CALIFORNIA
ENERGY
COMMISSION

Santa Rosa Geysers Recharge Project: GEO-98-001

FINAL REPORT

October 2002
500-02-078V1

CALIFORNIA ENERGY COMMISSION

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Contract No. GEO-98-001

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Table of Contents

List of Figures

Index of Tables

Acknowledgments

The City of Santa Rosa would like to acknowledge and thank the following for their support and assistance in securing funding for The Geysers Recharge Project through the California Energy Commission's Geothermal Program:

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Former Governor	Pete Wilson
Former State Senator	Mike Thompson
Assemblywoman	Virginia Strom-Martin

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1. Introduction and Purpose of Final Report

In May of 1999, the City of Santa Rosa working cooperatively with Unocal, Calpine and the State Lands Commission submitted an application for funding from the California Energy Commission's Geothermal Program for the City of Santa Rosa's Geysers Recharge Project.

On October 6, 2000 a contract for Project Number GEO-98-001 was executed by the California Energy Commission. This contract provided $3,563,000 in CEC funding. The project is now near completion and the CEC funding has been expended as anticipated. Prior to closing out the contract, Subtasks 5.2.3, - "Final Report" is required per the approved workplan.

2. Project Overview Including Final Reporting Requirements

The Geysers steamfields in northern Sonoma County have produced reliable "green" power for many years. An impediment to long-term continued production has been the ability to provide a reliable source of injection water to replace water extracted and lost in the form of steam. The steamfield operators have historically used cooling towers to recycle a small portion of the steam and have collected water during the winter months using stream extraction. These two sources however, could not by themselves sustain the steamfield in the long term. The Lake County Reclaimed Water Project (SEGEP) was initiated in 1997 and provides another source of steamfield replenishment water. The Santa Rosa Geysers Recharge Project provides another significant step in replenishing the steamfield. In addition, the Santa Rosa Geysers Recharge Project has been built with capacity to potentially meet virtually all injection water requirements, when combined with these other sources. Figure 2.1 graphically depicts the combination of injection sources.

Accomplishment of Project Objectives

The objectives of the project were as follows:

- Expend CEC-GRDA funds to provide partial funding of the Santa Rosa Geysers Recharge Project
- Specifically expend CEC-GRDA funds of 3.563M to partially fund construction of the Pine Flat North Pipeline Segment of the Geysers Recharge Project
- Extend the life of The Geysers geothermal field in Sonoma County
- Reduce amount of gases produced by steam and power production
- Increase future steamfield production from The Geysers reservoir by 85 additional megawatts

The following describes how each of these project objectives were accomplished:

- Objective: Expend CEC-GRDA funds to provide partial funding of the Santa Rosa Geysers Recharge Project.
- Accomplishment: Predesign, final design, and all environmental documentation was

completed on The Geysers Recharge Project, all construction contracts were awarded and are either completed or nearing completion. The project, consisting of 40-miles of pipelines, four pump stations, a million-gallon reservoir, steamfield improvements, and pump station power are anticipated to be operational in the Spring of 2003. The overall project cost is now estimated to be $225M. The CEC-GRDA funding has been combined with United States Department of Energy Grants, United States Environmental Protection Agency Grants, California State Revolving Fund Program (as administered by the Water Quality Control Board) and bond funding from the City of Santa Rosa.

- Objective: Specifically expend GRDA funds of $3.563M to partially fund construction of the Pine Flat North Pipeline Segment of the Geysers Recharge Project.

- Accomplishment: The construction contraction for Pine Flat North Pipeline was awarded for construction in 2001. The contract, as of October 15, 2002 is approximately 80 percent complete with construction contract closeout anticipated in the Spring of 2003. Pipeline construction activities are shown in Figures 2.2, 2.3 and 2.4. Pump Station construction activities are shown in Figures 2.11, 2.12, 2.13, and 2.14. Portions of the contract to be funded by CEC-GRDA funds have been completed and all funds have been expended with the exception of the 10 percent retention, pending acceptance of final report.

- Objective: Extend the life of The Geysers geothermal field in Sonoma County

- Objective: Reduce amount of gases produced by steam and power production.

- Objective: Economic objective is to increase steamfield production from The Geysers reservoir by 85 additional megawatts

- Accomplishment: These three overall objectives will not be realized until all construction is complete and recycled water delivery begins. Current schedule for startup is Spring 2003 with full production by Fall 2003, at which time an initial evaluation of effects will be prepared and correlated against anticipated results. This data and information will be forwarded to the California Energy Commission

Findings, Conclusions and Recommendations

The project is concluding with positive feedback from cooperating agencies including:

- United States Environmental Protection Agency
- United States Army Corp of Engineers
- United States Department of Energy

- State Water Quality Control Board
- County of Sonoma
- City of Windsor

Additionally, the project has received positive media coverage (See Figures 2.5 and 2.6).

In September 2002, the project was selected and presented with the 2002 Geothermal Excellence Award as given by the Geothermal Energy Association's Geothermal Research Council.

Future Intent of Grant Recipient to Maintain and Further Develop the Project

The contract between the City of Santa Rosa and the steamfield producers (Calpine Corporation) is for a minimum of 20 years with a 10-year option by either party and does not begin until the project delivers water (Spring 2003). Funding is in place to provide operation and maintenance of the facility for this period and beyond.

In addition, the final design of the project includes pipeline and pump station capacity greater than that required to meet commitments of the project. The City of Santa Rosa is already in the process of preparing an environmental document with various alternatives to increase the amount of water to The Geysers steamfield area by up to 2.5 times the contracted amount. Figure 2.7 graphically indicated the proximity of the project to other recycled water producers along the route that could provide additional water to The Geysers steamfields.

Benefits to the State of California

As described in detail in this report, the following are some of the benefits the State of California realized or anticipated from this project:

- 85 additional megawatts of renewable energy
- Reduction in gases produced in the steam and power plants at The Geysers steamfield
- Reduction in the decline of steam production extending geothermal field life
- A boost to the local economy in terms of temporary construction jobs and in long term employment in the steamfield area
- Additional revenues for lands under state ownership and for the State Teachers Retirement System (See Figure 2.8, 2.9 and 2.10)

Final Payment Request

A request for final payment (contract retention) has been submitted.

Consolidated List of Contractors and Subcontractors Funded in part by the Grant Recipient

The grant funds were used to fund only the construction aspects of the project:

- Contractor: Ford Construction, Inc.
  639 E. Lockeford St.
  Lodi, CA 9524

Ford's workforce has varied as the project has proceeded with a maximum of 80 personnel at any one time. Numerous local suppliers of construction materials and services have been employed throughout the length of the contract.

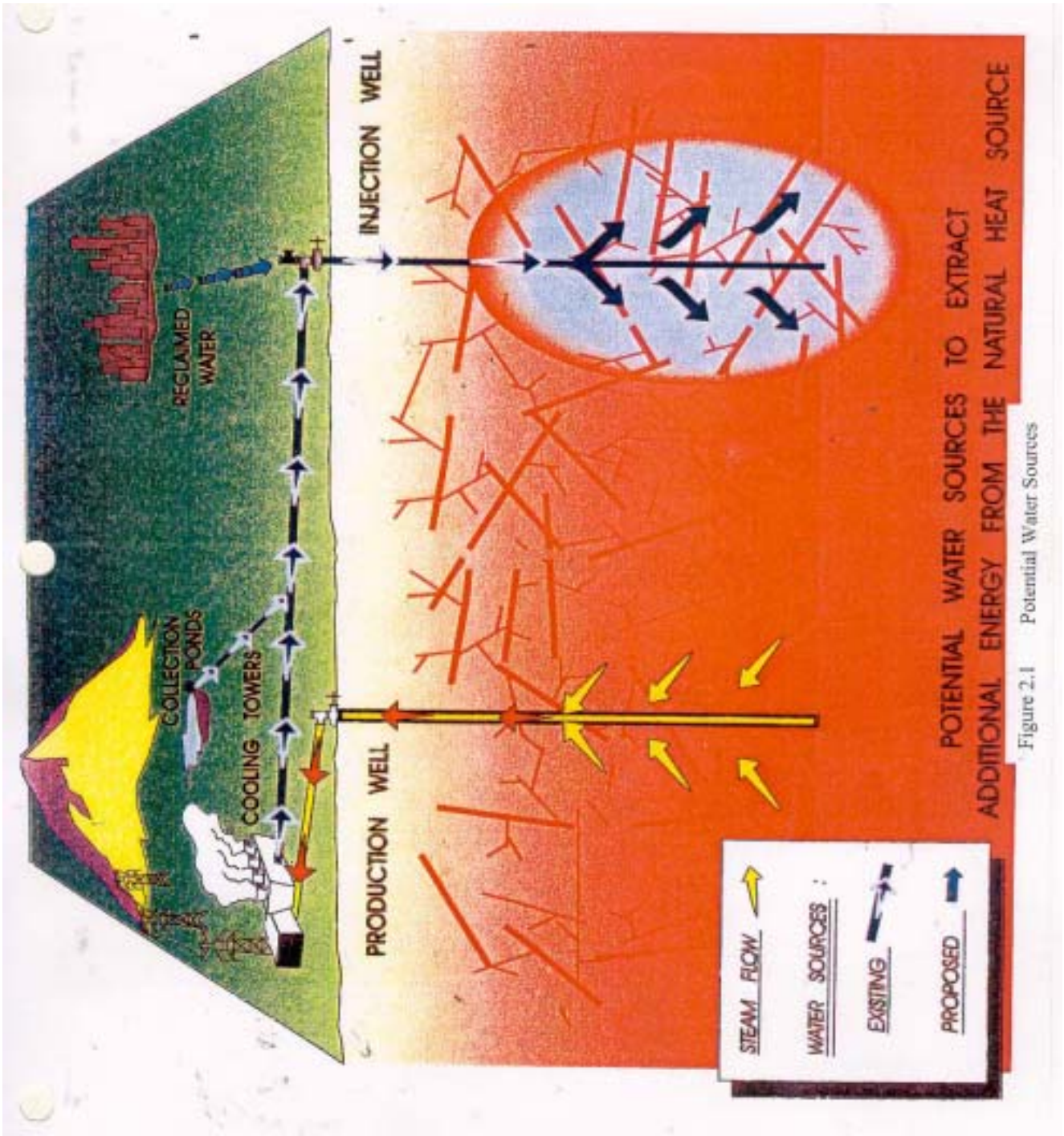


Figure 2.1 Potential Water Sources

Figure 2-1 Potential Water Sources

Figure 2-2 Pipeline Construction- Pine Flat Road

Figure 2-3 Terminal Tank and Pipeline Construction

Figure 2-4 Pipeline Construction- Pine Flat Road

San Francisco Chronicle

BAY AREA

AND CALIFORNIA

THE ENERGY CRUNCH

Steam Heat

Santa Rosa wastewater may soon recharge geothermal field

By Pamela J. Podger
CHRONICLE STAFF WRITER

SOCRATES POWER PLANT, The Geysers

Hard as it is to believe, the steam clouds drifting from the percolating coffee-colored water here offer a piece of the solution to California's energy puzzle.

These fumaroles — where 350-degree steam escapes from rock chasms — are an outward sign of an immense power source lying from the northern belly of The Geysers, a rare geothermal wonder that straddles Sonoma and Lake counties.

A giant Lego-like contraption spreads across 10 acres of land along the spine of the Mayacamas Mountains, with huge pipes snaking over the rugged terrain and carrying the steam here to 21 power plants. The steam then spins the blades that generate electricity and delivers 840 megawatts an hour — enough power for the entire North Bay, or for the city of San Francisco.

"When you flip one four light switch at home, I'm the one putting the juice in it," said Christine King, who single-handedly operated the Socrates Power Plant on a recent day.

At their peak in the 1980s, the steam fields produced almost 2,000 megawatts an hour. Now, four decades after the energy was first harnessed for electricity, power experts have concocted a plan — dubbed brilliant or a boondoggle, depending on one's perspective — that will keep production steady or, possibly, even boost output.

"Think of the Anakettle on the stove. If you keep taking 80 percent of the water out, ... pretty soon there will be nothing left."

FRANCIS GALLEY of Calpine Corp.'s geothermal division

► GEYSERS: Page A14 Col. 1

Natural hot springs bubble and steam around the Calpine steam generation plants at The Geysers on the border of Sonoma and Lake counties.

Christine King at work in the control room of the Calpine geothermal power plant, above. At left,

Figure 2.5 Steam Heat

Figure 2-5 Steam Heat

New steam power from 'old' water

▸ **GEYSERS**
From Page A1

By recharging the fields with treated effluent from Santa Rosa, pumping 11 million gallons a day through a 41-mile-long pipeline, they hope to keep The Geysers productive. The pipeline is so massive that it will take seven days for it to fill completely once the valves are thrown open.

"Think of the leakage on the stove. If you keep taking 80 percent of the water out, it will diminish and pretty soon there will be nothing left. We're using the wastewater to make up for the steam that is evaporated off in the cooling cycle," said Dennis Gilles, vice president of Calpine Corp.'s geothermal division. "The heat down in the ground isn't going to go away. I think the recharge could work well beyond 50 years."

In addition to creating more power for an energy-starved state, the plan also offers a solution to one of Santa Rosa's long-standing aggravations: how to prevent illegal discharges of its wastewater — such as the infamous four-day, 750 million gallon spill in 1985 — into the Russian River.

