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DRINKING WATER PROGRAM

APPLICATION

FOR UNDERGROUND INJECTION CONTROL PERMIT

for the

PUNA GEOTHERMAL VENTURE PROJECT

Submitted by

PUNA GEOTHERMAL VENTURE

June 1989

ENVIRONMENTAL MANAGEMENT ASSOCIATES

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101 Aupuni Street
Suite 1014-B
Hilo, Hawaii 96720

June 1989

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1. INTRODUCTION

Puna Geothermal Venture (PGV) plans to construct and operate the 25 MW Puna Geothermal Venture Project in the Puna District of the Island of Hawaii. The project will drill geothermal wells within a dedicated 500-acre project area, use the produced geothermal fluid to generate electricity for sale to the Hawaii Electric Light Company for use on the Island of Hawaii, and inject all the produced geothermal fluids back into the geothermal reservoir. Since the project will use injection wells, it will require an Underground Injection Control (UIC) permit from the Drinking Water Section of the State of Hawaii Department of Health.

The PGV Project is consistent with the State and County of Hawaii's stated objectives of providing energy self-sufficiency and diversifying Hawaii's economic base. The project will develop a new alternate energy source as well as provide additional information about the nature of the geothermal resource.

The proposed PGV Project is located approximately 21 miles southeast of the city of Hilo in the Puna District of the Island of Hawaii. The project will occupy about 25 acres of surface area within the dedicated 500-acre project area in the Kapoho section of the Kilauea Lower East Rift Geothermal Resource Subzone (LERZ).

This UIC permit application is being filed for wells classified as Class V, Subclass B injection wells, which applies to "injection wells which inject non-polluting fluids into any geohydrologic formation, including non-exempt aquifers." The PGV Project will be withdrawing geothermal fluid from a geothermal reservoir, extracting heat from that fluid to generate electricity, and then injecting the geothermal fluid back into the same geothermal reservoir from which it was withdrawn. The geothermal reservoir receiving the geothermal fluid is a non-exempt aquifer, as is the groundwater aquifer above it (both aquifers are mauka of the UIC boundary line). However, the water quality of the non-exempt groundwater aquifer is geothermally influenced, and the groundwater in this portion of the LERZ is not being used as a source as drinking water.

Section 2 of this application contains a brief summary description of the entire PGV Project to provide an overview of the proposed injection program. Section 3 of this document is the actual application form. Required supporting data to the form are supplied in Attachments A through F.

Under Chapter 23 of the Hawaii Administrative Rules, the application for an UIC permit is a two-step process, with the first step the application for approval to construct the injection wells and the second step the application for approval to operate the injection wells. This application is for the initial construction stage and includes the data required to be submitted under Sections 11-23-60(a)(1) through 11-23-60(a)(15) of the existing UIC regulations.

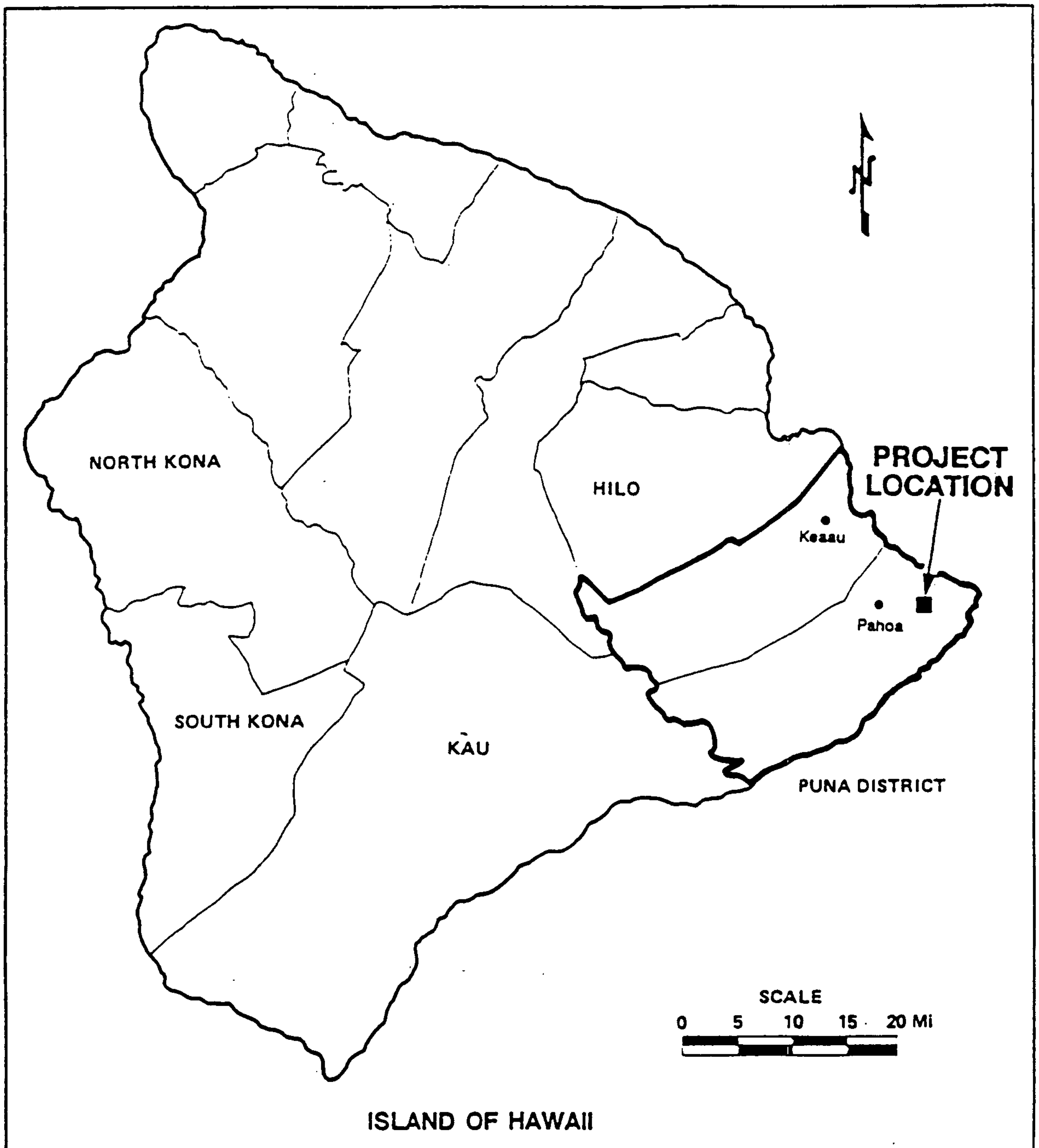
Since all of the proposed geothermal injection wells will be owned and operated by Puna Geothermal Venture, will be of similar design, will serve the same purpose, and will inject the geothermal fluid into the same injection zone on the 500-acre project area, PGV is applying for a well system permit. PGV currently plans to drill up to three geothermal injection wells from one single wellpad; however, since some wells drilled for the purpose of geothermal production may have marginal production characteristics but good injection characteristics, PGV may decide to use these "production" wells instead as geothermal injection wells. Therefore, this well system permit application also includes all of the proposed geothermal production wells in its application for an injection well system permit.

