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PREPRINT UCRL- 82871

CONF-790906--18

Lawrence Livermore Laboratory

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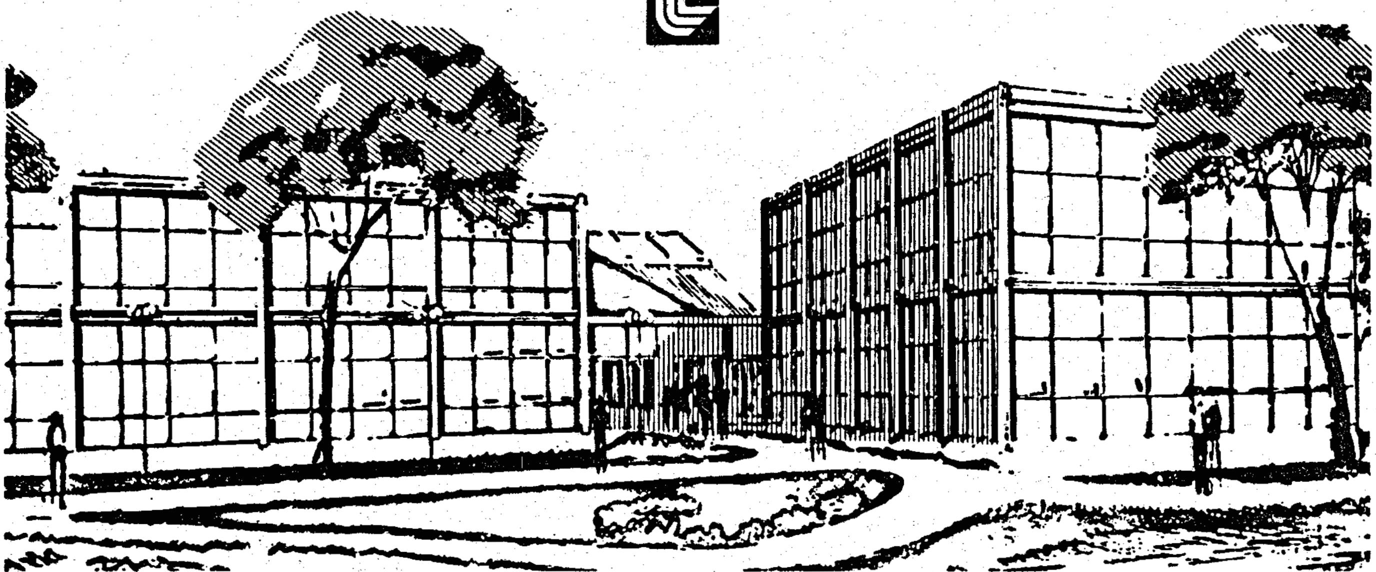
July 5, 1979

Environmental Sciences Division

This paper was prepared for submission to
1979 Annual Meeting of the Geothermal Resources Council, Reno, NV.
Setember 24-27, 1979



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WATER-RELATED IMPACTS OF GEOTHERMAL ENERGY PRODUCTION IN CALIFORNIA'S IMPERIAL VALLEY *

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ABSTRACT

To successfully develop the geothermal resources of the Imperial Valley, adequate supplies of cooling water must be obtained. The primary sources of water include waste waters from agricultural lands, condensate from flashed-steam facilities, and irrigation water. In this paper we examine the major advantages and disadvantages of these supplies and then assess the consequences of adopting six sets of water policies to support three scenarios of geothermal energy production. The assessment includes analyses of potential constraints to development as a result of restrictive water policies. It also includes predictions of changes in the Salton Sea's elevation and salinity caused by the consumption of agricultural drain water for cooling.