The city, which reclaims and distributes wastewater for the cities of Cotati, Rohnert Park, Santa Rosa, Sebastopol and portions of the county, has debated a variety of plans in the years since that spill.

In the late '80s, it considered a 25-mile pipeline to discharge wastewater into the ocean. In the 1990s, it pondered agricultural irrigation projects in the west and south county. Both of those options led to civic uproar — and lawsuits. The Geysers solution was the 1998 result of a five-year-long study.

The Geysers are a unique dry steam field that provides about half of the geothermal energy in California, with the rest coming from the Imperial Valley, Mammoth Lakes and Coso Geothermal Resource. (About 5 percent of the energy flowing into the state's grid comes from geothermal sources.)

Its rich history includes stories of Indians who cooked over the steam vents. Records show one of the earliest pioneers, William Bell Elliott, declared he had found the "Gates to Hades" as he stood among the hissing, bubbling hot springs while hunting a grizzly bear, Old Slewfoot.

The first wing of the Geysers Resort Hotel was built in 1854, and, in its heyday in the 1870s, the steam baths enticed notable travelers including past and future presidents — Ulysses S. Grant, William Howard Taft and Theodore Roosevelt — and writers such as Samuel Clemens and Jack London. The hotel's register was often signed in black ink drawn from a hot spring called the Devil's Inkwell.

The current "flush to flash" project — as it was nicknamed during the environmental review process — features the 41-mile pipeline from Santa Rosa to The Geysers. In a feat that makes engineers salivate, the mostly underground line will climb 3,200 feet on the west side of the Mayacamas. At other spots, it will be buried more than 50 feet down for two crossings of the Russian River near Healdsburg. The pipeline, which crosses five active earthquake faults, will be built in 10 legs and is expected to be operational by late next year.

Once it reaches The Geysers — which is a misnomer, as there are no geysers on the land — the water will be injected into the steam fields to renew the water that has evaporated.

The energy giant behind this venture is Calpine Corp. of San Jose, which acquired 19 of the Geyser's 21 plants in 1999 from Pacific Gas and Electric Co., in the aftermath of energy deregulation.

Energy managers hope to emulate the so-far successful venture begun in 1997 in Lake County, where a 29-mile pipeline delivers 8 million gallons of treated wastewater to generate 68 megawatts from the steam fields.

"From what I've seen from the Lake County project, the steam pressure in the areas is rebounding, and they are getting additional power," said Karl Gawell of the the Geothermal Energy Association in Washington, D.C. "Is it possible to expand The Geysers and get another 100 or 1,000 megawatts? I think those are open questions, based on the science."

Calpine will invest more than $140 million into The Geysers by 2005, Gilles said. He said the company hopes the wastewater will help sustain production at its current level — and, possibly, even boost output up to 1,000 megawatts per hour.

At its peak, The Geysers had about 500 steam wells. Calpine now has 368, plus 40 injection wells, where the condensed vapor is returned to the depths. Calpine will invest about $500,000 apiece to refurbish about 20 to 30 abandoned wells, and spend about $2 million apiece to drill several new wells.

"With energy prices higher, it is cost effective to go and invest money to refurbish those old wells," Gilles said.

Steve Burden, Calpine's project manager, said the company is also going to shell out about $74 million for the pipeline. Santa Rosa is spending $160 million but has some of its costs protected if Calpine should pull the plug.

Santa Rosa's project manager Dan Carlson said that the pipeline has changed from its original concept in response to community concerns. Capacity has been increased by one-third and the pipe will now be able to deliver 48 million gallons daily — which will give farmers a future option of using the water to irrigate.

In addition to solving its own wastewater problems, the city is exploring the possibility of shipping treated wastewater from other parts of the county to The Geysers.

Nonetheless, there are plenty of skeptics in the county — at least one may has called the project a "pipe dream" — and drawn its own share of lawsuits.

Farmers and other residents in the Alexander Valley were worried about the pipeline rupturing, or having mudslides wash out the 9¼ miles of pipe that will run along Pine Flat Road, which was hand-built by Chinese laborers for the old mercury mines. A suit filed by the Alexander Valley Association was finally settled in December for $321,000.

"I think pumping water 41 miles and up 3,100 feet is a boondoggle, or ridiculous, when they could use the water for farmers more locally," said Tim Barnard, the association's former president. "There is a still the threat of the pipeline rupturing once it is on the hill and installed. This is an earthquake-prone area and The Geysers has minor quakes all the time. There could be a 2 million-gallon flash flood of wastewater."

Carlson said the everything about the pipeline has been highly engineered to ensure safety — and that it is designed to shut off automatically in the event of a pressure change or earthquake.

"We've put more reliability into this project," Carlson said. "Once it is in place, we want it to function for 50 to 100 years without having to dig it back up."

Another lawsuit, settled in March for $1.1 million, was filed because the pipeline crosses over 1,400 acres of Audubon nature preserve known as the Mayacamas Mountain Sanctuary. The money will be used in part to hire a caretaker to maintain the sanctuary.

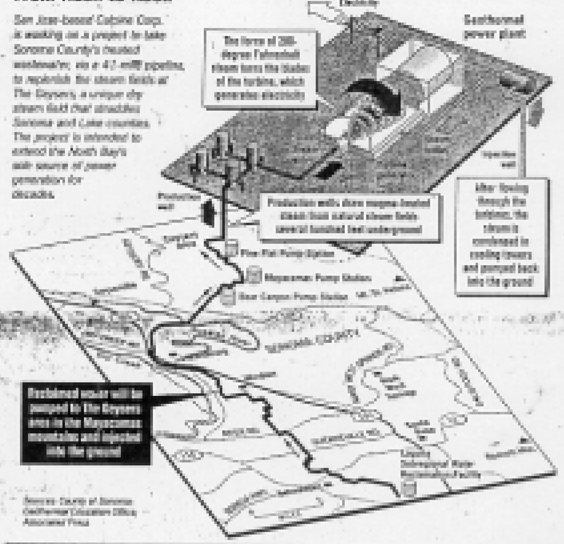
Joan Dzenjanin, past president of the Madrone Audubon Society, said the group is satisfied that there are sufficient protections for the bobcats, cougars, nesting California songbirds and other wildlife there.

Gilles said The Geysers is the only power generated in the North Bay, providing enough electricity to meet needs from the Golden Gate Bridge to Cloverdale.

E-mail Pamela J. Podger at ppodger@sfchronicle.com.

> *"Is it possible to expand The Geysers and get another 100 or 1,000 megawatts? I think those are open questions, based on the science."*
>
> KARL GAWELL, Geothermal Energy Association

From flush to flash



Chronicle Graphic

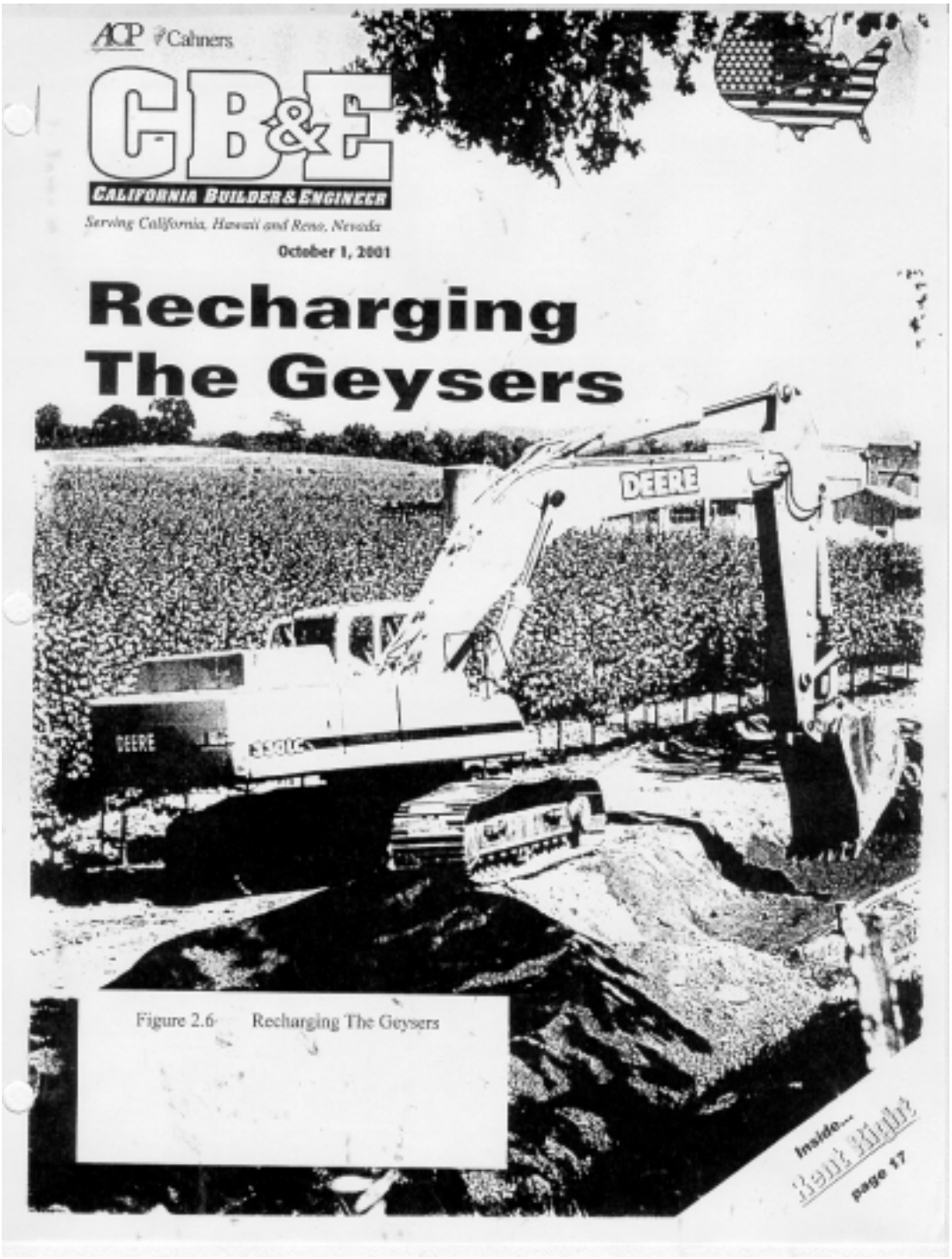


Figure 2-6 Recharging The Geysers

Recharging The Geysers

The City of Santa Rosa and communities along the way will benefit from an ingenious plan to inject purified wastewater into underground Geysers some 40 miles to the North.

■ *By Loren Faulkner*

The road to the Geysers Recharge Project hasn't been easy — or fast. What began as a no-win situation will end as a win-win, if things go as planned. The original no-win scenario looked like this:

Each year, the city of Santa Rosa reclaims, treats, then reuses some 4 billion gallons of regional wastewater to irrigate nearly 6,000 acres of local farmlands, vineyards, parks and school grounds. This is fine during summer months. But during winter, wastewater is stored in ponds and when nearing overflow, is allowed into the Russian River at a rate not-to-exceed five percent of the River flow. In drought years that same rate has caused the City to be in violation of its National Pollutant Discharge Elimination System (NPDES) permit. Fines can add up quickly, yet the treatment system needs to expand due to the area's population growth.

At the same time, The Geysers steam field located to the northeast has produced electricity for the region since 1960, when Pacific Gas & Electric built a power plant there. At peak production in 1987, enough electricity was generated to supply nearly two million people.

But only a portion of the steam can be recovered and re-injected into the underground reservoir. This has caused a decline in water levels that reach the super-heated underground rocks. Steam production has been declining steadily and now only about half as much electricity is produced at The Geysers. New ideas were needed for dealing with both situations.

Left:
Pipeline diameters range from 30-to-48-inches and stretch some 41 miles from Santa Rosa to the northeast portion of Sonoma County.

Top:
Pipeline worker inspects trench nearby.
Bottom:
Jim Winter, civil engineer with Winzler & Kelly Consulting Engineers looks over a recently covered section of trenching.

Rocky Road

The City of Santa Rosa and the Subregional Reclamation System from 1986 to the mid 1990s has had to jump a number of hurdles on the road to resolving their wastewater disposal problems. These ranged from various legal challenges in court relating to Environmental Impact Reports on a new plan to release wastewater into the Russian River, to a series of right-of-way, eminent domain and environmental issues.

Win-Win

The City studied four possible alternatives to simply releasing wastewater into the Russian River each winter. The best solution seemed to be the Geysers Recharge idea. Those plans called for laying a 41-mile, 30-to-48-inch diameter underground pipeline from a wastewater treatment plant in southern Sonoma county all the way up to the PG&E electrical plants at The Geysers. From a storage tank there, it will be injected underground between 4,000 and 11,000 feet to eventually be heated naturally to produce steam.

"The project will transport 11 million gallons of reclaimed wastewater, or recycled water, per day to The Geysers steam field for generating electricity," said Dan Carlson, capital projects coordinator for the City of Santa Rosa. "The additional water will initially produce 85 megawatts of electricity, enough to supply the needs of 116,000 Sonoma County residents; perhaps more could be produced in the future."

The estimated $160-million project will allow vineyards and other agricultural users to tap into the line along the way for a supplemental water source when needed, Carlson added. "The new delivery system will not only

Volvo L120C Tool Carrier transports earth for off-haul and backfill.

produce "green power", but will reduce wastewater discharge into the Russian River, accommodate future population growth and agricultural needs, and provide high level water management," he said. "It is a cooperative effort between the City, the State Lands Commission and Calpine, benefiting public and private industry."

