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MANAGEMENT PLAN - FISCAL YEAR 1981

Environmental Control Technology Project
Geothermal Development

Prepared by:
W. F. Morris and F. B. Stephens

For:
Environmental and Safety Engineering Division
Office of Environment
Department of Energy

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October 14, 1980

Lawrence
Livermore
Laboratory

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1.0 Environmental Control Technology Project - FY1981

The Environmental Control Technology Project for fiscal year 1981 will consist of four assessment tasks described in section 8 of this plan. The project is composed of other on-going and routine tasks concerned with reports, reviews, the Geothermal Loan Guaranty Program, workshops, special meetings and progress reports. The assessments concerned with H₂S abatement (8.1) and solid wastes from geothermal power production operations (8.2) constitute continuance of work undertaken in fiscal years 1979 and 1980. Two new assessments will be undertaken this year, one addressing potential problems associated with the use of agricultural water for geothermal power plant cooling in the Imperial Valley (8.3), and the other concerned with the characterization and evaluation of low total dissolved solids (TDS) brines (8.4). The latter assessment is an outgrowth of a FY80 task that evaluated defluoridation processes for the Boise Geothermal Project.

2.0 Items to be Delivered

- 2.1 Report - Assessment of Steam Stacking Strategies for Geothermal Power Plants
- 2.2 Report - Preliminary Characterization Studies of Geothermal Solid Wastes
- 2.3 Report - Highlights of Environmental Control Technologies for the Geothermal Industry
- 2.4 Review Comments on Environmental Impact Reports associated with Geothermal Loan Guaranty Applications
- 2.5 Monthly Progress Reports
- 2.6 Report (Draft) - Assessment of Current Progress in H₂S Abatement Technology
- 2.7 Report (Draft) - Assessment of Solid Wastes from Geothermal Power Production Operations: Characterization, Handling, and Disposal

- 2.8 Status Report (Draft) - Assessment of Problems Associated with the Use of Agricultural Drainage Water for Geothermal Power Plant Cooling in the Imperial Valley
- 2.9 Status Report (Draft) - Assessment of Liquid Dominated, Low Total Dissolved Solids Geothermal Resources: Characterization and Evaluation of Potential Problems due to Composition.

3.0 Reports

Draft reports reflecting work conducted in fiscal year 1980 will have been prepared in October 1980. After submission to DOE and other interested parties for review and comment, final reports will be prepared. The reports are:

- o Assessment of Steam Stacking Strategies for Geothermal Power Plants
- o Preliminary Characterization Studies of Geothermal Solid Wastes

The Environmental Control Technology Division of DOE has requested the preparation of a report highlighting environmental controls for the geothermal industry. An outline of this report has been prepared (WFM:80-17). The report is scheduled for completion by the end of December 1980. The report is entitled:

- o Highlights of Environmental Control Technologies for the Geothermal Industry

Reports associated with the four assessments described in section 8 will be prepared. These will be draft reports as shown in delivery items 2.6 through 2.9.

4.0 Reviews

LLNL will respond to DOE requests to review various reports, proposals, and environmental impact statements. Miscellaneous reviews requested by other agencies, for example, California Energy Commission and EPA (with the approval of DOE) will also be carried out.

5.0 Geothermal Loan Guaranty Program

Periodically LLNL will review environmental control aspects of Geothermal Loan Guaranty Program (GLGP) applications. Reviews are carried out in the GLGP office of DOE in Oakland, California. LLNL will submit written reviews to DOE and maintain a status table of loan applications.

6.0 Workshops and Special Meetings

LLNL personnel will participate in workshops and meetings concerned with environmental control technology. Meetings are called at various times during the year by organizations such as:

- o Geothermal Resources Council
- o California Energy Commission
- o EPA
- o Interagency Geothermal Coordinating Council

Trip reports of such meetings will be prepared and distributed.

D. Layton and W. Morris will present a paper entitled "Geothermal Power Production: Accidental Fluid Releases, Waste Disposal, and Water Use" (UCRL-83823, Preprint) at the 73rd Annual Meeting of the American Institute of Chemical Engineers in Chicago, Ill, November 16, 1980.

7.0 Progress Reports

LLNL will prepare monthly progress reports detailing technical achievements and financial status of the project.

8.0 Environmental Control Technology Assessments

Four environmental control technology assessments are planned for fiscal year 1981. Details are given in sections 8.1 through 8.4 and in appendices A through D.