INTRODUCTION

The geothermal resources of California's Imperial Valley have the potential of producing 6760 MW over 30 years.[1] This represents almost a third of the nation's total energy potential for hot-water geothermal systems. The ultimate extent to which the valley's geothermal resources are developed will depend in part on the availability of cooling water for geothermal power plants. The valley contains about 475,000 acres of farmland that require about three million acre-feet (af) of irrigation water each year from the Colorado River. Imported river water plus agricultural waste waters from irrigated lands are possible sources of cooling water. Other water supplies are steam condensate produced from power plants using flashed-steam energy conversion technologies, ground water underlying East Mesa, and the Salton Sea. The basic problem facing geothermal developers in the valley is how to acquire and use water without producing unacceptable impacts on the environment as well as agriculture.[2] To assess the impacts of using the different water supplies, we did the following: (1) quantified the cooling water requirements of power plants, (2) reviewed the advantages and disadvantages of the various water supplies, and (3) assessed water-related impacts using predictions of future water balances in the valley, scenarios of energy production, and sets of policies affecting the acquisition of cooling water supplies.

REQUIREMENTS FOR COOLING WATER

Waste heat from geothermal facilities in the valley will probably be rejected to the atmosphere through wet cooling towers. The quantities of water needed to make up for evaporative losses in cooling towers will depend primarily on the temperature of the geothermal fluids used in power plants. More specifically, as the temperature of fluids rise, conversion efficiencies of power plants increase; less rejected heat and correspondingly lower requirements for cooling water result. For the assessment we assumed that energy facilities in the Salton Sea resource area, where the highest temperature fluids are found, have an average conversion efficiency of 0.14; however, facilities in the E. Mesa, Heber, and Brawley resource areas have efficiencies of 0.10 because of lower resource temperatures. The high conversion efficiency translates to an evaporative loss of approximately 50 af per MW-yr, or about four times higher than that needed for coal-fired power plants. Facilities with the low conversion efficiency would consume about 75 af per MW-yr.

Blowdown discharged from cooling towers to control the salinity of circulating water must also be replaced. The amount of blowdown discharged from a cooling tower depends on the number of cycles the source water is concentrated by evaporation. As the cycles of concentration (C) increase, the discharges of blowdown decrease. The blowdown rate is equal to the tower evaporation rate divided by C-1. Usually the cycles of concentration associated with a particular water supply are a function of available options for the disposal of blowdown and the cooling system's ability to withstand saline circulating waters. We made the following assumptions to calculate blowdown discharges: irrigation water is concentrated four times and discharged to surface waters; steam condensate is concentrated 10 times and disposed of by subsurface injection; ground water, agricultural drain water, and Salton Sea water are concentrated 10, 5, and 2 times, respectively, and disposed of by subsurface injection or discharge to evaporation ponds.[3]

COOLING WATER SUPPLIES

Regulations, environmental impacts, government policies, economics, resource uncertainties, and technical difficulties will all play a role in controlling the selection of cooling waters to support geothermal development. We examined each water supply to find out how such factors would influence its use and found the following:

- Irrigation water imported from the Colorado River by the Imperial Irrigation District is an attractive source of cooling water because it is easily transported to each of the resource areas, and its quality is much better than other surface water supplies. Furthermore, blowdown produced by concentrating irrigation water three to four times can be disposed of into surface waters without exceeding water quality standards. Despite these benefits, it is unlikely that substantial amounts of irrigation water will be available for geothermal operations, because water policies originating at the local level will undoubtedly favor agricultural water users. There is a slight possibility, though, that surplus water may become available in the years ahead if water conservation in irrigation continues to improve.

- Steam condensate from flashed-steam power plants can supply all, or nearly all, the water requirements of those facilities. No external supplies of water would then be needed. However, concern over the possible effects of subsidence on the valley's irrigation and drainage systems has resulted in the adoption of a county policy favoring the full injection of withdrawn fluids. Developers cannot rely on condensate as the sole source of cooling water for geothermal facilities unless they can show that subsidence will be minor. The only exception would be for power plants on E. Mesa because there is no agriculture there and so subsidence is not expected to be harmful.

- Waste water from agricultural lands in the Imperial Valley amounts to over one million af annually, making it a significant water supply in this arid region. Nevertheless, there are several difficulties associated with its use including disposal of saline blowdown, the acquisition of unevenly distributed waste water flows, and the effects on the Salton Sea. The most important impact of consuming waste waters would be increases in the Salton Sea's salinity. Higher salinities would put added stress on the ecosystem of the sea.