Environmental concerns had been at issue during the entire project planning stages but have generally been worked out. It has been agreed that increased water re-use could help restore the habitat of the coho and steelhead salmon – both on the endangered species list.

Construction

The City of Santa Rosa is constructing the pipeline from Santa Rosa to The Geysers. From there, Calpine is building the power transmission facilities, distribution system and pipeline, as well as the underground injection system.

Challenges

"The last eight miles of the pipeline — the mountain portion leading up to the Geysers facilities — is the most challenging," said Carlson. "We have limited access on a single lane road, and we are working directly in a National Audubon Society sanctuary. Needless to say, we are being observed carefully in this highly restricted area."

The delayed availability of pipeline in general became apparent during the project, since so many water and gas projects are occurring within California, Carlson added.

Construction began last year and should be completed, with the water being injected at the Geysers by December, 2002. ❐

Figure 2-7 Proximity of the Pipeline

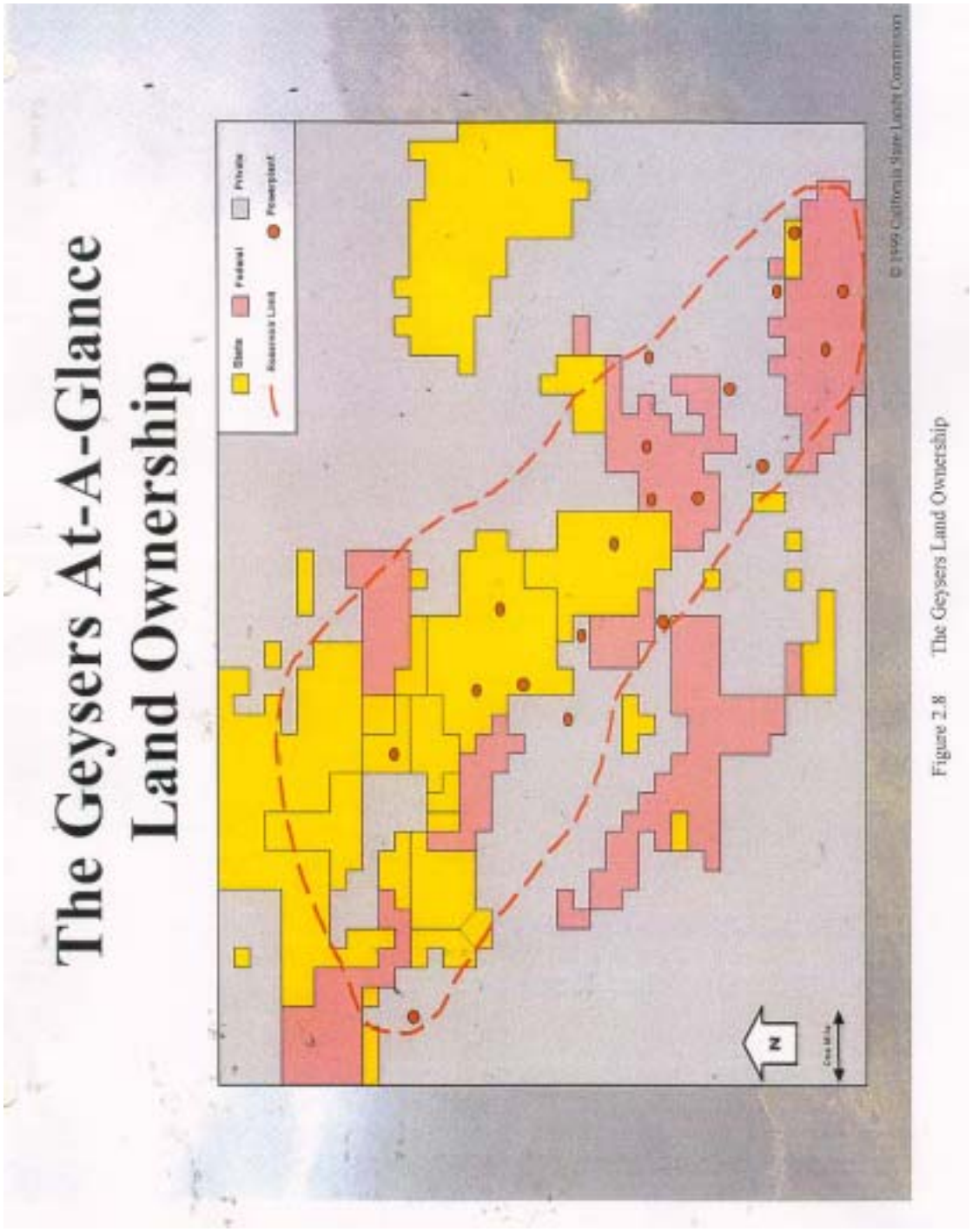


Figure 2-8 The Geysers Land Ownership

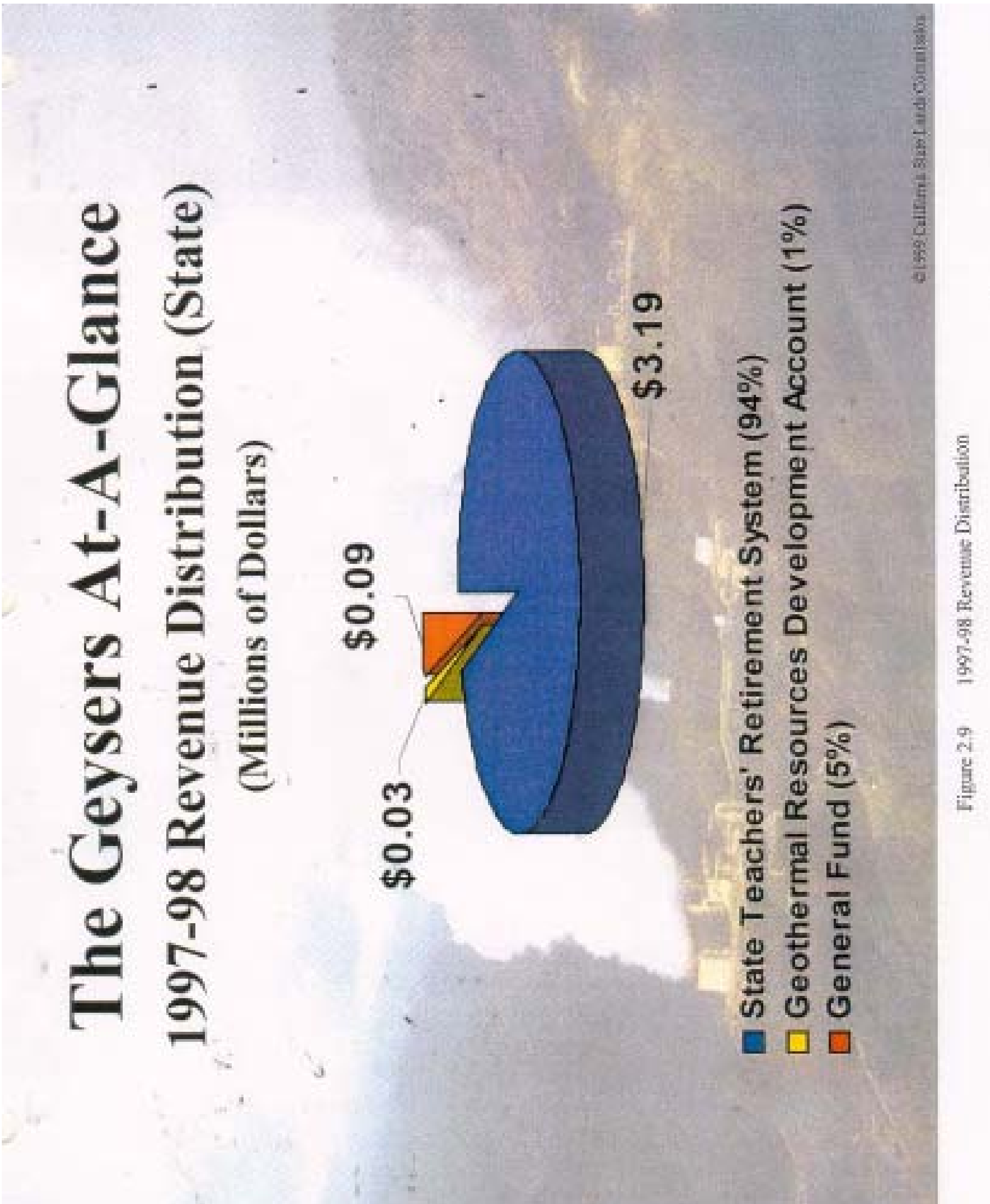


Figure 2-9 1997-98 Revenue Distribution

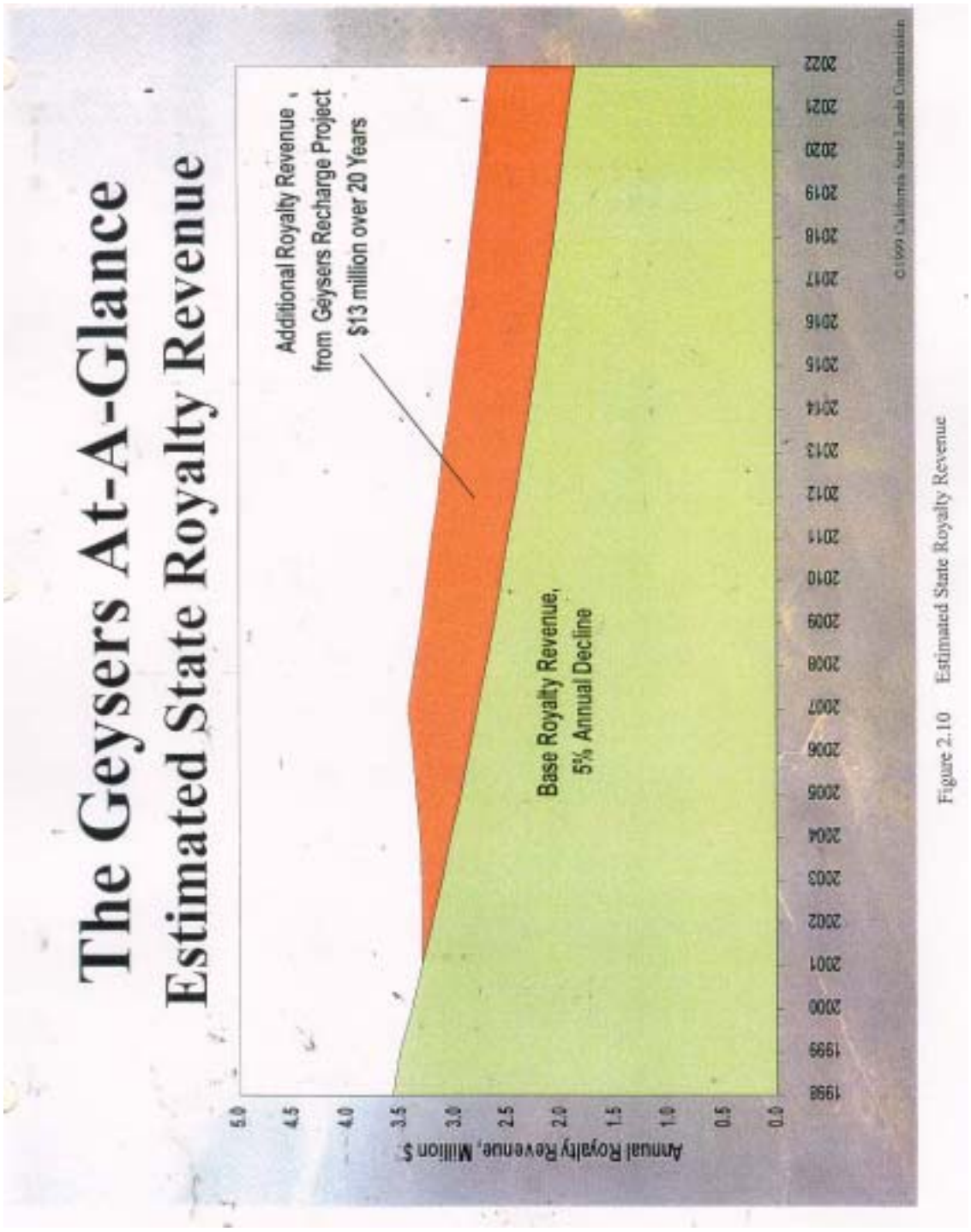


Figure 2-10 Estimated State Royalty Revenue

Figure 2-11 Bear Canyon Pump Station

Figure 2-12 Mayacamas Pump Station

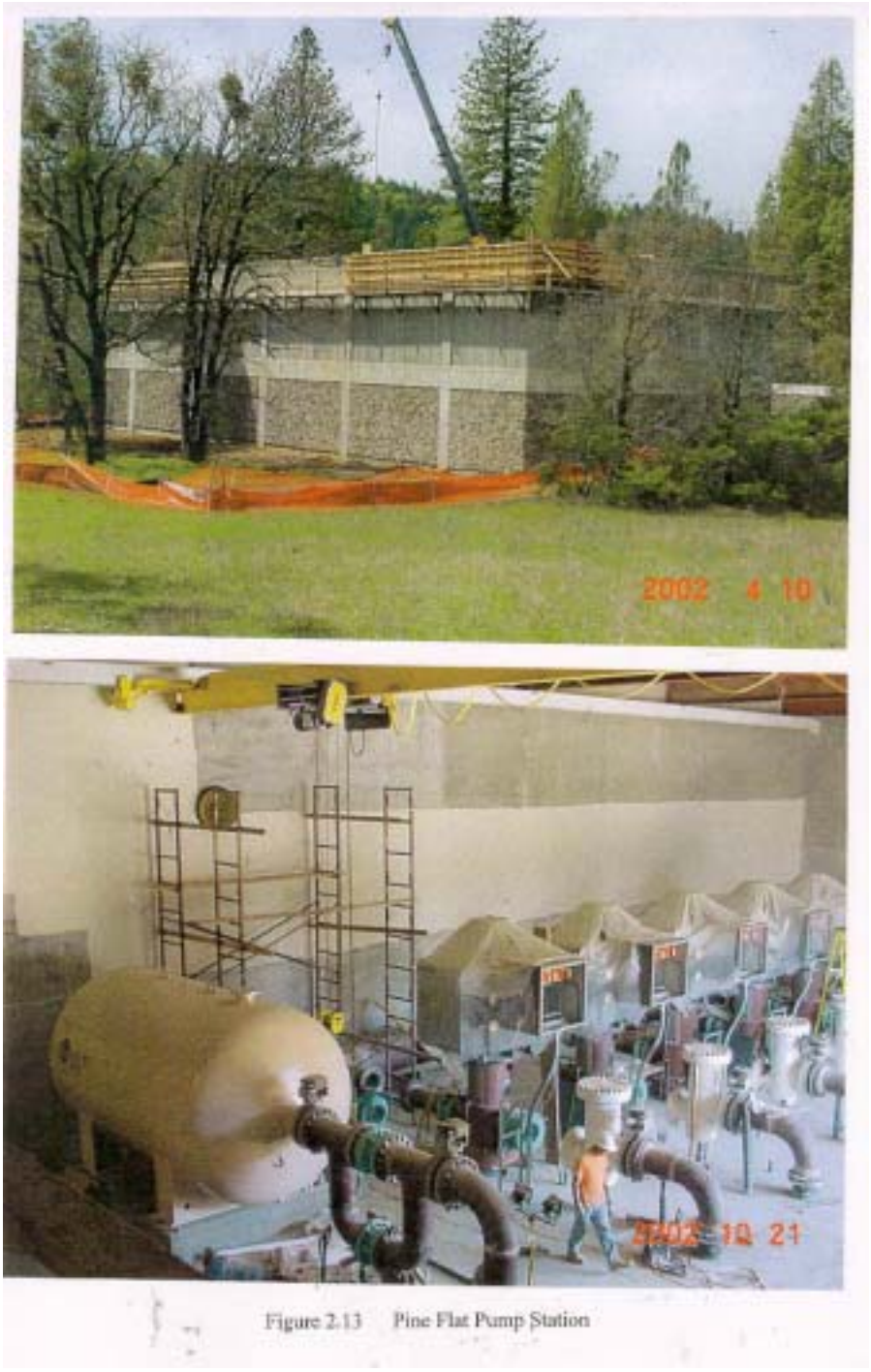


Figure 2-13 Pine Flat Pump Station

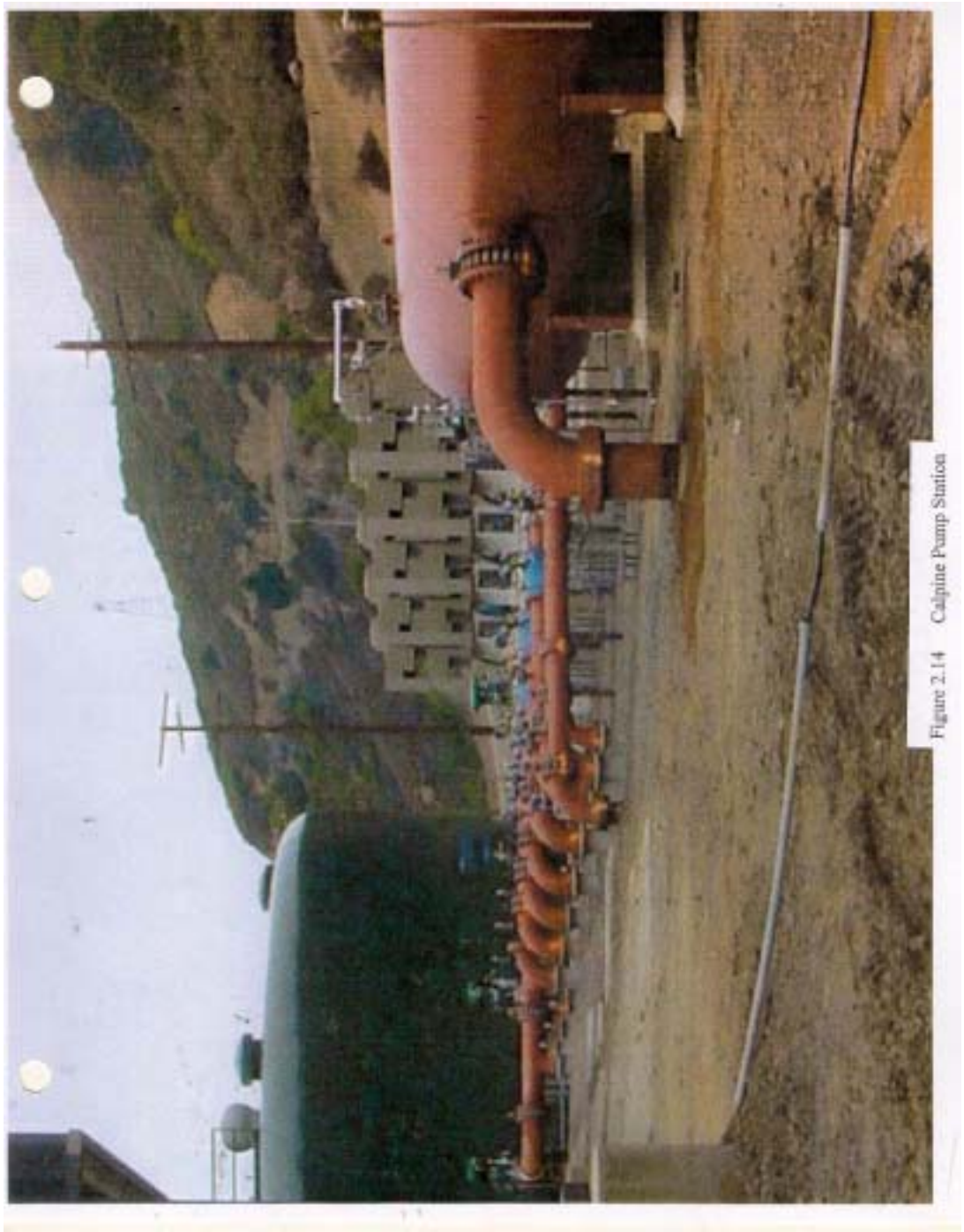


Figure 2-14 Calpine Pump Station

3. Description of the Geysers Recharge Project

The Geysers Recharge Project will provide for the use of 11 million gallons per day (mgd) of tertiary-treated reclaimed water furnished by the City of Santa Rosa to the northwestern portion of The Geysers geothermal field for injection into the steamfield. This project will generate enhanced energy production from The Geysers resource while allowing various research and development programs to be implemented. This continuous, reliable supply of water will enable enhanced geothermal system EGS) research in the hot dry or depleted areas of The Geysers reservoir. This project is consistent with recommendations made to the CEC by its Technical Advisory Committee (TAC) in September 1992 as a means to preserve and enhance The Geysers geothermal resource.