2. PUNA GEOTHERMAL VENTURE PROJECT SUMMARY

The proposed PGV Project is located approximately 21 miles southeast of the city of Hilo in the Puna District of the Island of Hawaii (see Figure 2-1). The project will occupy about 25 acres of surface area within a dedicated 500-acre project area in the Kapoho section of the Kilauea Lower East Rift Geothermal Resource Subzone. The Kilauea Lower East Rift subzone was established in 1984 (Act 151) under Chapter 205, Hawaii Revised Statutes, which mandates the designation of geothermal resource subzones for geothermal exploration and development.

The proposed PGV Project is designed to generate 25 MW (net) of electrical energy from geothermal fluids produced from the Puna geothermal field. The project, which is planned for an operating life of 35 years, will consist of:

- ten (10) integrated back-pressure steam turbine and air-cooled binary cycle turbine power generating modules;
- up to 30 geothermal wells drilled from six (6) wellpads;
- brine and steam pipelines;
- pollution control equipment;
- a brine surge tank and holding pond;
- a switchyard;
- an office, warehouse, workshop, and control buildings;



SOURCE: State of Hawaii, Department of Planning and Economic Development. STATISTICAL BOUNDARIES A-15. 1980:14

Figure 2-1. Location of the Puna District

- access roads; and

- auxiliary facilities such as air compressors, fire protection equipment, etc.

Figure 2-2 shows the locations of the major project facilities. The project will deliver 25 MW (net) to the switchyard, where the power will be purchased by HELCO to provide electricity to the Island of Hawaii.

The geothermal resources in the Puna geothermal area, located at depths generally greater than 4,000 feet, beneath impermeable caprock, are in excess of 600°F. The geothermal fluids produced from the Puna geothermal field are expected to contain a mixture of approximately 80 percent steam and 20 percent liquid at a pressure of about 200 psig and a temperature of about 390°F.

2.1. Wellfield Facilities

The proposed PGV Project will use the geothermal wellpads and wellfield as shown in Figure 2-2. Initially, the project is anticipated to require eight (8) production wells and two (2) injection wells, although the number of initial production wells may range from seven (7) to nine (9) and a third injection well may be necessary. Allowing for up to two (2) unusable wells (dry holes), nine (9) to fourteen (14) wells will need to be drilled for initial full-capacity operation. All wells will be drilled form up to six (6) wellpads. Additional makeup wells will need to be drilled over the 35-year economic life of the PGV Project, although all wells will be drilled from one of the six wellpads, and no more than a maximum of five (5) wells per wellpad will be drilled, for a maximum total of not more than 30 wells. Both production and injection wells will be drilled and cased down into the geothermal reservoir.

Each production well is expected to produce between 55,000 to 90,000 pounds per hour (lb/hr) of usable steam at a pressure of approximately 200 pounds per square inch gauge

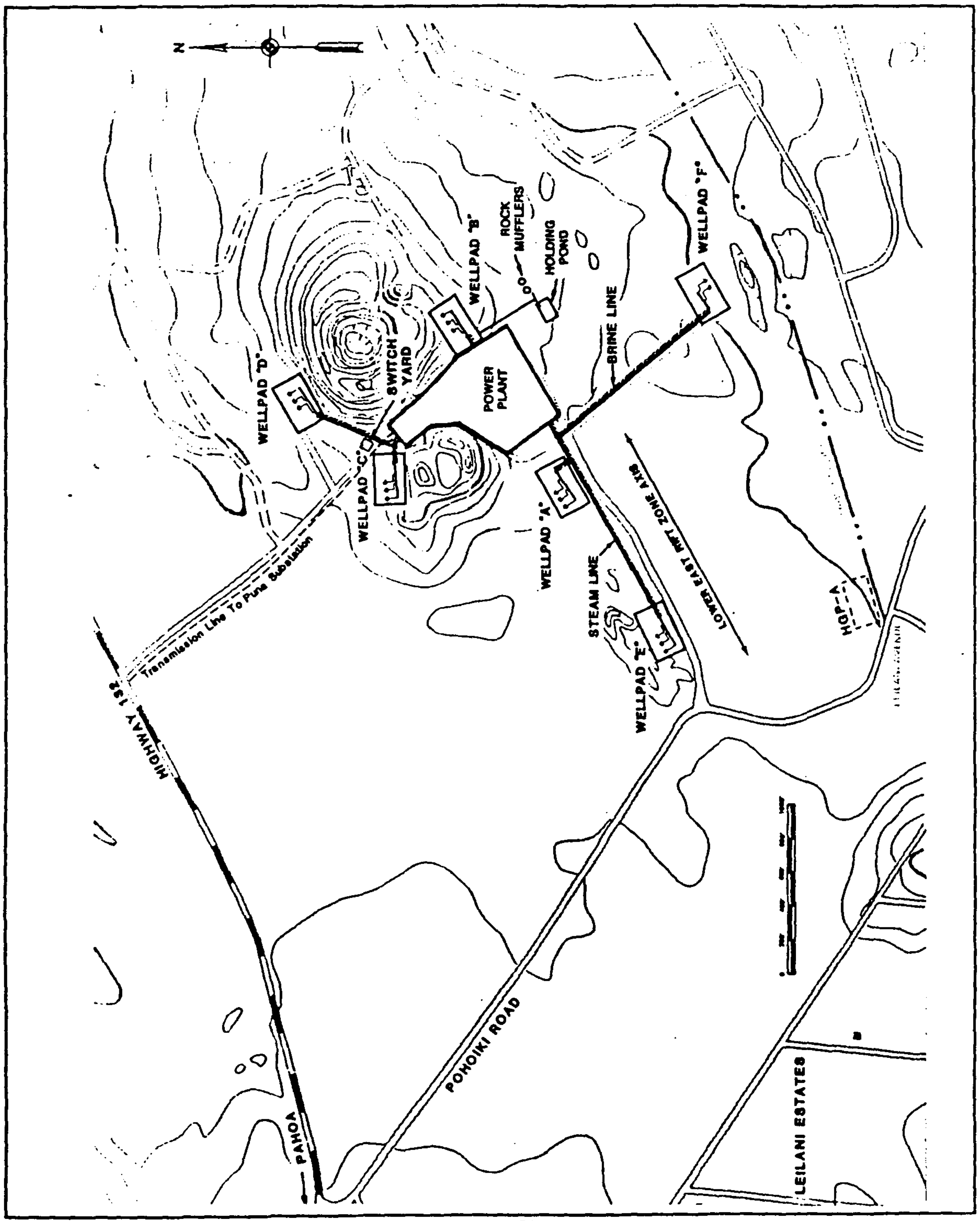


Figure 2-2. Puna Geothermal Venture Project Site Plan

(psig) and a temperature of 387°F at the wellhead, as well as 14,000 to 22,000 lb/hr of geothermal brine and approximately 50 to 120 lb/hr hydrogen sulfide (H_2S).