8.1 Assessment of Current Progress in H₂S Abatement Technology

Problem Definition. The status of H₂S abatement technologies has been described in a recent DOE publication (Stephens, et al, 1980). Since that time, there have been some advances in experimental pilot plant operations as well as additional valuable experience gained with existing technologies. In addition, the problem of the recovery and disposal of reaction products from H₂S abatement processes has not been fully addressed in any known previous publication. Another area that needs closer study is the applicability of current H₂S removal processes to proposed geothermal power plants in the Imperial Valley. There has also been some ongoing experience with steam handling techniques such as the automation of throttling valves and controls in steam supply networks.

Objectives. The objectives of this assessment are to examine and evaluate the most recent progress in all areas of H₂S control technologies as well as other related processes. Included in the assessment will be the applicability of current H₂S abatement methods in proposed power plants in the Imperial Valley. More background information and details of this assessment are given in Appendix A.

8.2 Assessment of Solid Wastes from Geothermal Power Production Operations: Characterization, Handling and Disposal

Problem Definition. Solid wastes generated by geothermal power production operations must be characterized under regulations established by EPA under the Resource Conservation and Recovery Act of 1976. During fiscal year 1980 a preliminary study characterizing various geothermal wastes was undertaken. Samples of four of the six major categories of geothermal waste were analyzed before and after the extraction

procedure recommended in the EPA regulations for the determination of toxic metals. Samples of two other categories of waste must be obtained and analyzed. In addition to this, an evaluation of the results must be carried out and an assessment made regarding the handling and disposition of the wastes.

Objectives. The objectives of this assessment are to characterize the various types of geothermal waste to determine if they contain toxic metals and if they should be classified as hazardous wastes. Having completed this task, the assessment should then determine what control technologies are needed for the handling, treatment, and disposal of the wastes. More background and details of this assessment are given in Appendix B.

8.3 Assessment of problems associated with the use of agricultural drainage water for Geothermal Power Plant Cooling.

Problem Definition. Agricultural drainage water is a primary candidate for use as cooling water in geothermal power plants in the Imperial Valley. The water is characterized by relatively high total dissolved solids (TDS) averaging about 4000 mg/l and suspended solids of about 200 mg/l. Before agricultural drainage water can be used in power plant cooling towers, the suspended solids will have to be separated and discarded. In addition to this, relatively large volumes of saline concentrate (blowdown) must be discharged periodically from the cooling towers to maintain minimal solids in the circulating water. Both of the above operations are capable of generating large quantities of solid waste that must be disposed in accordance with state and federal regulations. The regulations require that the wastes be characterized with regard to hazardous constituents in order to determine their handling and final disposition.

Use of agricultural drainage water may also pose problems affecting cooling tower performance and cooling tower drift (water vapor emanating from the cooling tower as a result of evaporation and caused to drift by local atmospheric air currents). Dissolved salts and suspended material in the water circulating in the cooling tower can be deposited on various components within the tower impeding air and water flow and can be emitted with the water droplets blown out of the tower and carried down wind with the drift.

Since agricultural drainage water is being considered as a primary candidate for use as cooling water for geothermal power plants in the Imperial Valley, it is imperative that it be fully characterized in order to assess the magnitude of the problems stated above. Much data is already available from various sources. Its usefulness and adequacy must be evaluated and a determination made regarding additional data that must be acquired by a sampling and analysis program.

Objectives. This assessment will determine the feasibility of using agricultural drainage water as a cooling water supply for geothermal power plants in the Imperial Valley. Compositional data will be gathered from available sources and by a sampling and analysis program. The data will be used to assess the requirements for handling and disposal of wastes associated with water pretreatment and cooling tower blowdown.

The data will also be used to assess potential adverse effects on cooling tower performance and cooling tower drift.

More background information and details of this assessment are given in Appendix C.

8.4 Assessment of liquid-dominated, low total dissolved solids geothermal resources: Characterization and evaluation of potential problems due to composition.

Problem Definition. Limited characterization of low total dissolved solids (TDS) brines and cursory evaluation of their compositional data may lead to unforeseen technical or environmental problems in geothermal processes utilizing the brines. Existing compositional data for low TDS brines produced from geothermal resource areas in the Western United States should be evaluated from chemical and physical points of view to assess technical and environmental problems. Adequacy and completeness of the data should be ascertained and a determination made regarding the need for additional sampling and analysis.

Objectives. The objectives of this assessment are:

- o to gather data from literature sources and by means of field and laboratory testing,
- o to evaluate the data in order to predict technical and environmental consequences due to constituents in the brine. More background information and details are given in Appendix D.