Water from the Salton Sea and ground water under E. Mesa are the other possible supplies of cooling water. It is doubtful, though, whether these supplies will receive widespread use. For instance, the use of sea water in a cooling tower would create major corrosion and scaling problems; and ground water is not a particularly attractive supply because of the costs of transporting it to the geothermal resource areas in the valley. Because of the uncertainties associated with Salton Sea and ground water, our assessment focused on the use of agricultural waste waters, steam condensate, and irrigation water as the most plausible sources of cooling water.

WATER-RELATED IMPACTS

The primary purpose of the water assessment was to answer this question: what are the water-related impacts of adopting different policies affecting use of the three main water supplies? To answer that question, we defined a series of five policies controlling the use of the different supplies. The policies were then combined into six sets to represent the scope of future regulatory controls. The availabilities of irrigation water and agricultural waste water were determined for two cases of future water use in agriculture. A conservation (CON) case was chosen to reflect increased efficiences in the distribution and application of irrigation water. A reference (REF) case based on the assumption that present water use practices will continue unchanged was selected as the other.

Low, medium, and high forecasts of future energy growth served as the basis for our analyses.[4] Each scenario of growth expresses different sets of future economic, technical, political, and resource conditions. The low forecast starts with 100 MW produced in 1986, and through a linear growth rate of 40 MW per yr, reaches 1000 MW in the year 2010. The medium forecast has a growth rate of 100 MW per yr and goes from 100 MW in 1982 to 3000 MW in 2010. The high forecast attains 8000 MW in 2010 after increasing at a rate of 250 MW per yr from an initial 100 MW in 1980.

WATER SUPPLY DEFICITS

In Table 1 are displayed the water policy combinations used to study the occurrence of water supply constraints. Each policy combination provided enough cooling water to support geothermal energy production following the low and medium energy scenarios. For the high growth scenario, though, water supply deficits caused by policy sets A, C, E, and F constrained growth in the Heber and E. Mesa resource areas. The most constraining policy combination is E. It limits the use of steam condensate to 50% of the projected energy production at the E. Mesa geothermal field. The remaining energy produced at that resource area, as well as the others must be supported by agricultural waste water for cooling. Under these conditions, the Heber resource area would be limited to producing about 800 MW and the E. Mesa resource area to 600 MW for for the CON case. As a result of the reduced energy output from the Heber and E. Mesa areas, the total energy generated in the valley amounted to approximately 6800 MW in the year 2010, or

Table 1. Water policy combinations representing future regulatory controls.

Water Policies		Policy Combinations A	B	C	D	E	F
I.[a]	Limited condensate	X	X			X	
II.[b]	Increased condensate			X	X		X
III.[c]	Fixed allocation of irrigation water	X		X			
IV.[d]	Variable allocations of irrigation water		X		X		
V.[e]	Unrestricted agricultural waste water use	X	X	X	X	X	X

[a]Policy I allows the partial injection of geothermal fluids only at E. Mesa so that steam condensate can be used for cooling. It is assumed that 50% of the energy is produced by flashed-steam power plants with the remaining 50% generated by binary plants.

[b]Policy II permits the use of condensate in all of the valley's resource areas for power plant cooling. Half of the energy generated in the E. Mesa, Heber, and Brawley areas is assumed to be from flashed-steam facilities, and 75% in the Salton Sea area.

[c]Policy III limits the use of irrigation water to the first 75 MW of energy generated in each resource area.

[d]Policy IV allocates surplus irrigation water to geothermal facilities for use in cooling.

[e]Policy V supports the unrestricted use of agricultural waste waters for cooling.