Most drilling will be performed using drilling muds which produce negligible H_2S and particulate emissions. While drilling in the production zone, aerated water or aerated mud, may be used as the circulating medium. Occasional inadvertent releases of steam during drilling with aerated water or aerated mud will be limited to five (5) to ten (10) minutes, which will produce emissions of 7.0 lb H_2S or less during any one event. A cyclone separator will control particulate emissions during these steam releases.

Best Available Control Technology (BACT) will be applied during well testing. After venting to cleanout the well bore, each well will be connected to a separator which will partition the steam and gases from the brine. The steamline will be equipped with chemical abatement equipment to abate H_2S emissions by 95 percent. The steam will then be released through a rock muffler to muffle the noise.

All of the wells at each wellpad will be connected to a flash separator that will partition the geothermal brine from the geothermal steam and noncondensable gases. At least two wellfield gathering systems will be used to move the geothermal brine and geothermal steam to the power plant. A third pipeline may be needed to collect geothermal steam condensate produced by heat losses in the steam gathering lines. These pipelines will gather the appropriate fluid(s) and gases from each wellpad and will be routed to the power plant site together and, where practical, adjacent to the wellpad access roads. The steam will be delivered to the power plant system; the brine will be delivered to the brine surge tank for injection.

Under normal power plant operations, essentially all of the geothermal fluids produced by the production wells and all of the noncondensable gases will be returned to the geothermal reservoir through the injection wells. In the present design, after the steam has passed through the power plant system and been condensed, the steam condensate will be mixed with the geothermal brine from the brine surge tank. The noncondensable gases will then be injected into the condensate/brine mixture, and this recombined geothermal fluid will then be injected back into the geothermal reservoir.

2.2. Power Production

The PGV Project will generate up to 28.5 MW of electrical power so that 25 MW can be delivered to the HELCO electric grid system, with the balance of the power being consumed by the plant equipment. The actual amount of power generated will vary in response to steam quantities, atmospheric temperatures and other operating conditions.

Several changes have been proposed to the previous PGV Project power plant design to increase project reliability and flexibility, decrease construction time and reduce the potential for emission of air contaminants.

The design of the power plant has been modified by:

- utilizing ten (10) nominal 3 MW modular turbine-generating units instead of two (2) 15 MW turbine-generator units. Each module will contain the following turbine-generating equipment:
    - a nominal 1.8 MW back-pressure steam turbine,
    - a nominal 1.2 MW binary cycle turbine that generates additional electricity from the low-pressure steam leaving the back-pressure turbines, and
    - a common 3 MW generator;

- utilizing air-cooled condensers for the working fluid in the binary cycle instead of the water-cooled condensers, thus eliminating the cooling towers and the release of gases; and

- injecting all of the produced geothermal fluids (geothermal brine, steam condensate and noncondensable gases) back into the geothermal reservoir, thus eliminating all but negligible fugitive emissions of hydrogen sulfide during normal operations.

Figure 2-3 shows a simple schematic diagram of the PGV Project steam turbine/binary cycle power plant system. The proposed 1.8 MW modular back-pressure steam turbines operate much the same as the condensing steam turbines proposed in the previous PGV Project design, but the steam leaving the back-pressure turbines remains slightly above atmospheric pressure. Thus, the steam retains a significant amount of heat energy which is converted into electricity by the binary power generating units, known as Ormat Energy Converter (OEC) units. These OEC units, manufactured by Ormat Turbines, Ltd., apply principles and technologies well-tested in various industries and successfully applied in other geothermal fields throughout the world.

The OECs operate on the same basic principles as steam turbines, but use an entirely closed organic working fluid system instead of steam. OECs use the heat energy of the geothermal fluid to vaporize the organic working fluid (isopentane), which expands through a small turbine to generate electricity. The isopentane vapor is then condensed back into a liquid state in a condenser.

The PGV Project is also proposing that the binary working fluid condenser be cooled with air, rather than with water. Air cooling is also a well-tested technology that has been utilized in previous geothermal power plants. In this system, the binary working fluid vapor leaving the organic fluid turbines goes to the air coolers, where large fans force air across tubes containing the vapor. This air cools the binary working fluid vapor and condenses it