This project includes the construction of a 40-mile pipeline, four pump stations and associated facilities. It also includes an electric transmission line; a geothermal field distribution system, including well conversions for water injection; and various research and development activities. The field distribution system will consist of pipelines to convey reclaimed water from storage to various geothermal injection wells located in the northwest portion of The Geysers steamfield. This geothermal field will be upgraded by converting several existing wells to injection wells. The new system will also be tied to some of the existing injection pipeline facilities in order to provide flexibility and additional capacity for water injection. Existing and ongoing research and development activities will be augmented by several new research opportunities only made feasible by this project and dependent upon water provided by the City of Santa Rosa.

The project is being constructed (anticipated completion date of all portions of the project is Spring/Summer 2003) in a series of construction contracts, some managed by the City of Santa Rosa and some managed by Calpine Corporation. Figure 3.1 shows the City's portion of the construction projects. Figure 3.2 shows Calpine's portion of the project. Table 3.1 describes the various City construction contracts and Table 3.2 describes Calpine's construction contracts.

Startup of the project is currently anticipated for Spring 2003, with full operation by Fall 2003.

Figure 3-1 Santa Rosa Geysers Recharge Project Pipeline Alignment

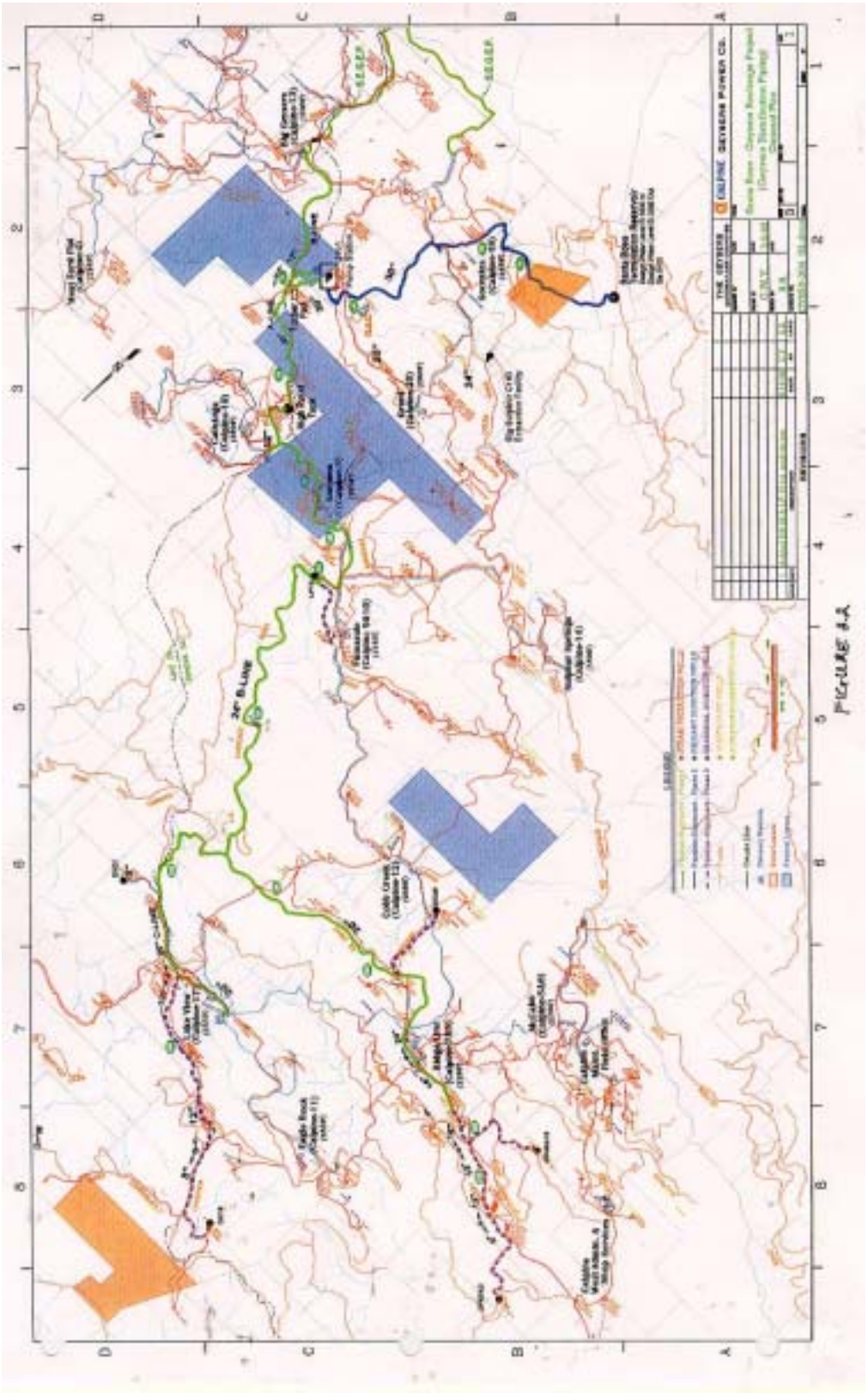


Figure 3-2 Calpine's portion of the project

Table 3- 1 City of Santa Rosa's Construction Contracts

Contract Name	Description	Completion or Estimated Completion Date	% Complete as of October 15, 2002
Llano/Mark West Pipeline	7.9 miles of 48" welded steel pipe and related appurtenances	June 2002	100%
Mid-South Pipeline	6.5 miles of 48" welded steel pipe and related appurtenances	November 2002	98%
Windsor Pipeline	6.8 miles of 48" welded steel pipe and related appurtenances	December 2002	95%
Healdsburg North and South Pipelines	6.8 miles of 48" welded steel pipe including 2 pipeline tunnels under the Russian River	December 2002	95%
Healdsburg Central Pipeline	2.1 miles of 48" welded steel pipe and related appurtenances	January 2003	93%
Pine Flat South Pipeline	0.3 miles of 48" welded steel pipe and 3.7 miles of 30"/34" welded steel pipe/ high-density polyethylene (HDPE) pipe.	April 2003	80%
Pine Flat North Pipeline	5.5 miles of 30"/34" welded steel pipe/ HDPE pipe. Also includes 1 million gallon steel reservoir tank.	April 2003	85%
Pump Stations Pipeline	4 pump stations: Llano, Bear Canyon, Mayacamas and Pine Flat. Also includes fiber optic communications network for all 40 miles of pipeline	June 2003	60%
Environmental Restoration	Restoration of all areas impacted by construction	Fall/Winter 2003/2004	2%
Geysers Operations Center	Office, operations, and maintenance facility including computer for control monitoring and security.	September 2002	100%

NOTE: CEC funding was used to help fund the construction of the "Pine Flat North Pipeline" segment of the project.