Before proceeding with the assessment, a determination should be made whether other organizations are currently collecting and evaluating such data. If it is determined that the problem is already being addressed, then a summary report of current activities will be prepared. The project (proposed here) will be suspended and reevaluated at a later date.

9.0 Tasks, Priorities, Levels of Effort and Assignments

The project tasks, their priorities, levels of effort, and the assigned personnel are listed in Table 1. Top priority will be given to the completion of reports covering work carried out in fiscal year 1980. Equally high priority is also assigned to the assessment tasks 8.1, 8.2, and 8.3.

Table 1. Tasks, Priorities, Levels of Effort and Assignments

<u>Task</u>	<u>Priority</u>	<u>Effort^a</u>	<u>Assigned Personnel</u>
● Reports ^b	1	8	W. Morris, F. Stephens, L. Rigdon
● Reviews		2	Staff
● Geothermal Loan Guaranty Program	2	3	W. Morris
● Special Meetings	2	4	Staff
● Progress Reports	2	2	W. Morris
● Task 8.1 - H ₂ S Control Technology ^c	1	12	F. Stephens, W. Morris
● Task 8.2 - Solid Wastes Assessment ^c	1	25	W. Morris, Staff
● Task 8.3 - Cooling Water Assessment ^c	1	28	L. Rigdon, Staff
● Task 8.4 - Low TDS Brines ^d	3	2	W. Morris, L. Rigdon

^a level of effort in man-weeks

^b Finished reports of work completed in FY80, delivery items 2.1, 2.2, and 2.3

^c Includes draft reports, delivery items 2.6 through 2.8

^d Major part of this task is not expected to be pursued in FY81.

10.0 Task Schedules

Figures 1a and 1b show the estimated time intervals within which various project activities are scheduled to be carried out. It is expected that changes will be necessary especially in field trip scheduling. The latter may be required to avoid conflicts with production operations in the Imperial Valley and Geysers resource areas. Some activities, e.g., reviews, meetings, and GLGP work are shown at equally spaced intervals for convenience. The activities will be carried out at appropriate times by mutual agreement or when schedules are more definite.

11.0 Project Costs

Most of the expenditures for fiscal year 1981 are expected to be taken up by the assessment tasks 8.1, 8.2, and 8.3 and are expected to amount to approximately \$185,000. Approximately \$65,000 is divided among the preparation of reports, GLGP, and various reviews, meetings and progress reports. Table 2 gives the estimated cost breakdown according to tasks and figure 2 shows the projected expenditure rate for FY81.

	10	11	12	1	2	3	4	5	6	7	8	9
● Reports												
- Assessment of Steam Stacking Strategies for Geothermal Power Plants												
- Preliminary Characterization Studies of Geothermal Solid Wastes												
- Annual Report - Highlights of Environmental Control Technologies for the Geothermal Industry												
- Assessment of Current Progress in H ₂ S Abatement Technology (Draft)												
- Assessment of Solid Wastes from Geothermal Power Production Operations: Characterization, Handling, and Disposal (Draft)												
- Assessment of Problems Associated with the Use of Agricultural Drainage Water for Geothermal Power Plant Cooling in the Imperial Valley (Draft)												
- Assessment of Liquid-Dominated, Low Total Dissolved Solids Geothermal Resources: Characterization and Evaluation of Potential Problems due to Composition (Draft)												
● Reviews (Task 4.0)												
- Reviews of Miscellaneous Reports Related to Environmental Controls												
● Geothermal Loan Guaranty Program (Task 5.0)												
● Special Meetings and Workshops (Task 6.0)												
- Geothermal Resources Council Annual Meeting												
- California Energy Commission Meetings												
- Interagency Geothermal Coordinating Council (ECT Panel)												
- Miscellaneous Meetings												
● Progress Reports (Task 7.0)												
● Assessment - Current Progress in H ₂ S Abatement Technology (Task 8.1)												
- Literature Search												
- Correspondence, Meetings and Discussions												
- Site Visits												
● Assessment - Characterization, Handling, and Disposal of Solid Wastes from Geothermal Operations (Task 8.2)												
- Definition of Data Requirements												
- Field Sampling and Tests												
- Laboratory Tests												
- Evaluation of Tests												
- Assessment of Waste Handling, Treatment and Disposal Technologies including Costs												
- Assessment of Potential for Mineral Recovery and Associated Costs and Benefits												
- Report (see Reports)												