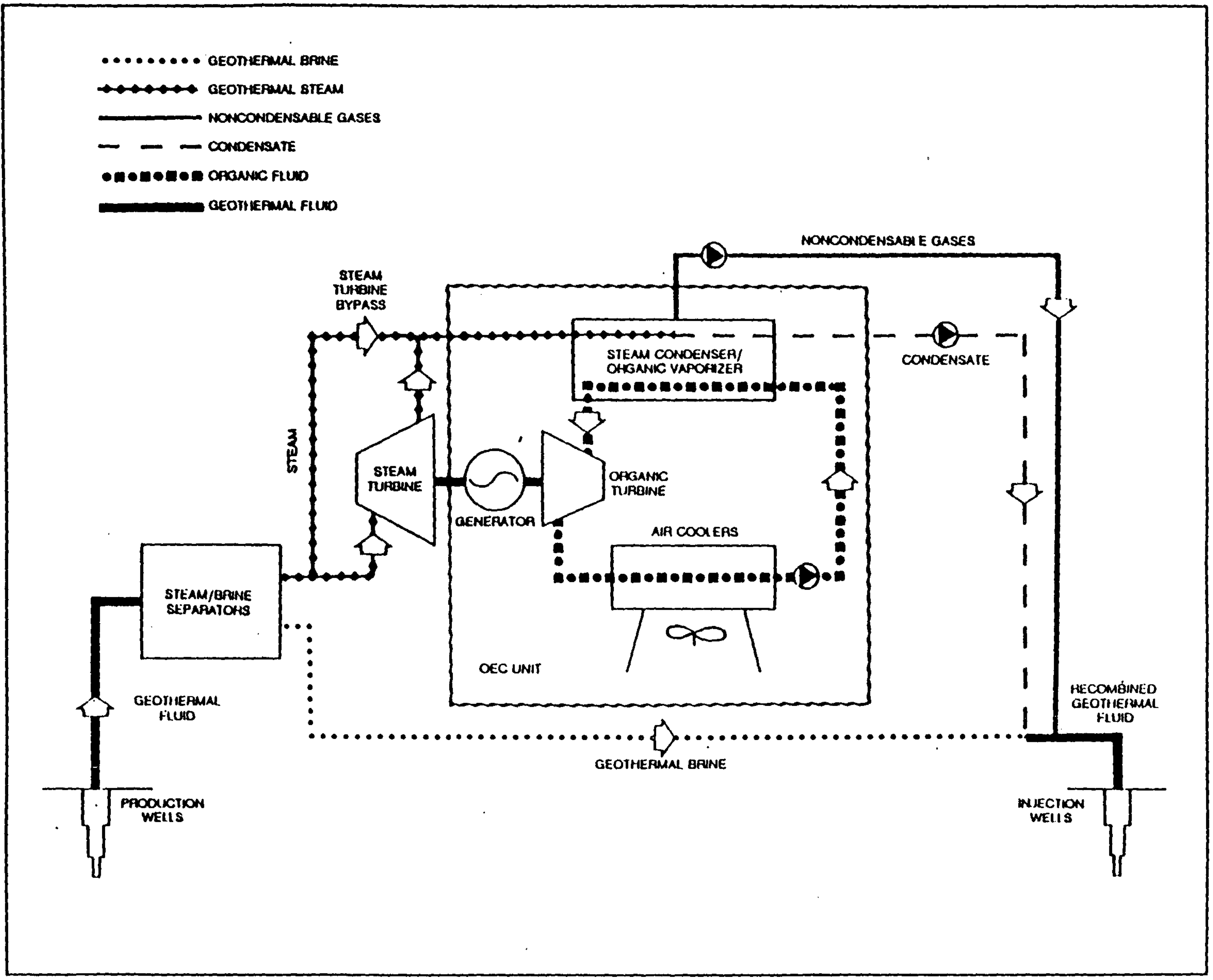


Figure 2-3. Simplified Process Flow Diagram

into a liquid which is collected and routed back to the vaporizer and the turbines. Because air coolers have replaced the cooling towers, the PGV Project does not need to utilize the geothermal steam condensate as cooling tower makeup water. Thus, all the geothermal fluids (brine, steam condensate, and noncondensable gases) produced by the production wells can be injected back into the geothermal reservoir via injection wells.

The back-pressure steam turbine/binary cycle power plant is a closed system that, during normal operations, does not release any H_2S or other gases to the atmosphere. The geothermal fluids at the Puna field contains up to 1,300 ppm H_2S and 600 ppm carbon dioxide (CO_2). A small fraction of the noncondensable gases will remain in the geothermal brine during the initial separation process. However, most of the noncondensable gases will be partitioned with the steam during the initial separation process, pass through the steam turbine, and be routed along with the low pressure steam to the heat exchangers in the OEC units. There the working fluid will condense the steam. The steam condensate will then be mixed with the brine for injection. The remaining gases, still under low pressure, will exit the OEC units and be compressed, and injected into the mixture of condensate and brine, and the recombined stream injected into the geothermal reservoir.

The process of dissolving H_2S and/or CO_2 into water is common practice in the field of chemical engineering. Injection of the combined fluid stream into the geothermal reservoir has been successfully demonstrated at the Coso geothermal field in California since July, 1987. Based on these results, the noncondensable gases produced from the Puna geothermal reservoir will be dissolved and entrained in the produced geothermal fluids by in-line mixing, and all of the produced fluids and gases will be injected into the geothermal reservoir. To ensure the reliability of the injection system, a spare pump, a spare compressor, and a spare injection well will be provided. A holding pond is provided to collect liquids for the unlikely event of an upset in the liquid injection system.

A major advantage of the proposed design is the ability of the OEC units to operate on high temperature steam when the steam portion of the module is not operating. Thus, when one or more steam turbines fail, the power plant can continue to operate, although at reduced rates; the actual rate of reduction will depend on the number of steam turbines that are shutdown. As long as the entire power plant uses at least 50 percent of the steam flow, there will be no emergency steam release.

To enable this mode of operation, a steam turbine bypass system will be installed on each steam turbine unit so that its OEC unit can operate even when the steam turbine portion is not in operation (such as during plant start-up). In this situation, the geothermal steam bypasses the steam turbine and enters directly into the OEC vaporizer, where it condenses as during normal operating conditions.

When the entire power plant is shut down, an emergency steam release facility will be used to release steam, treated with sodium hydroxide (NaOH) to remove 96 percent of the H_2S, through a rock muffler (which will reduce noise levels) while the wellfield production rate is being reduced to 50 percent of full flow. After this reduction, the power plant will emit less than 2 percent of full flow uncontrolled H_2S (98 percent control) until normal operation is resumed.

3. PERMIT APPLICATION FORMS

APPLICATION FOR
UIC PERMIT
(REF. 11-23-12, 11-23-13)

FOR OFFICE USE:

FILE NO.: __________

PERMIT ISSUED:

Instructions: Submit completed application and attachments to:

Department of Health
Environmental Protection and
Health Services Division
Environmental Permits Branch
P.O. Box 3378
Honolulu, Hawaii 96801
Reference: Ch. 11-23 UIC

heck One)

☐ Individual Well ☒ Well System (See Attachment A)

Nature of Application

☐ Existing Well ☐ Deepen Existing Well ☒ New Well ☐ Abandon & Seal ☐ Other (Describe)

Drilling Contractor Parker Drilling Company
(For existing wells, name of contractor may be submitted later.)

Facility Name: Puna Geothermal Venture Project

Location: 500-acre project area is located in the Kopoho Section of the Kilauea Lower Rift Geothermal Resource Subzone. The N and NW boundary of the project area is Highway 132. The SW boundary is Pahoa-Pohoiki Road. (See Section 2)

a. Street Address Not established.

Town __________ Island Hawaii Zip Code __________

b. Attach map showing general location of facility on the island. (See Section 2, Figure 2-1)

c. Tax Map Key No. 1 - 4 - 01: 19 and 2 (See Attachment B)
(Give only one parcel, where the well(s) is(are) located and attach TMK map showing the exact location of well(s) on the property.)

d. Attach USGS topographic quadrangle or good copy (scale 1:24,000) indicating the location of the facility and all other wells within one-quarter mile of the facility. (See Attachment C)

e. Latitude ____°____'____" and Longitude ____°____'____" (See Attachment D)

Owner/operator of facility: Puna Geothermal Venture

If facility is situated on leasehold property, attach written consent of owner of record.