Table 3- 2 Calpine's Construction Contracts

Contract Name	Description	Completion or Estimated Completion Date	% Complete as of October 15, 2002
Phase 1 Pipeline	8 miles of 12"-30" steamfield distribution pipeline	July 2002	100%
Phase 2 Pipeline	5 miles of 20"-30" steamfield distribution pipeline	July 2002	100%
SR-1 Pump Station	Steamfield pump station to distribute water	August 2002	100%
21KV Powerline	10 miles of above and below ground electrical transmission line to provide power for pump stations for City of Santa Rosa pump stations	May 2003	50%
Phase 3 Pipeline	4.5 miles of 8"-12" spur lines to outline injection areas	May 2003	10%

4. Development of The Geysers as a Geothermal Energy Resource

Current Installed Geothermal Capacity at The Geysers - 1.5 MW

Current Delivered Electricity from The Geysers - 1.0 MW

The Geysers

Seventy-two miles north of San Francisco in the Mayacamas Mountains, a range of rugged hills, there's a place where nature has created a great natural boiler not far below the earth's surface. Steam from this subterranean cauldron sometimes drifts up from the very hillsides, giving the area its name - - The Geysers. Experts will tell you that the visible steam escaping from the hillsides in the area are called fumaroles, not geysers. Unlike "Old Faithful" geyser in Yellowstone National Park, there are no geysers spouting great columns of hot water here, but "The Geysers" it remains.

This natural of "geothermal" steam is harnessed and put to work spinning turbine-generators in power plants to create electricity. (See Figure 4.1)

The Geysers is the largest complex of geothermal generating plants in the world. (See Figures 4.2 and 4.3)

Wells, some greater than two miles deep, have been drilled to tap the natural steam. The steam is piped to a number of moderate-sized generating units dotting the California hillsides in Sonoma and Lake Counties.

Today, there are19 units at The Geysers with a total net generating capacity of about 880 megawatts of electricity --- enough to power 880,000 homes. A megawatt can power 1000 homes for one hour.

History

Native Americans first inhabited The Geysers about 12,000 years ago. By the mid-1800's when

many settlers came to California, six tribes lived there. The hot springs and fumaroles were used by these people for healing purposes and may have had ceremonial significance.

In 1847, explorer-surveyor William Bell Elliott, hiking through the mountains between Cloverdale and Calistoga hunting grizzly bears, came upon a startling site: puffs of steam coming from the hillside. Elliott had “discovered” The Geysers. The awe-struck hunter later told friends he thought he had come upon “The Gates of Hell.”

With stagecoach service beginning in 1863, the area became a modest tourist attraction. Presidents Ulysses S. Grant and Theodore Roosevelt and other famous people came to visit, but the remote resort never attracted large numbers of visitors. Its future lay along another path.

Power Development

The first attempt to develop the electric power potential of The Geysers area came in 1922. Driller succeeded in tapping the steam, but the pipes and turbines of that day couldn’t stand up to the abrasion and corrosion of the particles and impurities in the steam.

Nor was the time ripe -- hydroelectric sites were still available and were cheaper to develop. The project was abandoned.

In the mid-1950's, Magma Power Company and Thermal Power Company, working jointly, began a new attempt to harness the steam. It succeeded because of advances in well drilling and power plant technology. Now that steam could be developed economically, Pacific Gas and Electric Company (PG&E) began a series of experiments and studies that led to the decision to build and operate an 11-megawatt generating plant. This first unit went into commercial operation on September 25, 1960, heralding the nation’s entry into the world of geothermal energy.

In 1967, Union Oil Company of California (now Unocal) joined pioneering Magma and Thermal power companies and was named operator of the steam fields. This move made technical and financial resources available to increase exploration and development of the steam field. Magma’s interest in The Geysers was eventually purchased by Unocal, and in 1994 Calpine purchased the Thermal Power Company stock.

Many other companies and utilities have played an active role in drilling steam wells and operating power plants in the area. Development at The Geysers reached its peak in 1989 with a total generating capacity of about 2,000 megawatts.

In 1980, PG&E build Big Geysers power plant (Unit 13), the first to be located in Lake County, rather than Sonoma County. When it began commercial operation at 133 megawatts, it because the world’s largest geothermal unit.

In 1988, Calpine began operating its very first electric generating plant of any kind, at The Geysers. Its one megawatt interest in the 20 megawatt Aidlin geothermal power plant marked Calpine's entry into the energy production market. Since then, Calpine has significantly expanded its role at The Geysers. In 1990, Calpine acquired a majority interest in the 27 megawatt West Ford Flat and 20 megawatt Bear Canyon power plants and steam fields, as well as steam fields supplying PG&E's Big Geysers (Unit 13) and Quicksilver (Unit 16) plants, and the SMUDGE01 plant owned by the Sacramento Municipal Utility District (SMUD). The 72 megawatt SMUDGE01 plant was added to Calpine's power portfolio in 1998 when the project was purchased from the SMUD and renamed Sonoma power plant (Unit 3).

In March 1999 Calpine purchased all of Unocal's remaining interests in the steam fields that fuel the power plants in Sonoma County. In May, Calpine acquired all of PG&E's power plants - 14 units altogether. In July, the company increased its ownership of the Aidlin plant to 55 percent. And in October, the purchase of the 80 megawatt Calistoga plant from Florida Power and Light was completed.

In June, 2000 Calpine increased its ownership of its first geothermal project, Aidlin power plant (Unit 1), to 100 percent.

Today, Calpine owns and operates 19 geothermal plants that together generate 880 megawatts of electricity - enough power to meet the needs of a city the size of San Francisco. The plants are operated using steam gathered from ore than 350 active steam wells. At present, over 40 wells are use to inject water into the steam reservoir. (See Figures 4.4, 4.5, 4.6 and 4.7)

History of Injection/Recharge

Injection of water into The Geysers reservoir began in 1969. Steam condensate, which originates from the power generation process, was disposed of in marginally productive wells. This process continues today, resulting in replacement of 25 to 30 percent of the annual steam produced from the reservoir. Numerous research projects and field tests of the effects of injection are ongoing using condensate injection wells. (See Figure 4.8)

In the late 1960s and 1980s, Unocal developed an extraction system in Big Sulfur Creek in order to access additional fresh water for injection. Regulatory and water rights permits allowed this water to be extracted only during periods of high flows in the rainy winter months. This system has provided significant volumes of additional water for injection by annual flows are highly variable and unpredictable.

The Lardarello geothermal field in Tuscany, Northern Italy is a large steam (vapor) dominated field with a long productive history. Production in this field for power generation began in 1914 and continues today. Substantial production declines have occurred in the old, heavily exploited

central portion of this field. In 1979, field tests began to evaluate the ability of condensate injection to increase steam flow in old depleted wells. The success of these studies led to the start-up in 1994 of a 24-mile long pipeline to deliver 2.0 mgd of groundwater and steam condensate from other geothermal areas to Lardarello. To efficiently utilize the low-pressure steam developed from injection into the Lardarello field, the Italians have installed a new generation of 60 MW modular power plants supplied by steam developed entirely from water injection.

In 1995, a consortium of steam suppliers, including Calpine, Unocal, the Northern California Power Agency (NCPA) and supported by PG&E, signed various funding and operating agreements with the Lake County Sanitation District for construction of a 26-mile pipeline to deliver 7.8 mgd of secondary treated water and Clear Lake water to The Geysers. This project became operational in September 1997 and by December 31, 1998 had delivered 3.2 billion gallons to the southern portion of The Geysers for injection into approximately 7 to 10 wells. The benefits of increased water injection in this portion of the reservoir include increased steam production and reduced field decline rates. A reduction in the concentration of various gases produced in wells surrounding the injection wells has also been noted. The initial gas concentrations in the natural steam in this area were already very low; therefore, the impact of this change on plant operations has not been significant.

The Geysers Recharge Project will inject 11 mgd into the northern portion of The Geysers field. The geothermal resource in this portion of the steamfield is significantly different from that of the southeastern portion of the field, which is the location of the current Southeast Geysers Effluent Pipeline Project (7.8 mgd). Generally, the geothermal resource in the northern Geysers area exists over a greater area and is thicker, hotter and contains a greater concentration of gases (including hydrogen sulfide) and corrosive constituents than the resource in the southern portion of the field. This difference provides greater opportunity for resource enhancement and RD&D studies from this project, leading to more efficient, less costly and more environmentally benign geothermal resource development and production in this area.

The positive injection results in the SE Geysers project to date and at Lardarello decrease the potential risks associated with the injection of large volumes of water into vapor-dominated systems. At Lardarello, the geologic conditions are such that shallow, low volume injection has proven to be most beneficial in maintaining steam supply and avoiding problems associated with water moving into nearby steamwells. While this was initially deep into the reservoir, often at high rates, has proven beneficial. The geologic similarities and differences of the two areas, coupled with the results of the two water injection projects, provide The Geysers operators with a better understanding of the conditions impacting injection results from The Geysers reservoir.

The SE Geysers project has provided useful information on the particular characteristics of regions of The Geysers reservoir that will benefit most from water injection. This knowledge will be used in locating injection wells to optimize steam recovery.

The Santa Rosa Reclaimed Water - Geysers Recharge Project will provide 11 mgd of additional

water for injection into the northern portion of The Geysers reservoir. Steam produced from this area of the field typically contains higher non-condensable gas concentrations and has more corrosive constituents than steam produced in the southern end of the field. Generally, there are fewer wells in the northern area compared to the southern portion of the field, making the recovery of injection-derived steam more viable. Most importantly, the northern area is underlain by a higher temperature (>300°C) zone know as the High Temperature Reservoir. This reservoir is poorly understood but produces very superheated steam that contains high concentrations of gases and corrosive constituents. This high temperature zone has not been found in the southern portion of the field. The successful development of injection into this zone could mitigate the steam quality problems in this area and add significant areas to reserves for further steam development. One of the primary goals of The Geysers Recharge Project is the mitigation of steam quality conditions in the northern portion of the field. This was not possible in the SE Geysers project since steam produced in the southern end of the reservoir contains very low concentrations of non-condensable gas and corrosive constituents.

Technology transfer will be accessible through the publication of the results of tests and experiments conducted during the life of this project in various industry journals and presentations at various meetings. The reservoir conditions in the northern portion of the field are important to the development of enhanced geothermal system technology, particularly in the high temperature sections, where previously developed hot, dry rock technology for fracturing and well stimulation will be used. Techniques and results developed from this project can be used by other operators of high temperature reservoirs, such as those located in Hawaii, Mexico, Indonesia and the Coso and Glass Mountain fields of California.