1200 MW less than specified in the high energy scenario. However, the high scenario used inflated estimates for resource potentials, and so energy production will not be constrained unless additional resources are actually found. Policy combination A resulted in slightly lower deficits than combination E because irrigation water was available to satisfy the cooling needs of producing 75 MW in each resource area. Policy sets C and F allowed the use of condensate with flashed-steam facilities for cooling (without the need for an external supply of water for injecting into a geothermal reservoir to control subsidence) and resulted in limited constraints to energy production. Variable allocations of surplus irrigation water, included in policy combinations B and D, provided large amounts of water for development under the CON case. Surpluses of irrigation water became available with that case as the efficiencies of water use in agriculture increased over time, reducing agricultural water requirements.

EFFECTS ON THE SALTON SEA

The consumption of agricultural waste waters can lower the Salton Sea's surface elevation and increase its salinity. The sea's elevation has been rising in recent years, inundating shoreline property. Consequently, lower surface elevations resulting from geothermal use of waste waters would be beneficial. However, as salinities increase, negative impacts on the sea's aquatic ecosystem will start. Of all the policy combinations affecting the acquisition of cooling water supplies, combination E would have the greatest effect on the sea because it promotes the greatest use of agricultural waste waters.

We predicted the effects of modifying the inflows to the sea using a recursive salt and water-balance model. In Fig. 1 predictions of future elevations are shown for the REF and CON cases without geothermal development and for the REF case with medium energy growth and policy combination E. All of the predictions are based on average hydrologic conditions and normal evapotranspiration from crops in the valley. Policy combination E and medium energy growth does result in lower surface elevations, yet it takes nearly 30 yr before the 1975 elevation is reached. Elevation declines associated with the CON case indicate that increased efficiencies in irrigation could have an even greater impact on elevations than geothermal development.

In Fig. 2 predictions of salinity are presented for the same REF and CON cases without geothermal energy production and the REF case with the medium scenario of growth and policy Set E. The use of agricultural drainage to support geothermal development results in salinities that are significantly greater than those resulting from the REF case and no energy production. Adverse impacts on the sea's ecosystem are expected when salinities exceed 40 x 10^3 ppm TDS. Without geothermal development, toxic levels are not attained until the early 1900's, but with development, toxic salinities appear between 1985 and 1990 under both REF and the CON cases. Increases in the sea's salinity could be mitigated by implementing the policies of combinations C, D, or F, which encourage the use of steam condensate for cooling. A greater reliance on condensate would reduce the dependence on waste waters normally flowing to the sea. The use of condensate for cooling, nevertheless, will only be

Figure 1. Changes in the Salton Sea's elevation.

Figure 2. Changes in the Salton Sea's salinity.

possible if partial injection of withdrawn geothermal fluids is allowed; and that is unlikely unless the effects of subsidence prove to be tolerable in the irrigated portions of the valley.

CONCLUSIONS

There is enough agricultural waste water in the Imperial Valley to sustain development of almost 7000 MW of geothermal energy even if increased water conservation in irrigation reduces discharges of drain water. Withdrawing waste waters for evaporative cooling, however, will accelerate increases in the Salton Sea's salinity. Such increases would not be beneficial to the sea's aquatic ecosystem. Until decisions are made by government agencies on the acceptability of using waste waters normally flowing to the sea, the use of that important supply will be in doubt. An alternative to agricultural drain water is steam condensate from flashed-steam power plants. The use of condensate for cooling would reduce the need for external sources of cooling water; but requirements for the full injection of withdrawn geothermal fluids to control subsidence now preclude its extensive use. Condensate will not become an accepted water supply option until information is acquired about effects of land subsidence resulting from the operation of an actual geothermal plant. Irrigation water could be used as a supplemental source of cooling water for facilities using agricultural drainage; but that would only be possible if surplus irrigation water becomes available because of increased water conservation in agriculture.

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* Work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore Laboratory under contract number W-7405-ENG-48.

This report represents work (primarily) sponsored by the Office of Technology Impacts, Office of the Assistant Secretary for Environment, U.S. Department of Energy.