Legal contact or authorized representative:

Full Name: Maurice A. Richard

Position: Hawaii Regional Development Manager

Permanent Address: 101 Aupuni Street
Suite 1014-B
Hilo, Hawaii 96720

Telephone Number(s): [redacted]

Nature and source of injected fluids (check box and describe):

☐ Private STP ☐ Municipal STP ☐ Industrial ☒ Other

Geothermal (See Attachment E)

Proposed Volume of Fluids: 7.4×10^8 gallons per year
(For existing wells, enter actual volume.)

Proposed Injection Rate: 1,400 g.p.m.

Pressure: 200 p.s.i.g.
(For existing wells, enter actual rate and pressure.)

Describe the injection system, including emergency sumps, standby wells or monitoring wells, if any. Attach preliminary system plans.

(See Attachment E)

Describe proposed injection testing. Diagrams may be attached, if needed for clarity.

(See Attachment E)

Regional Water Quality (Attach data from nearest supply wells, including: chloride, total dissolved solids, coliform, organic chemicals, inorganic chemicals, pH and temperature.)

(See Attachment F)

Well Siting

a. Request for mauka side of roadway interpretation?

☐ Yes ☒ No

b. Does site overlie artesian volcanic aquifer?

☐ Yes ☒ No

Signatory and Certification Statement to UIC Permit Applications

I certify that:

(for a municipal, state, federal, or other public agency)
I am a principal executive officer or ranking elected official; or

In the case of Federal agencies, I am the chief executive officer of the agency, or I am the senior executive officer having responsibility for the overall operations of a principal geographic unit of the agency.

(for a partnership or sole proprietorship)
I am a general partner (partnership) or a proprietor (sole proprietorship).

(for a corporation)
I am President, Vice President, Secretary or Treasurer of the corporation and in charge of a principal business function, or I perform similar policy or decision making functions for the corporation; or,

I am the manager of one or more manufacturing, production or operating facilities employing more than 250 persons or having gross annual sales or expenditures exceeding $25 million (in second-quarter 1980 dollars), and authority to sign documents has been assigned or delegated to me in accordance with corporate procedures.

****

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Description of Document

Application

Type of Organization (please circle): 1. sole proprietorship [✓ 2. partnership] 3. corporation 4. municipal 5. state, federal or other public agency

Signature 06/26/89.

Name Maurice A. Richard

Title Hawaii Regional Development Manager

Date June 26, 1989

Company Name Puna Geothermal Venture

Phone Number [redacted]

3/20/85 EPB

FOR OFFICE USE:

CLASSIFICATION:

ADDITIONAL DATA REQUIRED:

☐ YES ☐ NO

APPROVAL:

☐ YES ☐ NO

DATE PERMIT ISSUED: ______________________________

WELL NUMBER ______________________________(NEW)

______________________________(OLD)

ATTACHMENT A

Puna Geothermal Venture Injection System

Puna Geothermal Venture is applying for a well system permit for the injection wells it will require over the life of the geothermal project. Section 11-23-12 (c) of the Department of Health Administrative Rules allows a system permit if the wells meet all of the following conditions:

1. Are owned by the same person;
2. Are operated by the same person;
3. Are similarly designed;
4. Serve the same purpose; and
5. Inject into the same aquifer or injection zone at the same property.

Although PGV plans to drill its injection wells from one wellpad, if it drills a production well with marginal production characteristics and good injectivity, it may choose to use this well as an injection well.

All the production and injection wells on the PGV project will be owned and operated by PGV, which will own and operate the entire 25 MW geothermal project. All the wells will have a similar design, which is described in more detail in Attachment E, with the primary difference between production and injection wells being the addition of a hang-down liner to the injection wells. The injection wells will be used to inject geothermal fluids back into the geothermal reservoir after some energy (heat) has been extracted and used to generate electricity for sale on the Big Island. All of the wells will inject these fluids into the same aquifer from which they were withdrawn, the geothermal reservoir found at depths of between approximately 4,000 feet and 7,000 feet. All of the bottom hole locations will be within the 500-acre project boundary which is indicated on Figure A-1. The 500-acre project boundary includes the following Tax Map Key (TMK) designations (see Attachment B):

- TMK 1-4-01:2 (portion) containing approximately 300 acres
- TMK 1-4-01:3 (all) containing 3.741 acres
- TMK 1-4-01:19 (portion) containing approximately 200 acres
- TMK 1-4-01:58 (all) containing 0.0758 acres

This project area is contained entirely within an 816-acre parcel that PGV subleases from the Kapoho Land Partnership.