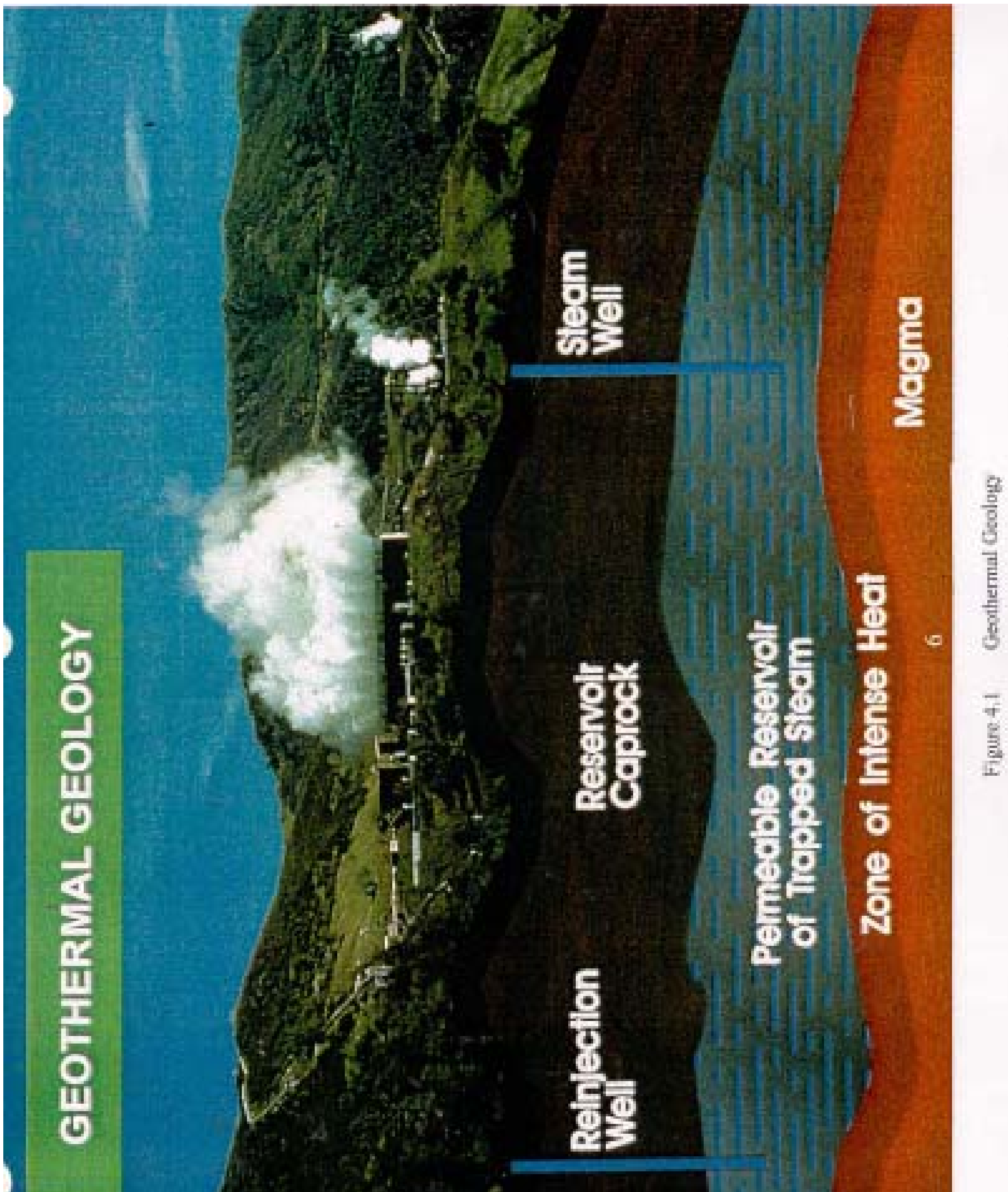


Figure 4-1 Geothermal Geology

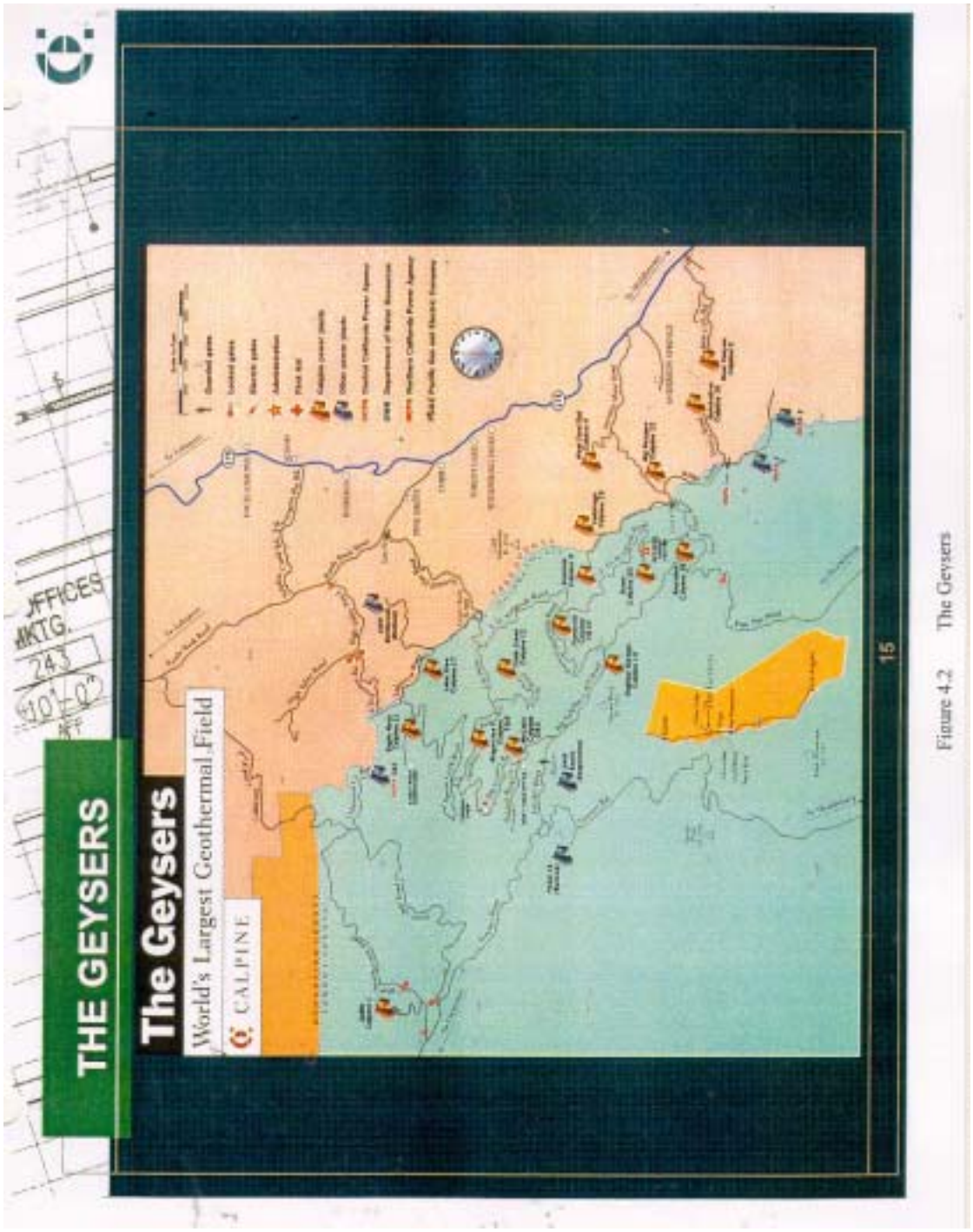


Figure 4-2 The Geysers

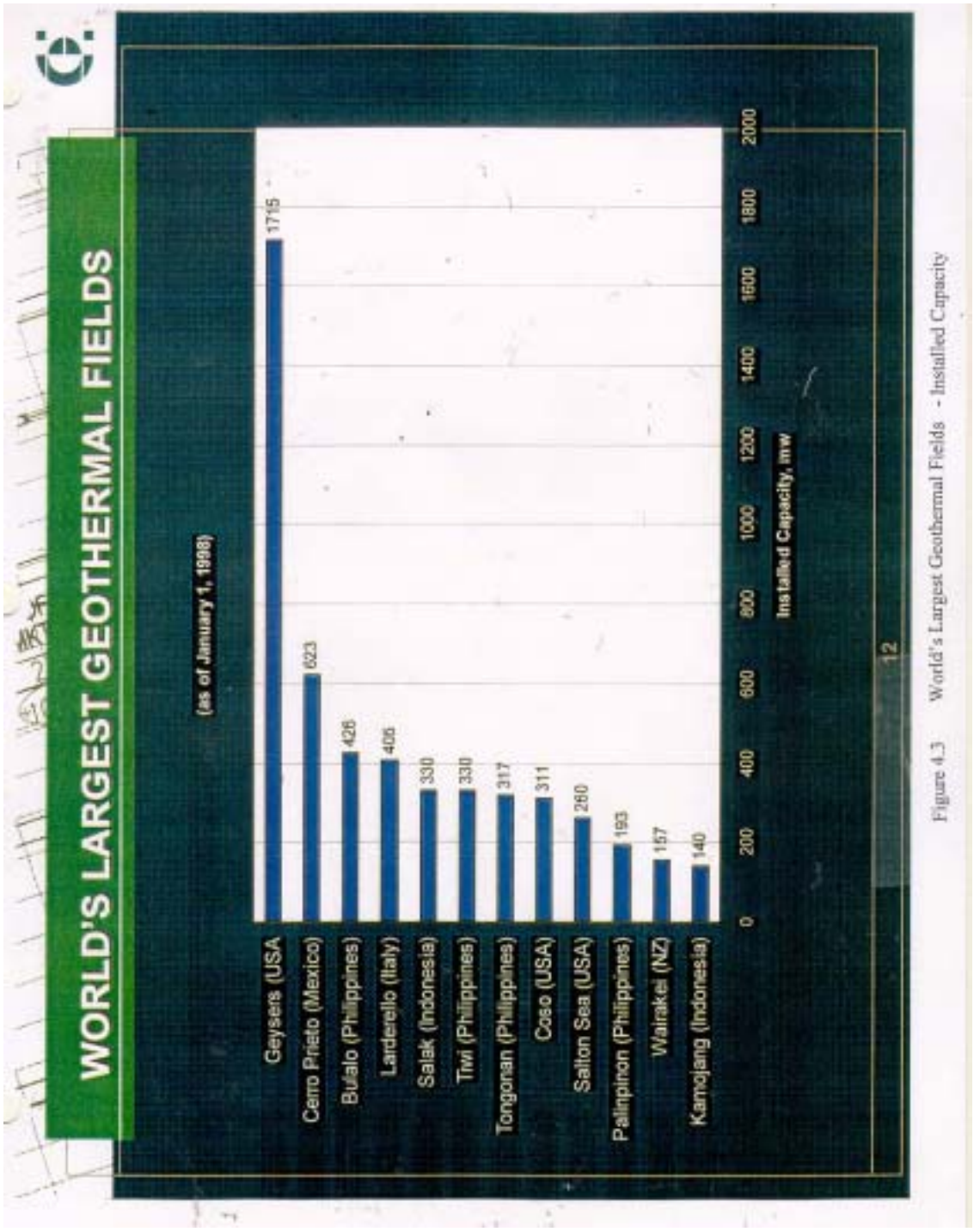


Figure 4.3 World's Largest Geothermal Fields - Installed Capacity

Figure 4-3 World's Largest Geothermal Fields- Installed Capacity

Figure 4-4 From Steam to Electricity

Figure 4.5 From Steam to Electricity - continued

Figure 4-5 From Steam to Electricity- continued

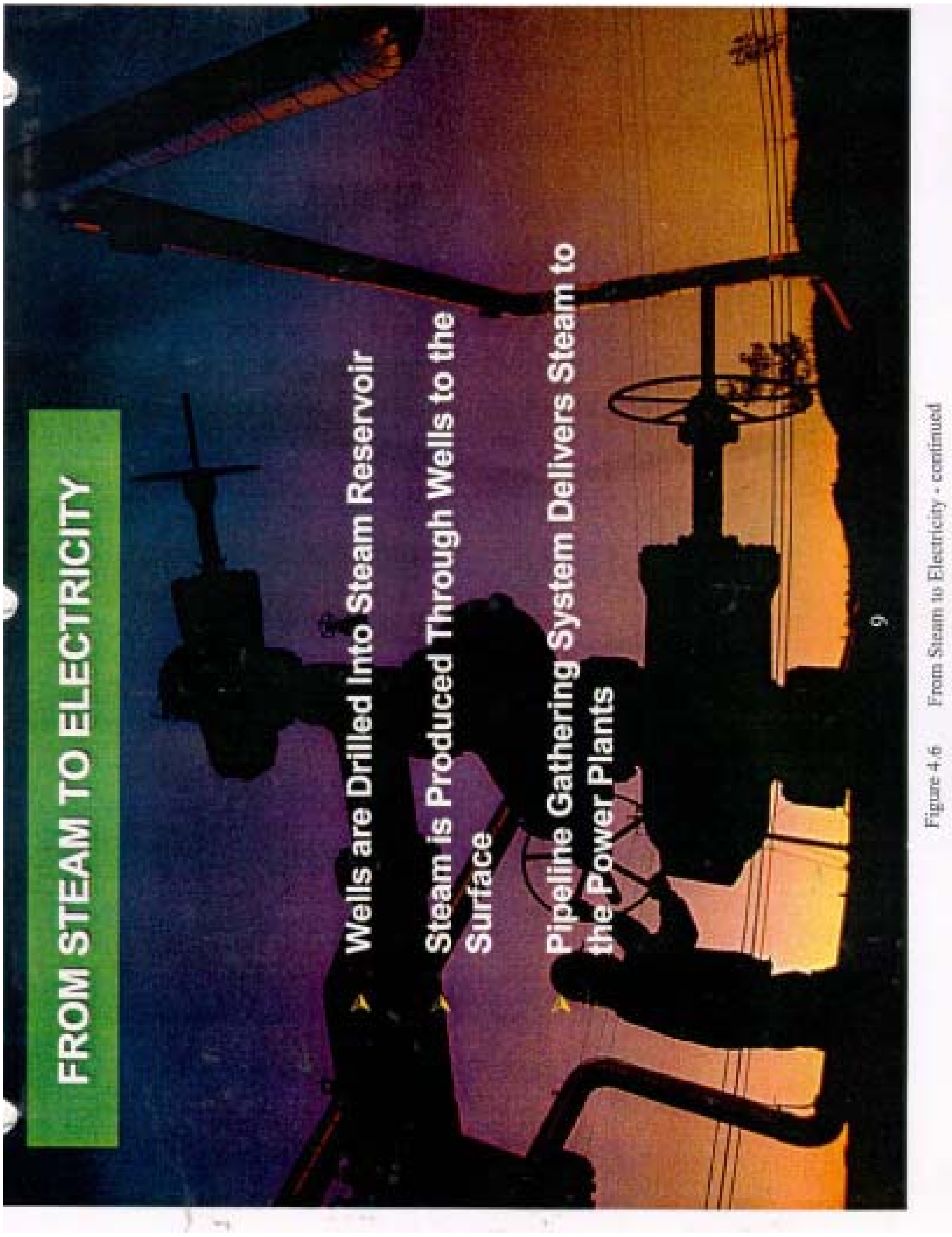


Figure 4-6 From Steam to Electricity- continued

Figure 4-7 From Steam to Electricity- continued

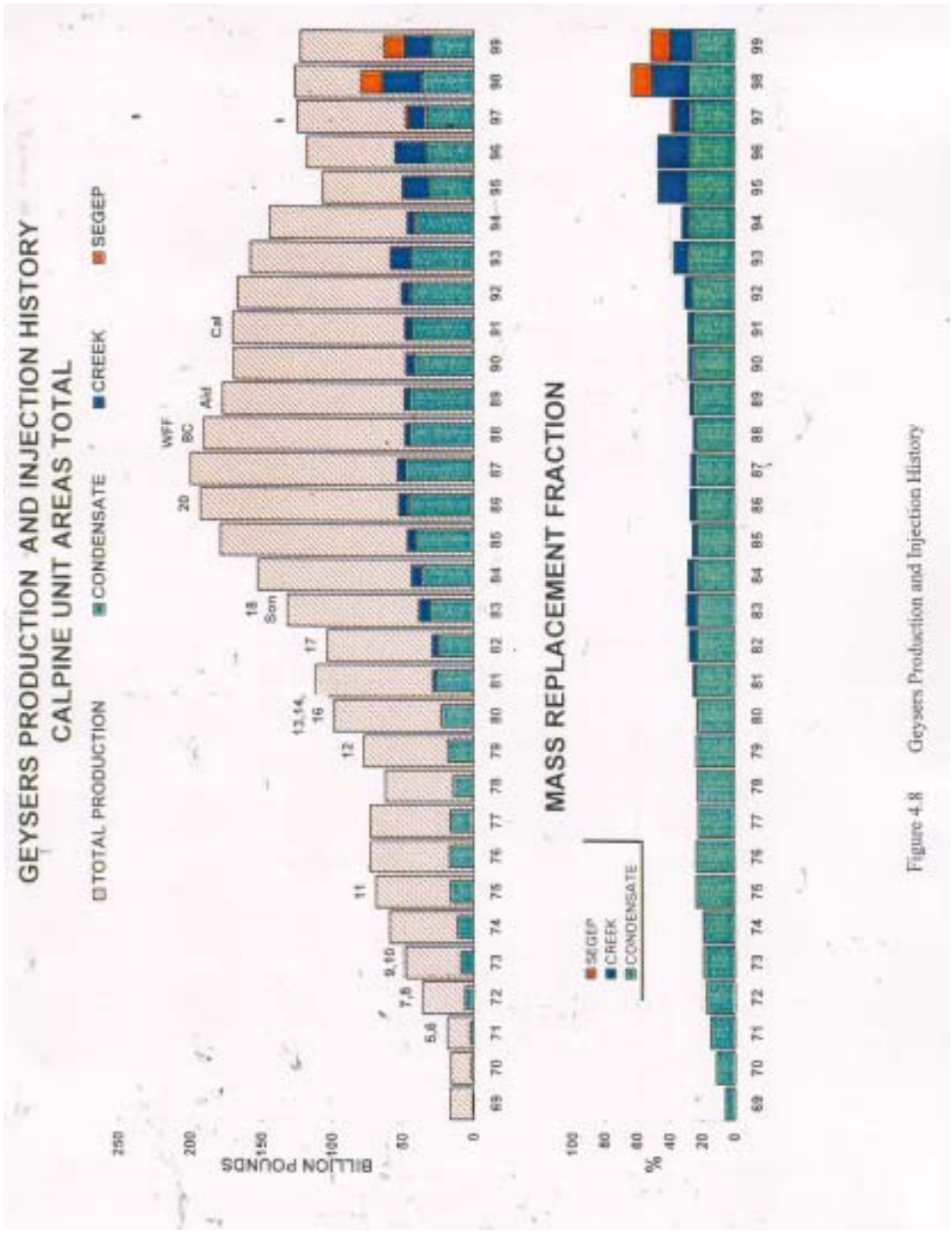


Figure 4-8 Geysers Production and Injection History

Figure 4-8 Geysers Production and Injection History

5. Benefits Provided of The Geysers Recharge Project

Large-scale wastewater injection in The Geysers field will enhance and preserve this valuable indigenous, renewable resource, thereby extending the life of an important source of energy, employment and tax dollars both locally and statewide. The potential overall benefits are:

(1) Increase plant generation levels and extend field life as the result of increased steam production and a reduction in steam production decline. The results to date of the smaller, Southeast Geysers Effluent Pipeline Project, which currently delivers approximately 7.8 mgd to injection wells in the southern portion of the field, indicate the viability of wastewater injection to increase field output of power plants at The Geysers by 85 MW over time and extend the economic life of The Geysers resource significantly.

Water injected in to The Geysers reservoir is returned as steam from wells in the area in which the water has been injected. This fact is well documented in technical publications and is based on numerous tracer tests and well performance evaluations. The results of these various tests and observations have shown that the amount of injected water recovered as steam can vary significantly depending upon the characteristics of the area in which the water is injected. Recovery factors, defined as the ratio of the amount of the increased production in the wells affected by injection to the total amount of water injected, vary from five to 50 percent during the first year of operation. Historical data indicates initial recovery factors can be sustained or even increased over the initial five to seven years of injection, but eventually, recovery factors begin to decline as boiling efficiency in the area reduces due to heat loss in the reservoir.

Ten years of high rate injection into one area on Calpine's lease resulted in initial recovery factors of 50 to 70 percent, which was sustained for approximately five years. Current recovery factors in this area remain excellent, at approximately 30 percent. Using available field test data and the results of tritium tracer test data in the northern portion of the field, the annual recovery factors shown in Table 5.1 were used to estimate the amount of additional steam produced from injection of the 11 mgd (3.82 million pounds per hour) of reclaimed water. This steam production rate is expressed as megawatts of capacity using the current, average plant conversion efficiency in The Geysers of 19,000 pounds per megawatt.

Based on historical recovery factors, this projection may be somewhat conservative, particularly given the very high subsurface temperatures in the northern portion of the field. Periodic relocation of injection wells will reduce the potential for substantial cooling in areas of the reservoir.

Since recovery factors, as defined, reach only 42 percent of the water mass injected, the

remaining 58 percent of the total amount injected is expected to add significantly to the long term (30 years) production at The Geysers Research Project.

(2) Reduce the life cycle costs of future electrical generation. Currently, steam produced from some portions of The Geysers reservoir contains relatively high concentrations of gases such as carbon dioxide, methane and hydrogen sulfide. Locally, the steam produced can also be corrosive due to the presence of chloride. The injection of significant amounts of clean water into these areas should produce clean, gas-free steam that can dilute the existing natural steam. A reduction of the amount of gas produced to the power plants, particularly hydrogen sulfide, will result in increased plant efficiency and lower operating costs. A reduction or elimination of the corrosive constituents in the steam will significantly extent well, pipeline and physical plant life, thereby reducing replacement costs.

(3) A reduction in the amount of gases, primarily hydrogen sulfide gas, produced by the power plants will also result in a significant environmental enhancement to this already clean source of electrical power.

(4) The Geysers Recharge Project will allow experimentation on the extraction of thermal energy from currently unproductive or marginally productive sections of the reservoir, including the high temperature zone known to exist in the northern portion of The Geysers field. The successful development of enhanced energy recovery from these hot, dry areas of the field could further add to the future output and the extension of field life.

In order to realize these potential benefits, a sound injection strategy, including a detailed plan to monitor the impacts of The Geysers Research Project on The Geysers resource, will be implemented. The scientific and operational knowledge gained from the Southeast Geysers Effluent Pipeline project and a number of completed and proposed field research projects will be critical to the success of The Geysers Recharge Project. Such knowledge coupled with additional information for the Santa Rosa project will lead to enhancement of The Geysers resource and more efficient operation of The Geysers field. The knowledge gained from the operation of injection wells and analysis of the impact of injection on resource conditions will provide benefits through application to other producing geothermal fields.

Table 5- 1 Steam Production Rate

YEAR	RECOVERY FACTOR (percent)	STEAM PRODUCTION (KLBS/HR)	MEGAWATTS (projected)
2004	14	532	28
2005	28	1069	56
2006	42	1603	85
2007	42	1603	85
2008 - 2023	42	1603	85

6. Issues Facing Geothermal Energy Development at The Geysers