Figure 1a Schedule of Tasks FY81

- Assessment - Potential Use of Agricultural Drainage Water for Geothermal Power Plant Cooling in the Imperial Valley (Task 8.3)

- Review of Power Plant Cooling Technologies
- Review of Alternative Water Supplies in the Imperial Valley
- Definition of Data Requirements
- Field Tests
- Laboratory Tests
- Evaluation of Tests
- Assessment Findings in Relation to Cooling Tower Operation and Characteristics of Cooling Tower Drift
- Report (see Reports)

- Assessment - Characterization of Liquid-Dominated, Low Total Dissolved Solids Geothermal Resources. Evaluation of Potential Problems due to Composition (Task 8.4)

- Review other Contractor Efforts
- Evaluate Commitment to Task
- Review of Published and other Source Data*
- Evaluation of Data*
- Field Tests*
- Laboratory Tests*
- Evaluation of Tests*
- Report (see Reports)*

*Note: These activities will be pursued only if it is determined that the work is not a duplication of work being conducted by other contractors.

- Administration

Figure 1b Schedule of Tasks FY81

Table 2. Estimated Costs for the Environmental Control Technology
Project - FY1981

Task 8.1 - H ₂ S Control Technology Assessment	\$30,000
Task 8.2 - Solid Wastes Assessment	\$70,000
Task 8.3 - Cooling Water Assessment	\$80,000
Task 8.4 - Low TDS Brines	\$5,000 (Max)
Reports	
Geothermal Loan Guaranty Program	
Reviews	
Special Meetings	\$65,000

12.0 References

Morris, W. F. and F. B. Stephens, 1980. Preliminary Characterization Studies of Geothermal Solid Wastes (Draft).

Stephens, F. B., Hill, J. H., Phelps, P. L., State of the Art Hydrogen Sulfide Control for Geothermal Energy Systems: 1979, Dept. of Energy, Washington, D.C. DOE/EV-0068 (1980).

Rosen, L. C. and C. R. Molenkamp, 1978. An Environmental Overview of Geothermal Development: The Geysers-Calistoga KGRA, Volume 2, Air Quality, Lawrence Livermore Laboratory, Livermore, Calif., UCRL-52496.

Rigdon, L. 1980. Defluoridation Study for Boise Geothermal Water, Lawrence Livermore Laboratory, Livermore, Calif., UCID-18646.

Appendix A

Background Information and Details Assessment of Current Progress in H₂S Abatement Technology

Background

During the development and operation of geothermal power plants the emission of hydrogen sulfide (H₂S) is inevitable. To avoid the environmental consequences of this emission and to meet environmental air quality standards, suitable control technologies must be employed. Detailed information about hydrogen sulfide emissions and their release points have been described by Rosen and Molenkamp (1972). A recent report by Stephens, et al (1980) has described state of the art control technologies for the abatement of H₂S as applied to geothermal energy systems. Table A1 lists the approximate relative amounts of H₂S released to the atmosphere at the Geysers geothermal development and Table A2 shows the status of control technology currently used in the abatement of the various H₂S emission sources.

Approach

Downstream Abatement of H₂S. Most of the existing H₂S abatement processes in actual use today are those that remove H₂S downstream of the power plant. This assessment is expected to examine and evaluate recent progress and performance data available from presently operating Stretford units (on units 15 and 13 at The Geysers) as well as the performance of the ion catalyst systems. Associated with these technologies is the question of the efficiency of partitioning of H₂S between condensate and noncondensable gases. This is a particularly important factor in the efficient removal of H₂S in conjunction with the Stretford process. Any progress in steam condenser designs will also be assessed.

The DOE has funded a study for H₂S abatement using the UOP catalytic oxidation (Sulfox^{*}) process. Progress reports of this research study will be evaluated.

^{*}Registered trademark of UOP Incorporated.

- o Upstream Abatement of H₂S. Investigations into upstream H₂S removal have been an important part of the research and development effort funded by DOE and others. One of the objectives of the report will be to evaluate recent progress in technologies using solid sorbents and steam condenser-reboiler systems.

One of the most successfully tested pilot plant upstream abatement technologies has been the copper sulfate (Cuprosul^{**}) process carried out for the Pacific Gas and Electric Company under cooperative agreement with the DOE. An assessment of the most recent tests with this process will be made.