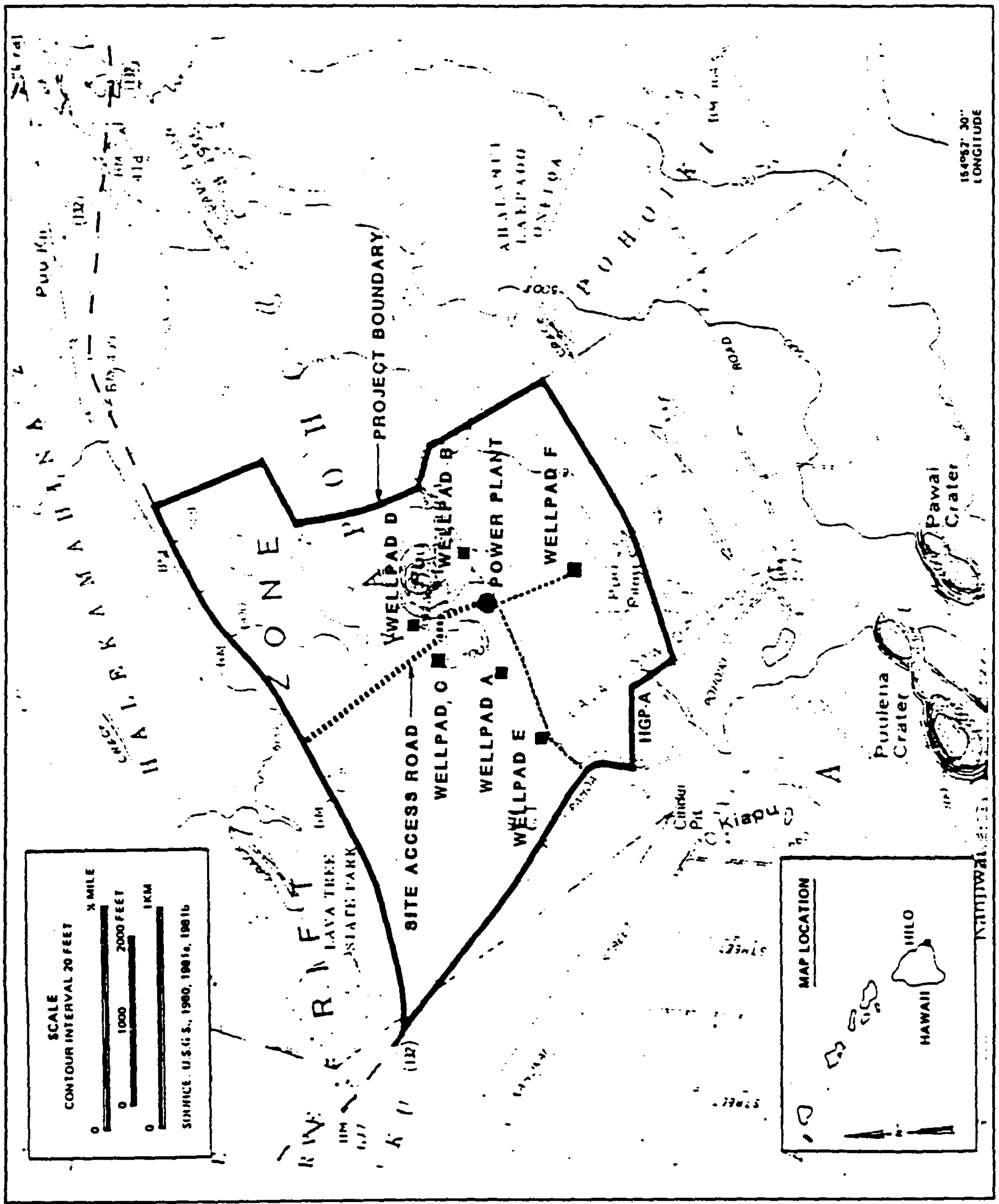


Figure A-1. Puna Geothermal Venture Project Area and Vicinity Map

ATTACHMENT B

Tax Map Key Map

ATTACHMENT C

USGS Topographical Map

ATTACHMENT D

Approximate Wellpad Latitudes/Longitudes

PROPOSED INJECTION WELLPAD

Wellpad F:	Latitude	19° 28' 45"	Longitude	154° 53' 28"

PRODUCTION WELLPADS (see below)

Wellpad A:	Latitude	19° 28' 49"	Longitude	154° 53' 35"
Wellpad B:	Latitude	19° 28' 55"	Longitude	154° 53' 21"
Wellpad C:	Latitude	19° 28' 59"	Longitude	154° 53' 39"
Wellpad D:	Latitude	19° 29' 08"	Longitude	154° 53' 30"
Wellpad E:	Latitude	19° 28' 41"	Longitude	154° 53' 40"

The proposed wells to be located on Wellpad F would be drilled specifically for the injection of geothermal fluids. However, the proposed production wells to be located on Wellpads A, B, C, D, and E may be converted to injection wells at some future date. After production wells on these wellpads have been drilled, if they are found to be only marginally useful as production wells and not economical to use in producing electrical energy, they may be used as injection wells. Both production and injection wells will have the similar casing programs; all wells to be used for injection will also have hang-down liners installed (see Attachment E).

ATTACHMENT E

Details of Proposed Wellfield Injection System

The PGV Project is located in a geologic region known as the Lower East Rift Zone (LERZ), found on the eastern flank of Kilauea Volcano. At depths below 8,000 feet beneath the surface features of the LERZ, a 5- to 15-mile wide dike complex is thought to exist, where temperatures approach 1,900°F, the melting point of basalt. A secondary magma chamber may be located within the LERZ beneath the geothermal reservoir. The series of dikes are thought to convey heat to the high-temperature geothermal reservoir, a system of vertical to near-vertical fractures which contains, below 4,000 feet, a two-phase geothermal resource with temperatures as high as 600°F. Overlying the high-temperature geothermal reservoir is a relatively impermeable layer of capping rock, generally at depths of between 4,000 and 2,500 feet below the surface, although both the upper and lower boundaries are variable and dependent upon the local permeability (fractures). A zone of groundwater extends from the top of the caprock to the water table, approximately 600 feet below the surface. This water in this area of the LERZ is chemically and thermally influenced by natural leakage of geothermal fluids through the caprock. Additional details regarding the geothermal reservoir are presented in Attachment F.

E.1. Geothermal Fluids Injection System

Under normal operating conditions, essentially all geothermal fluids produced during operation of the PGV Project wellfield and power plant (geothermal brine, geothermal steam condensate, and geothermal noncondensable gases) will be injected back into the geothermal reservoir at depths of 4,000 feet or greater, below the layer of impermeable caprock.

Recombining of all the geothermal components will probably be in the following sequence: first, the condensate will be cooled and combined with the brine; second, the compressed noncondensable gases will be mixed with the combined condensate and brine to produce one geothermal fluid, which will have basically the same composition as the original geothermal fluid. Table E-1 shows the composite geothermal noncondensable gas composition; Table E-2 presents the composite chemical composition of the geothermal fluids. Although the recombined fluid will have essentially the same chemical composition

Table E-1 Composite Geothermal Noncondensable Gas Composition

Element	Observed Content in Steam[a] (ppmw)	Design Composition (ppmw)
CO_2	250 - 1,042	600
H_2S	800 - 1,300	1,300
NH_3[b]		-
Ar	6 - 13	-
N_2	10 - 700	50
CH_4[c]		-
He	<0.009	-
H_2	11 - 1,412	20
Total NCG	1,500 - 2,200	1,970

Composite data from three wells on the PGV site (KS-1, KS-1A, and KS-2) and the HGP-A well

(a) Wellhead pressure = 155 psig;
Wellhead temperature = 368°F
(b) Below detection limit (<1.5 ppm NH_3 in KS-1A)
(c) Below detection limit (<0.2 ppm CH_4 in KS-1A)

Table E-2 Composite Geothermal Fluid Chemical Composition

Element	Brine(a) (ppmw)			Steam Condensate(a) (ppmw)
Na	600	-	10,000	0.17
K	123	-	2,700	0.1
Ca	40	-	920	0.1
Mg	1	-	2	<0.1
Fe	<1	-	8.4	0.05
Mn	<1	-	8.5	-
B	4	-	11	<0.5
Br	40	-	80	-
I	<20			-
F	0.2	-	0.9	-
Li	1	-	9	<0.01
Cl	925	-	21,000	<2
NH	<0.01	-	0.10	0.12
SO_3(b)	9.2	-	24	13
Hg	<0.001	-	<0.05	-
As	0.09	-	0.4	<0.01
S(c)	5	-	100	-
Total Alkalinity	≤10			<10
HCO_3	0	-	18	0
CO_3	0			0
SiO_2	420	-	1,500	0.7
TSS	70			-
TDS(d)	2,500	-	35,000	15
pH	≤5	-	5.5	3.5
Conductivity (mhos/cm)	3,100	-	67,000	120
Density	1.03			-

Composite data from three wells on the PGV site (KS-1, KS-1A, and KS-2) and the HGP-A well.