(1) Portions of The Geysers reservoir are currently considered uneconomic to develop due to the existence of high concentrations of non-condensable gases and corrosive constituents in the steam. Successful water injection in these areas would result in increased steam well and, possibly, plant development in these areas. That is particularly applicable to the development of the high temperature reservoir (HTR) known to exist in the northern portion of The Geysers reservoir.

(2) The long term, stable supply of clean water for injection into the hot, depleted sections of The Geysers reservoir is necessary in order to develop improved techniques to extract the remaining energy in the geothermal system. These techniques would be applicable for use in other hot, fluid depleted or dry geothermal systems throughout the world. Enhanced geothermal system (EGS) research conducted in hot, dry sections of The Geysers Recharge Project has the potential to lead to the commercialization of the hot, dry rock approach to geothermal development.

(3) Research and development programs are needed to provide tools and techniques to enhance geothermal energy production from other depleting geothermal reservoirs. These tools may include improved reservoir models, which can be used to enhance reservoir management, as well as improved tracer techniques, logging tools and measurement techniques. The Geysers Recharge Project has the potential to provide these tools and techniques.

7. Economic Benefits and Issues

Public revenues from The Geysers Recharge Project would come from property taxes and royalties paid by the steamfield operators to the U.S. Bureau of Land Management and the State Lands Commission, a portion of which returns to Sonoma County. Average annual property taxes are estimated to range from $51,000 to $128,000; royalties would range from $321,000 to $771,000 depending on the amount of water delivered to The Geysers. The present value of the total public revenues is estimated to range between $3.5 million and $8.5 million over a 20-year period. Sonoma County should receive about 10 percent of these revenues.

Updated incremental royalty revenue projections from State and BLM leases are less conservative and are now estimated at $13 million and $8 million dollars, respectively, over the life of the project. Four million dollars (50% of the expected BLM royalty) will be deposited into the State's Geothermal Resources Development Account (GRDA). The GRDA revenue is distributed further, 40% to the county of origin, 30% to the California Energy Commission for grants to local jurisdictions or for technical assistance, and 30$ to the Renewable Resources investment Fund. The $13 million incremental royalty generated for State Lands Commission leases is paid directly into the State Teacher's Retirement Fund.

At the time of funding approval, it was estimated that, The Geysers Recharge Project would generate;

(1) 400,000 man-hours of construction work ($22M in labor costs);

(2) $30M in piping materials (manufactured in California); and

(3) $15M in materials manufactured in Sonoma County or nearby (bedding, fittings, valves, backfill, etc).

These estimates were based on a $132M project cost. Actual project costs are approximately $230M and each of the preceding three estimates will like be doubled by the time all work is complete.

In addition, The Geysers Recharge Project has provided economic benefits to the Sonoma and Lake county steamfields by creating jobs for operations and maintenance of the system. Assuming 85 MW of energy is generated from the injected water, approximately 35 to 40 existing operations and maintenance positions will be preserved throughout the 20 to 30-year life of the system. Local businesses will also benefit by providing services and materials for construction and operations of the system.

8. Enhancing Productivity of the Geysers Resources

Promotes Geothermal Energy Development or Demonstration in California

This project contributes to continuing California's world leadership in geothermal power production. It also reduces the cost of environmentally preferred ("green") power generation statewide. The Santa Rosa Reclaimed Water - Geysers Recharge project will also provide significant research opportunities for enhanced geothermal development in California.

The Geysers is a high-permeability, fluid-depleted hydrothermal reservoir. The Geysers Recharge Project will significantly increase injection into the reservoir and extend the life of the reservoir. As such, it presents developers with an opportunity to carry out field experiments aimed at developing and proving new tools and techniques to extract heat from underground hot rocks. These experiments can:

- Help extend the commercial steam producing life of The Geysers and other producing geothermal fields;
- Expand current capabilities; and
- Help lay the groundwork for development of enhanced geothermal systems resources in the future.

Examples of Research and Development opportunities include:

<u>Optimizing Large-Scale Field Injection Activities in Geothermal Systems</u>

Categories of activities include:

(1) Perform field experiments and develop field monitoring techniques in three types of reservoirs: mass-depleted hydrothermal reservoirs, deep, high-temperature corrosive gas reservoirs, and hot low-permeability rock volumes;

(2) Develop and apply geophysical and geochemical methods to monitor movement of injected water under various pressure conditions; and

(3) Evaluate long-term performance implications of alternate field experiments.

New injection strategies will be developed that should prevent premature thermal breakthrough between wells and should optimize the recovery of energy from the reservoir, contributing to long-term sustained energy production.

These new strategies are expected to minimize generation of corrosive gases and pipeline scales. Corrosive gases are presently neutralized at the surface or in well casing and are not released into the atmosphere. Reducing gas content in the reservoir and scaling in pipelines will reduce field-operating costs.

The Geysers Recharge Project offers an opportunity to improve methods that:

- Advance seismic monitoring techniques to improve the predictive abilities of the regional information network which includes the U.S. Geological Survey and the University of California;

- Track the location and mass of water vapor and injected water, key factions in production ; and

- Increase understanding of the structure and effective use of natural barriers that affect water distribution within the reservoir.