- o Steam Supply Networks. A well developed geothermal power generating facility such as the one at The Geysers requires a vast network of steam gathering pipelines. There are various points of H₂S release along these lines, but the largest release occurs when a power generating unit goes down and the full flow of steam is allowed to vent to the atmosphere. Release of H₂S from this source is diminished by controlling the steam flow. One proposed method is to reroute the steam by "crossover lines" to another generating unit. To accomplish this, well designed throttling valves and controls will be required along with steam parameter measurement devices. An automatically controlled network system has been installed on Unit 15 at The Geysers. This assessment will review the performance of that system and if possible examine new or proposed systems.
- o Other Processes Associated with H₂S Abatement. There are other processes and ongoing investigations related to H₂S abatement. All abatement technologies lead to the production of reaction products that must be disposed of

*Developed by EIC Corporation, 55 Chapel St., Newton, Mass.

either as waste products or a useful by-product. The assessment will include an evaluation of the recovery and disposal of these reaction products.

Another ongoing area of investigation, also funded by DOE is a program to study how terrain-dominated, air-flow phenomena affect the problem of pollutant transport over complex terrain. This program for Atmospheric Studies in Complex Terrain (ASCOT) is presently focusing on nighttime drainage winds in The Geysers area of California and Rattlesnake Mountain in Southeast Washington. Although not an abatement process for H_2S , the model resulting from the study may elicit useful information applicable to the abatement methods described above. Such information will be evaluated.

TABLE A1 Approximate amounts of H₂S emitted to the atmosphere at The Geysers geothermal development for various release points.

Release points	1976 unabated H ₂ S emissions, kg/h	Without abatement		With 90% downstream abatement	
		kg/h	Percent of Total	kg/h	Percent of total
Total power plant emissions		1152 ^b	90.8	115 ^b	49.6
Pre-plant emissions					
Well drilling	4	5 ^c	0.4	5 ^c	2.2
Testing & clean-out	13	17 ^c	1.3	17 ^c	7.3
Well bleeds	3	4 ^c	0.3	4 ^c	1.7
Steam stacking	28	37 ^c	2.9	37 ^c	15.9
Pipeline vents	14	19 ^c	1.5	19 ^c	8.2
Uncontrolled well	33	33	2.6	33	14.2
Natural fumaroles	2	2	0.2	2	0.9
Total pre-plant		117	9.2	117	53.4
Total emissions		1269	100.0	232	100.0

^b Estimated for 1979 @ 663 MW total generating capacity:
 $1.83 \times 663 \times 0.95 = 1152$,

where

1.83 = kg H₂S/MWh from Table 4,
663 = 1979^c capacity in MW,
and 0.95 = emission factor (H₂S in source fluid actually emitted).

^c Value from Ref. 22 multiplied by 1.33 to estimate 1979 value.

Table A2 Hydrogen Sulfide Emissions and Their Abatement

Release Point	Applicable Abatement Technology	Status
<u>Pre-Plant Emissions</u>		
• Well drilling (Geothermal stratum-air drilling)	• Hydrogen peroxide-sodium hydroxide spray injected into steam entering blooie line.	• Routinely practiced. Up to 98% effective for H ₂ S concentrations over a range of several hundred ppm.
• Well flow testing	• Hydrogen peroxide-sodium hydroxide spray injection is a potential solution.	• No abatement practiced
• Well bleeding	• Requires cost-effective technology. Consider collection system for multiple wells.	• No abatement practiced
<u>Operating Plant Emissions</u>		
• Steam transmission line venting	• Vent collection system, condensation, injection. Note: upstream technology described below can be used to abate transmission line venting	• Routinely practiced • Possible alternative
• Cooling tower or non-condensable gas ejector	<u>Upstream Technology</u> • Copper sulfate (EIC) process • Solid Sorbents, e.g. ZnO • Deuterium process • Steam Converter with supplemental off-gas H ₂ S control. • Dow oxygenation process • Hydrogen Peroxide (FMC Corp.)	• >95% removal of H ₂ S; possible cu corrosion problems. • Regeneration of sorbent is difficult, expensive. • Development for Geothermal use is doubtful. • Expensive. Also heat energy of steam supply to turbine is decreased. • Reaction time may be too slow to bring about effective abatement of H ₂ S. Process is more adaptable to liquid resources. Also corrosion problem is possible. • High cost. Handling problems.
	<u>Downstream Technology</u> -Direct contact condenser System- • Iron catalyst process peroxide supplemented • Ozone process • Wackenroder reaction -Surface Condenser System- • Stretford process • Jefferson Lake Process • Burner-Scrubber Process • Catalyst-Scrubber Process • Ferrox Process • Caustic Soda Process • Sodium hypochlorite Process • Potassium permanganate Process	<u>Condensate</u> • Up to 90% effective. corrosion problems • Not adequately investigated • Not adequately investigated <u>Non-Condensable Gases</u> • Up to 99% effective for removal of H ₂ S from non-condensibles. • Economics questionable • Up to 90% effective on non-condensable gases. However, approximately 40% of the H ₂ S was partitioned into the condensate. • Poor efficiency • More development required. Chemical hazards • Waste disposal costs are high. • Not adequately investigated • Chemical waste hazards, high cost
<u>Plant Shut-Down Emissions</u>		
• Steam Stacking	• Upstream technology can provide control during steam stacking. Potential processes are: EIC, UOP and Coury-Stretford processes. • Hydrogen peroxide - Sodium hydroxide spray injection system proposed for DWR-Bottle Rock plant.	• Current practice includes throttling of steam flow and redistribution of steam to nearby plants. • Proposed system will incur high operating costs and use of hazardous chemicals.