(a)Wellhead pressure = 155 psig;
Wellhead temperature = 368°F
(b)Concentration high due to oxidation of $S^=$ to $S0_4$
(c)Concentration low due to oxidation of $S^=$ to $S0_4$

as the original fluid, its temperature will be approximately 265 °F, significantly cooler than the 400 °F to 600 °F fluids found at this depth.

PGV anticipates that all three geothermal streams will be combined into one (1) stream and injected into one (1) well, but depending upon the chemical behavior of the combined stream, there is a possibility that brine and condensate will be injected in two (2) separate wells. This decision will be made prior to power plant operation.

Initially, wells will be drilled specifically for the injection of the geothermal fluids. Alternatively, marginal geothermal production wells, which are production wells producing less-than-desired steam flow or steam fraction and, therefore, are not economical to use in producing electrical energy, may be used as injection wells. Wells drilled specifically for injection would still be drilled into the geothermal reservoir, but would likely be more shallow than wells drilled as geothermal production wells. This would still ensure reliable, safe injection of the geothermal fluids back into the geothermal reservoir. The cooler injection fluids will have a greater density than the high temperature fluids in the reservoir and will tend to sink after they enter the reservoir. The injection wells will be cased to the top of the injection zone with solid steel liners cemented in place with premium quality geothermal (high temperature resistant) cement. The top of the injection zone will be at depths between 3,500 and 4,000 feet below ground level depending on the location of the well.. The fluids will be injected through a string of pipe hung inside the cemented casing. These hang-down liners are removable and will protect the cemented well casing from any damage due to corrosion or scaling. The annular space between the hang-down liners and the casing will have nitrogen injected into it to keep the geothermal fluids injected into the well under pressure and thus prevent these fluids from returning to the surface during injection. Up to three injection wells (one or two operating plus a spare) will be required to inject the maximum anticipated 675,000 lb/hr (1,400 gpm) of produced geothermal fluids.

Two alternative injection well designs are planned. Alternative 1 (see Figure E-1) is basically the same design as the production wells with the addition of a 7 inch hang-down

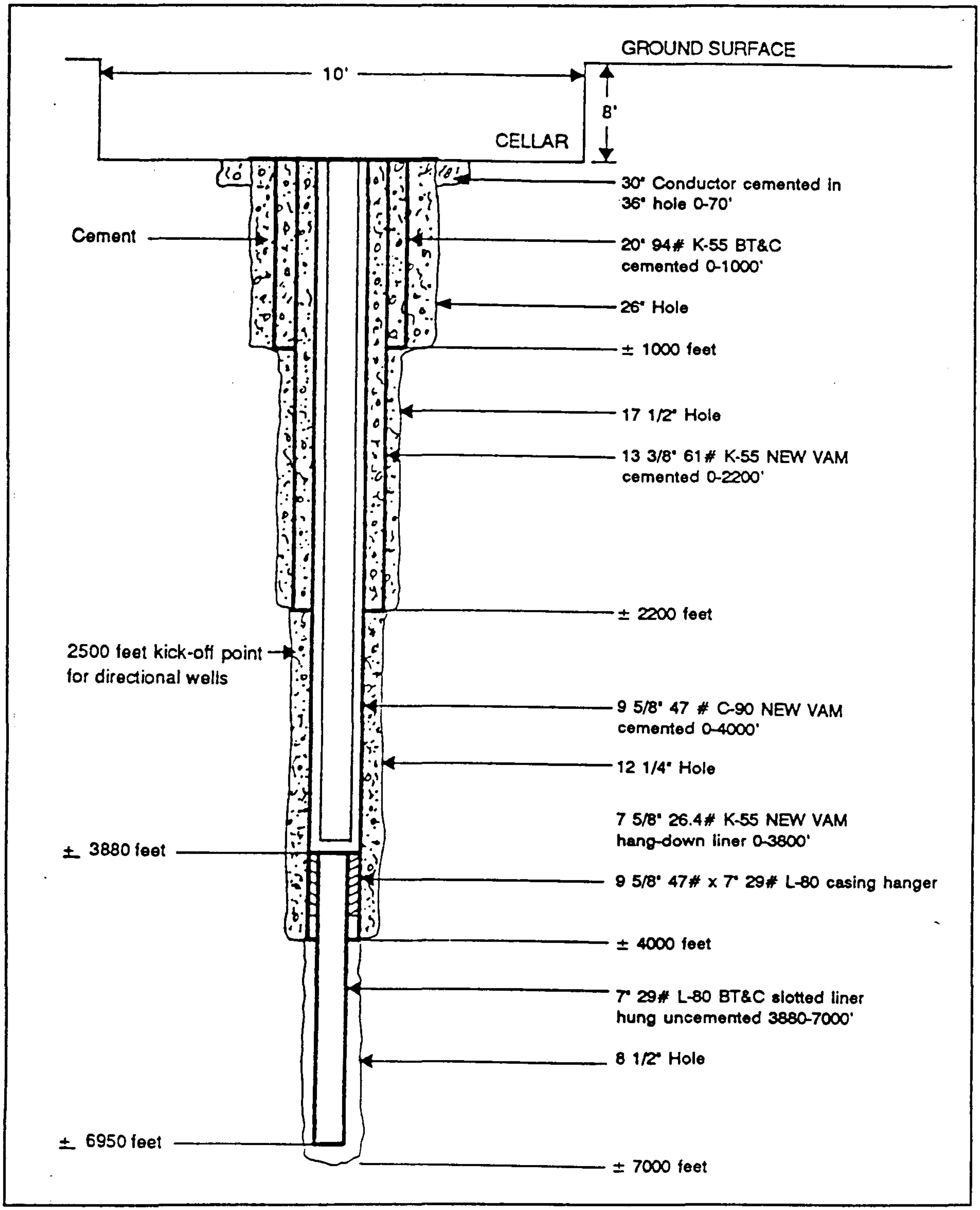


Figure E-1. Alternative 1 Injection Well Design liner. This design will be employed for injection wells located in the high temperature (>400 °F) regions of the geothermal reservoir or for production wells converted to injection wells. This design provides the same level of groundwater protection as the production wells, even though the injection wells will contain lower temperature fluids and will not be subject to the high transient temperatures of production wells (particularly when they are being shut in). Alternative 2 (see Figure E-2) will be used for dedicated injection wells located in the lower temperature (<400 °F) regions of the geothermal reservoir. This design allows for a larger diameter hang-down liner and permits larger injection volumes. The Alternative 2 design will only be used where there is certainty as to the temperature that will be encountered in the well, otherwise the Alternative 1 design will be employed. The Alternative 1 design will be used for the first injection well.