Analyzing Large-Scale Injection in Geothermal Systems

Categories of activities include:

(1) Examine injection performance in three types of reservoirs: mass-depleted hydrothermal reservoirs; deep high-temperature corrosive gas reservoirs; and hot, low-permeability rock volumes; and

(2) Develop new methods to model and monitor how and where steam conversion takes place in each type of reservoir. This will include the key factors of water vaporization, rock cooling, rock-water-steam interaction, crack formation and movement of injected water and vaporized steam.

This work could greatly extend the productive life of The Geysers Recharge Project and other geothermal fields. The basic information obtained should support use of injected water to extract energy from hot fractured rocks in many locations in the U.S. and elsewhere, and this project can test production strategies for all three reservoir types at The Geysers.

Mining Historical Data to Improve Reservoir Performance

Categories of activities include:

(1) Examine the large volume of detailed production, injection and field performance data from The Geysers field for relationships between rates and locations of injection wells, movement of injectate, field operating conditions and production performance; and

(2) Identify relationships that can be used to improve field performance during large-scale water injection.

Improved strategies for injecting water at The Geysers Recharge Project to increase and extend the life of power generation will be developed. These methods may be transferable to injection projects in other fields.

New data mining technologies using artificial intelligence and super computers at national laboratories can now analyze the long history and large public domain database on operations at The Geysers Recharge Project to improve energy extraction.

Improving Long-Term Integrity of Geothermal Wells

Categories of activities include:

(1) Develop high temperature instruments for non-destructive examination and monitoring of geothermal well linings, wellheads and production facilities; and

(2) Develop tools and techniques to repair and extend the useful life of these wells.

This will allow continued production of low-cost, clean electric power and continued safe disposal of excess reclaimed municipal water. It will use existing wells to avoid the cost and disruption associated with drilling new wells.

Existing well fields are designed for a 30-year productive life, but sustained production by large-scale injection could require 50 to 75 years of reliable performance. This will require new materials and techniques for monitoring and repair.

9. Environmental Benefits and Issues

The Geysers Recharge Project was selected for implementation after extensive environmental review. The City of Santa Rosa completed both the California Environmental Quality Act (CEQA) process and the National Environmental Policy Act (NEPA) process prior to selecting The Geysers Recharge Project. The environmental documents were extensive and contained in 25 volumes. An environmental benefit of the project is protection of the waterways in the Russian River watershed. This project ensures protection of water quality and has fewer negative impacts than other studied options such as construction of large reservoirs and irrigation systems.

In addition to direct geothermal and water quality benefits, this project will provide reclaimed water to restore habitat in upper tributaries of the Russian River critical to the survival of threatened steelhead and coho salmon. This could be accomplished through steam-flow augmentation, or by providing reclaimed water to agriculture to replace the currently being drawn from steams. Measures to protect Eel River habitat could result in a decrease in water currently transferred from the Eel to the Russian rivers, increasing the value of the reclaimed water. The project will also provide water for agricultural users that would otherwise be drawn from the same tributaries. The cost of the habitat restoration and future agricultural re-use is not included in the budget shown in the previous table.

An added air quality benefit of the geothermal power produced from the injected water is that greenhouse emissions (CO_2) are less than 5 percent of that of fossil fuel-powered generation (See Table 9.1). Thus, geothermal power generation reduces the nation's total greenhouse gas emissions. It is also anticipated that injection-derived steam will contain less non-condensable gas, which will further reduce CO_2 emissions and increase power plant efficiencies.

The anticipated additional output results in annual emissions reductions of 570 million pounds of CO_2 and 253,000 pounds of NO_x in comparison to natural gas-fired plants.

Figures 9.1 and 9.2 from internal Calpine reports show the concentration of hydrogen sulfide present in the main steam flow to Units 13 and 16 since 1987. The SE Geysers project became operational in September 1997 and is responsible for the 16 to 19 percent reductions in H_2S concentrations at these plants during the first year of project operation. Locally, the reduction of H_2S concentration in selected wells has exceeded 50 percent in this area. Further reductions in H_2S concentrations are expected, but the ultimate benefit cannot be accurately estimated at this time. Hydrogen sulfide concentrations in the northern portion of The Geysers exceed 300 parts per million in some areas, so significant reductions are likely to be realized from water injection in these areas.

The reductions in hydrogen sulfide concentrations in the main stream are discussed above. Since the power plants are required to abate their emissions to Air Pollution Control District (APCD)

permit requirements, little change in the overall emissions from plant operations is expected. However, a general reduction in H_2S levels will result in less chemical usage and less waste disposal from the pollution abatement process.

Table 9- 1 Emissions for a typical 250MV Plant (Thousands of Tons/Year)

	Geothermal	Gas (1)	Coal (2)
CO_2	26	973	1,700
SO_2	0	.003	4.1
NOx	0	1.4	2.4
Sludge	0	0	168
Ash	0	0	60

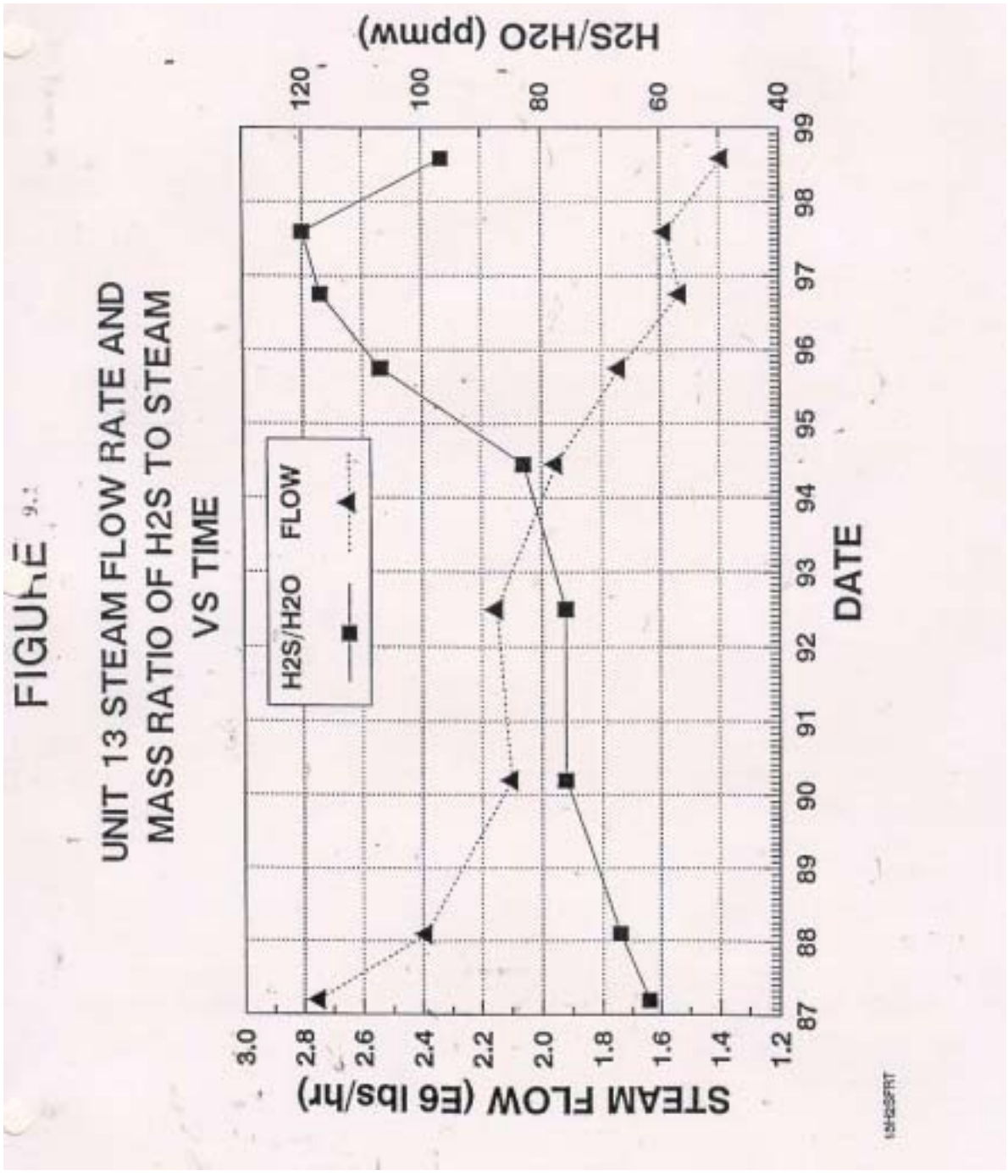


Figure 9-1 Unit 13 Steam Flow Rate and Mass Ratio of H_2S to Steam vs. Time

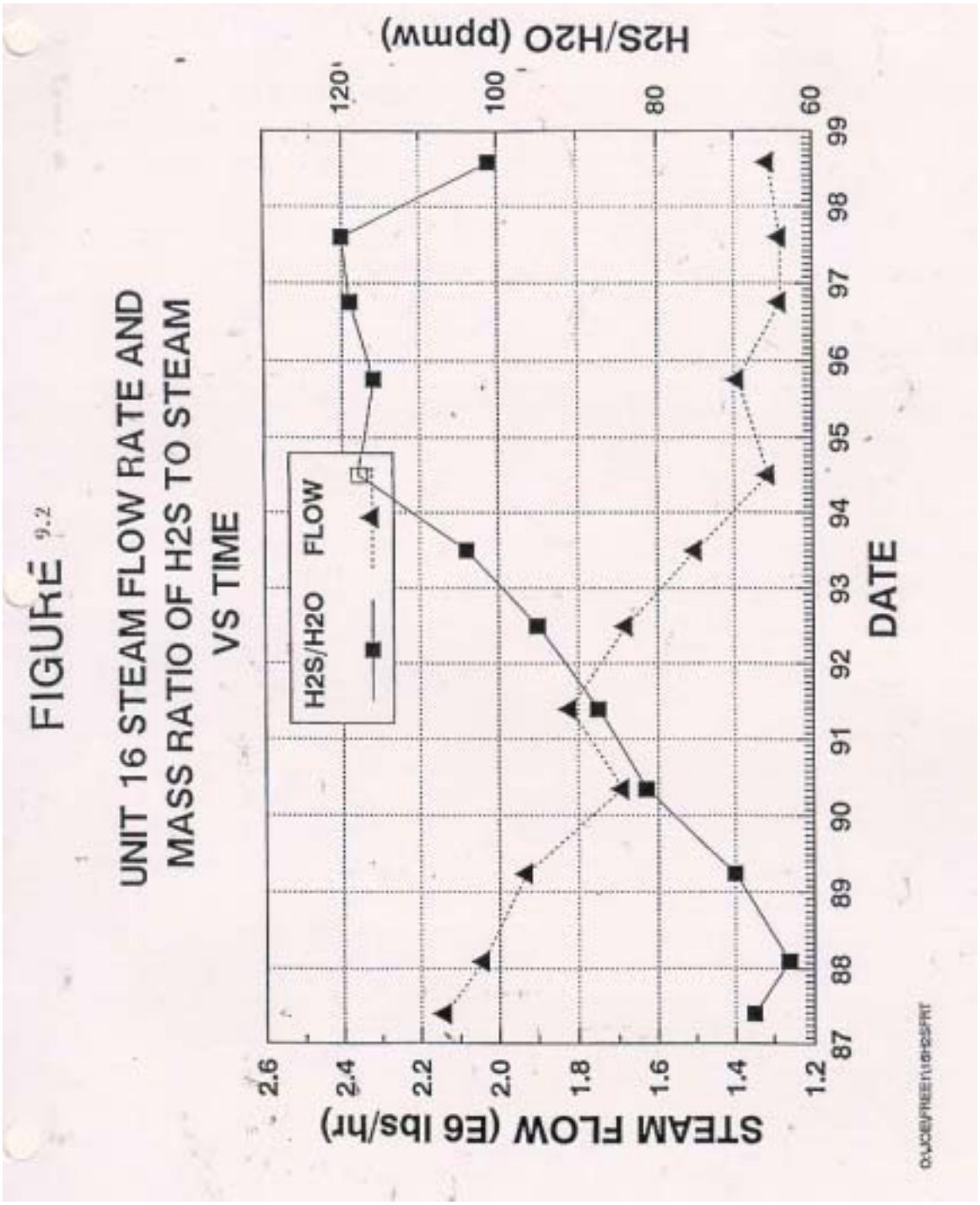


Figure 9-2 Unit 16 Steam Flow Rate and Mass Ratio of H_2S to Steam vs. Time

10. Future Report Requirements for GEO-98-001

The City of Santa Rosa and Calpine Corporation are committed to ongoing research and development activities, reservoir productivity monitoring, and project monitoring related to recycled water injection made possible by The Geysers Recharge Project.

The following is a list of these activities and all data will be made available to the Commission as it is developed:

Ongoing Research and Development Activities

- DX 10 injection monitoring
- DV 11 tracer test
- Downhole sampler development
- High resolution seismic array for injection monitoring

Reservoir Productivity Monitoring

- Well flow rates, pressures and temperatures
- Number of megawatts produced
- Chemical sampling
- Modeling

Project Monitoring

- Water supply system operation
- Pounds of steam produced
- Megawatts produced
- Steam quality improvements
- Corrosivity decrease
- Non-condensable gas decrease
- Jobs created
- Royalty revenues increased

Additional activities and research projects will be developed over the life of the project and this data will also be made available to the Commission.