Appendix B

Background Information and Details Assessment of Solid Wastes from Geothermal Power Production Operations: Characterization, Handling, and Disposal

Background

During fiscal year 1980, a preliminary characterization study of various geothermal solid wastes was performed. (Morris, W. F. and F. B. Stephens, 1980) The primary intent of the study was to determine if certain types of geothermal wastes contained toxic elements that would classify the wastes as hazardous as defined in section 261.4 of the EPA Hazardous Waste Permit Regulations (Fed. Regist. 45, 1980). These regulations were promulgated by EPA in response to a directive from Congress under the Resource Conservation and Recovery Act (RCRA). Other metals of interest to EPA water programs were also determined in the wastes. These metals along with the toxic metals are listed in table B1.

The preliminary study showed that toxic metals and other elements of concern are present in geothermal brine and scale and that appreciable amounts can be extracted from the waste samples. The wastes analyzed included: drilling mud and cuttings from geothermal wells, brine waste, separated solids from preinjection treatment of brine, and scale from the low temperature side of the geothermal loop experimental facility in the Imperial Valley.

Additional work is required to complete the study of geothermal solid wastes. Included in the work are sampling and analysis of cooling water wastes, high temperature scales, and by-product compounds from H₂S abatement units.

Objectives

The objectives of this study are to obtain samples representative of the different kinds of water that may be used for geothermal production plant cooling as well as high temperature scales and by-product samples from H₂S abatement units.

The results of the analyses performed in the FY80 preliminary study as well as results from the samples described above must be evaluated and a determination made whether additional sampling and analyses are needed.

Based on the evaluation of the analytical results, a determination will be made whether the samples exhibit the characteristic of EP toxicity under EPA's regulations. The determination will form the basis for assessing control technologies for handling, treatment and disposal of the wastes.

Additional compositional data obtained from spectrographic and x-ray fluorescence analyses will be used to evaluate the economic potential for recovering minerals contained in the wastes.

Table B1. Toxic metals and other contaminants of interest in geothermal solid wastes.

Silver	Boron
Arsenic	Beryllium
Barium	Copper
Cadmium	Lithium
Chromium	Nickel
Mercury	Antimony
Lead	Strontium
Selenium	Zinc

Appendix C
Background Information and Details
Assessment of Problems Associated with the Use of
Agricultural Drainage Water for Geothermal Power Plant
Cooling in the Imperial Valley

Background

Power plants require large volumes of cooling water to optimize the efficiency of the turbine system. Because of their relatively low energy conversion efficiencies, geothermal power plants are expected to consume between 7 to 11 m³ of water per MW-h of energy produced. This compares to approximately 2 m³/MW-h needed for a conventional fossil-fueled power plant.

The principal sources of cooling water for potential use by the geothermal industry in the Imperial Valley consist of irrigation water imported from the Colorado River, waste water discharged from agricultural lands, and steam condensate from flashed-steam power plants. The availability of these sources is greatly complicated by irrigation priorities, seasonal and yearly variations in supplies, qualities of both the supply and receiving water bodies, and a variety of local, state and federal requirements, policies, and agreements. Layton, (1978) has studied various combinations of the above factors to determine if geothermal energy production will be constrained by deficits in water supplies in the Imperial Valley. He isolates two policies that exert significant constraints on two potential and attractive water supplies, namely irrigation water and steam condensate. In the case of irrigation water, diverted into the Imperial Valley from the Colorado River, county policy restricts allocation to such an extent that long-term use as cooling water for geothermal power plants is ruled out. The use of steam condensate on the other hand is affected by a policy intended to protect agricultural lands from possible subsidence as a result of geothermal operations in the Imperial Valley. The policy requires full injection of all fluids withdrawn from geothermal sources. Since steam condensate constitutes as much as 25% of the fluids withdrawn, it must be injected or, if used for cooling, an alternative supply must be acquired to substitute as injection fluid.