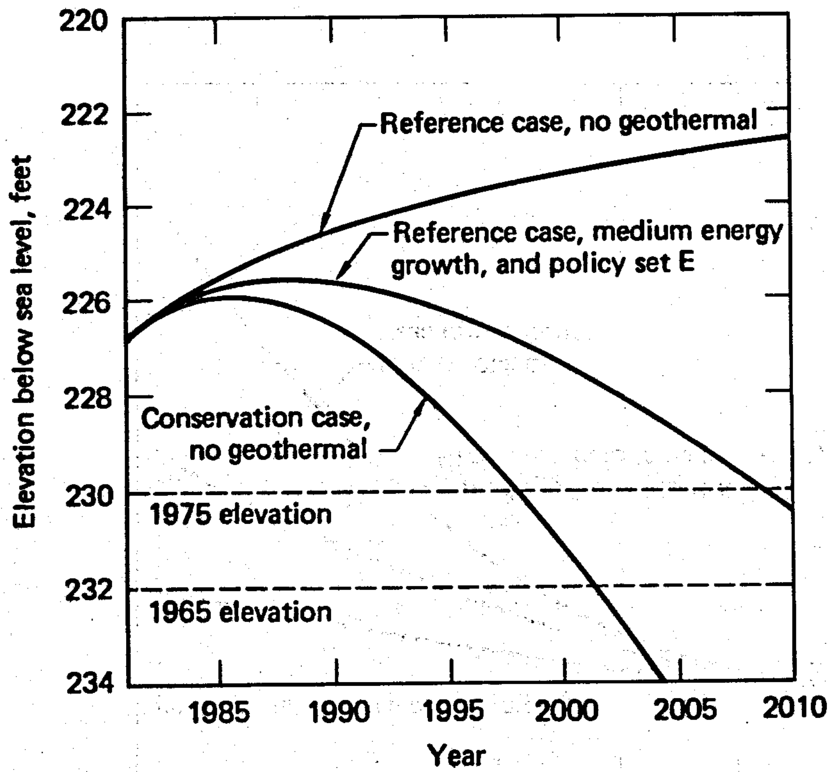

Fig. 1

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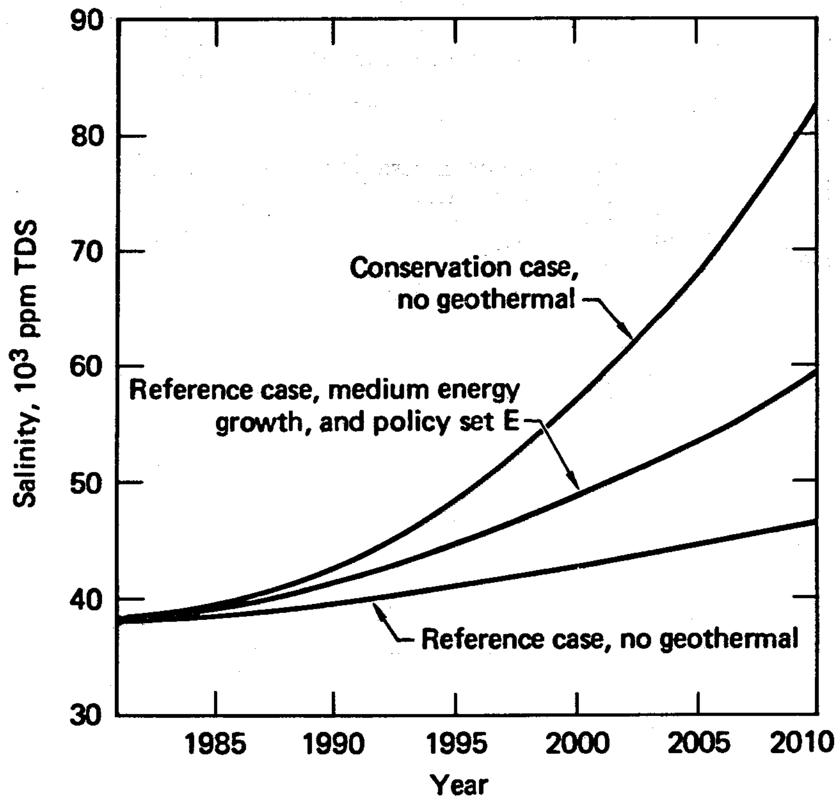

Fig. 2

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