	30-60	<10	<10
Zn	40-70	35-50	35-45	20-50	<10	<10
Zr	150-250	150-250	150-250	150-250	<3	<3

¹ Range of concentrations for four samples from four sites on the Alamo river.
 NA = Not analyzed

TABLE 8. Constituents determined in total dissolved solids from All American Canal water.

Constituent	Concentration, $\mu\text{g/g}$	
	Imperial Dam ¹	Imperial Valley ²
Ag	<.3	<.3
Al	25	25
As	<30	<30
B	50	30
Ba	60	60
Be	<.3	<.3
Bi	<3	<3
Cd	<10	<10
Co	<3	<3
Cr	<1	10
Cu	6	4
Hg	<20	<20
Fe	300	90
Mn	20	<3
Ni	1	<1
P	<400	<400
Pb	<3	<3
Sb	<30	<30
Si	1600	1200
Sn	<3	<3
Sr	600	600
Ti	20	5
V	<10	<10
Zn	<10	<10
Zr	<3	<3
Ca, K, Mg, Na	see Table 4	

¹ Sample taken at McKinley Road, just below the Imperial Dam, June 3, 1981.

² Sample taken at Anza Road, 4 miles east of Calexico, Imperial Valley, June 3, 1981.

TABLE 9. Constituents determined in total dissolved solids from steam condensate.

Constituent	Concentration, $\mu\text{g/g}$
Ag	<.3
Al	40
As	<30
Ba	60
Be	<.3
Bi	<10
Ca	800
Cd	<10
Co	<3
Cr	6
Cu	30
Fe	1500
Hg	<20
K	<300
Mg	100
Mn	40
Ni	50
P	<300
Pb	5
Sb	<30
Si	1000
Sn	<3
Sr	30
Ti	30
V	<10
Zn	<10
Zr	<10

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