If by reason of the above constraints, the major cooling water supply is limited to agricultural drainage water (a supply amounting to approximately $1.2 \times 10^9 \text{ m}^3$ annually), then it is possible that large quantities of solid waste could accumulate either from processes that separate suspended material from the water prior to use in cooling towers, or from cooling tower blowdown. The latter process involves the withdrawal of saline water from the cooling tower to maintain a desired level of solids in the circulating water.

If suspended solids are not removed from the makeup agricultural water before its use in the cooling tower, then unacceptable levels of sludge will accumulate in the basin of the tower. A 50 MW geothermal power plant using high temperature fluids, such as those found in the Salton Sea resource area, requires about $440 \text{ m}^3/\text{h}$ of agricultural waste water to replace evaporative losses of $350 \text{ m}^3/\text{h}$ and blowdown discharges of $90 \text{ m}^3/\text{h}$, based on five cycles of concentration. In lowering the concentration of suspended solids in agricultural effluents from 200 to 50 mg/l, we estimate that approximately $4.4 \times 10^5 \text{ kg}$ of solids will be separated each year, assuming a plant capacity factor of 0.75. A cost effective way to separate suspended material from cooling water is to use a settling pond (EPRI, 1979) from which the accumulated solids must be removed periodically and discarded in a dump site.

An acceptable method must also be found to dispose of saline blowdown water. Ponding and subsurface injection are two possible options. If the first option were exercised, then blowdown would be discharged to a pond and evaporated leaving a residue of solid salts requiring disposal. Accumulated blowdown solids could exceed $1 \times 10^7 \text{ kg}$ annually for a 50 MW power plant discharging $90 \text{ m}^3/\text{h}$ of blowdown averaging 20,000 mg/L TDS. The land requirements for ponding make the option unattractive relative to subsurface injection; however there remains a distinct possibility that some solid wastes due to blowdown must be handled in this way and ultimately disposed of.

In addition to the waste disposal problems associated with the use of agricultural drainage water for cooling, other potentially adverse effects on cooling tower performance and cooling tower drift must be

evaluated. Cooling tower designs for Imperial Valley power plants are expected to employ state-of-the-art drift eliminators. Optimum performance of the cooling towers will require that honeycomb passages or closely-spaced frameworks of passages making up the drift eliminators remain free of deposits and the buildup of organic and inorganic substances that could impede the flow of air and drainage of water within the cooling towers. Even though drift eliminators are expected to be used, some drift will persist. Recognizing this fact, it is important to assess the composition of the drift, its effect on the surrounding environment, and its relationship to the quality of the makeup water used in the towers.

Potentially adverse effects on cooling tower performance that may result from the use of agricultural drainage water include: fouling caused by silt or organic debris, formation of algae, fungi and bacteria, and deposition of scale. Deleterious cooling tower drift could result from the use of agricultural drainage water containing boron, herbicides, pesticides or substances added during cooling tower operations such as scale inhibitors, toxicants, or anti-fouling substances.

An assessment of the feasibility of using agricultural water for cooling in geothermal power plants is required in the near future. Fundamental to such an assessment is the accumulation and evaluation of data on the composition of Imperial Valley agricultural waters. These data will be used to evaluate the nature and magnitude of solid wastes, the effects on cooling tower performance and the potential effects of drift on croplands in the Valley.

Objectives

This assessment will determine the feasibility of using agricultural drainage water as a cooling water supply for geothermal power plants in the Imperial Valley. The assessment will examine three problem areas:

- o The handling and disposal of wastes from pretreatment of the agricultural water prior to use in the cooling tower and waste blowdown fluid periodically discharged from the cooling tower.

- o Adverse effects on cooling tower performance related to constituents in the source water. The adverse effects are: fouling caused by inorganic and organic debris; growth of algae, fungi, and bacteria; and formation of scale.
- o Adverse effects on the composition of cooling tower drift resulting from constituents contained in or added to the source water, such as insecticides, herbicides, boron, scale inhibitors, anti-fouling substances and toxicants.

The primary objective of this project is to gather data on inorganic and organic constituents in agricultural water from locations in the Imperial Valley most likely to be used by power plant installations. Data already available in the literature will be accumulated and evaluated. Additional field and laboratory sampling and analyses will be carried out as needed to acquire appropriate data. Multiple sampling and analyses will be carried out as necessary to reflect seasonal and agricultural activity differences. These data will be used to assess the problem areas described above.

Appendix D

Background Information and Details

Assessment of Liquid-dominated, Low Total Dissolved Solids

Geothermal Resources: Characterization and Evaluation of Potential Problems Due to Composition

Background

Most of the geothermal resources in the western United States are "liquid dominated" or hot water resources. The one exception is The Geysers "steam dominated" resource in Northern California. Liquid dominated resources vary in size and in the temperature and composition of the fluids. The geothermal fluids of the Imperial Valley KGRA, for example, are considered to be the largest liquid dominated resources in the United States representing about one third of the nation's total identified resources applicable to hydrothermal energy systems. They are characterized by high total dissolved solids (TDS) ranging up to 250,000 mg/l and are known to present technical problems such as scaling and corrosion and environmental problems associated with emission of H_2S , and generation of liquid and solid wastes.

Brines characterized by low TDS are prevalent in a number of areas in the western U.S. In most cases they are being, or are destined to be, developed for space heating or process heating applications. The Boise Geothermal project is an example of a space heating project where geothermal fluid is to be used for heating residential and commercial buildings. The geothermal fluid to be used by the project is of relatively high purity as shown in Table D1. However, due to environmental constraints, the high fluoride content prevents convenient discharge of the spent hot water into the Boise River or other easily utilized discharge basin. The project, therefore, faces a problem that will increase its overall cost and possibly cause delay (Rigdon, 1980).

Problems of this nature and others such as scaling and corrosion and the formation of precipitates and sludges are possible in other

developing geothermal hot-water resource areas. Potential problems can be predicted and possibly solved early on if the fluids are well characterized and evaluated relative to potential technical and environmental problems.

Objectives

The objectives of this assessment are: 1) to gather data on the inorganic constituents in low TDS brines from geothermal areas in the western United States; 2) to evaluate the data with respect to the constituents present and their potential for precipitation, sludge formation and for causing scaling and corrosion; and 3) to evaluate the data with respect to environmental consequences and chemical options available for mitigation of the consequences.

Data will be gathered from literature sources and will be evaluated regarding adequacy and completeness. Sampling and analysis will be carried out to obtain information not otherwise available.

Approach

Two of the principal sources of data on geothermal resource fluids are the U.S. Geological Survey and the data base maintained by the Lawrence Berkeley National Laboratory, Earth Sciences Division. Direct contacts will be made with resource developers to supplement the above sources and to obtain more up-to-date information. Where data are lacking, arrangements will be made to visit appropriate sites where sampling and analysis will be carried out. A field test kit will be used to perform some analyses on site. Samples will also be taken in accordance with standard practice and returned to LLNL for laboratory analysis.

All of the data (both literature and newly acquired data from sampling and analysis) will be evaluated by LLNL staff chemists to determine the potential effects of composition on proposed processes and the environment.

Table D1. Composition of Boise Geothermal Water Penetentiary Well,
Boise, Idaho

Chemical Analysis^a

Total Dissolved Solids	285
Hardness as CaCO ₃	2
Alkalinity as CaCO ₃	120
pH	9.3
Ca	0.5
Cl	12
F ⁻	18.4
HCO ₃ ⁻	145
Mg	0.3
Na	84
SiO ₂	78
SO ₄	20

Spectrographic Analysis^{a,b}

Ag	n.d.	.002	Ni		.02
B		.04	Pb	n.d.	.02
Ba	n.d.	.02	Sn	n.d.	.02
Be	n.d.	.002	Sr		.02
Bi	n.d.	.01	Ti	n.d.	.02
Cd	n.d.	.02	V	n.d.	1.
Co	n.d.	.02	Zn	n.d.	.02
Cr	n.d.	.02	Zr	n.d.	.1
Cu	n.d.	.01	K		1.
Fe	n.d.	.01	Li		.02
Mn	n.d.	.002	Rb	n.d.	.05
Mo		.03			

a Numbers = milligrams per liter, except pH

b n.d. = not detected

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