Following completion of drilling of each injection well, the drilling mud will be circulated out into mud tanks and replaced with fresh water. The wells will then be back-flowed to the storage pit for 4 to 6 hours to clean the injection formations of drilling debris. Flowrate, pressure and temperature will be monitored during this period. Injection testing will consist of injecting fresh water into the wells at four to five different step rates for about two hours each or until stable pressure and flowrate conditions are established. Stabilized wellhead and downhole pressure and flowrate will be measured at each step. A spinner survey will be run in the wells at the highest injection rate in order to identify the major injection zones. The required well drilling and/or conversion permits will be obtained from the Department of Land and Natural Resources (DLNR), as necessary.

To ensure high reliability of the geothermal fluids injection system, each component of the system will be backed by a spare. A spare fluid pump, a spare noncondensable gas compressor, and a spare geothermal injection well will be provided. However, in the unlikely event of an upset in the injection system, an unlined holding pond will be constructed at the power plant site to receive, and temporarily store the geothermal brine and/or condensate until it infiltrates. Prior to discharge to the holding pond, the brine will

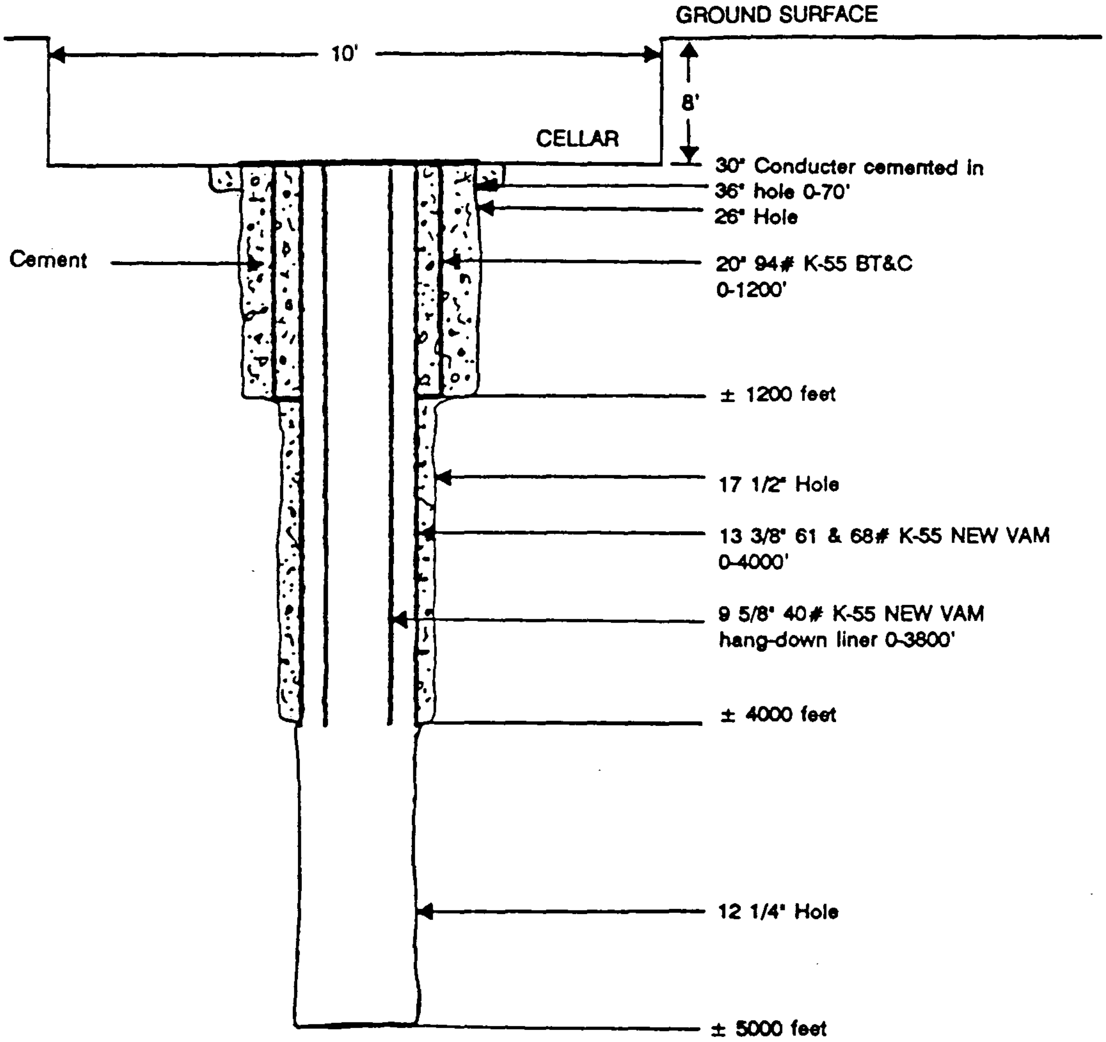


Figure E-2. Alternative 2 Injection Well Design pass through the emergency steam release facility and a small amount of steam and H_2S would be released through the rock muffler.

E.2. Wellfield Development Plan

To date, six deep test wells have been drilled in the general PGV Project area (see Figure E-3). Four of the wells appear to have been drilled into the high-temperature Puna geothermal reservoir, as they encountered temperatures in excess of 600°F at depths below 4,000 feet: Kapoho State 1 (KS-1) and Kapoho State 1-A (KS-1A), drilled from PGV Wellpad A; Kapoho State 2 (KS-2), drilled from PGV Wellpad B; and the HGP-A well. Currently, KS-1, KS-1A and KS-2 are suspended with cement plugs in their bores. The fourth well, HGP-A, is currently producing steam for the 3 MW HGP-A demonstration plant, which is located immediately outside the PGV Project boundary, south of proposed PGV Wellpad E. The other two wells, Lanipuna 1 and Lanipuna 6, encountered lower temperatures and appear to be located on, and define, the southeast margin of the high temperature geothermal system in the immediate area. The proposed PGV Project geothermal wellfield development plan has been designed to maximize the possibility of drilling geothermal production wells that intersect, below approximately 4,000 feet, these near-vertical fractures, which are generally aligned along the axis of the LERZ and which carry the geothermal fluids. To accomplish this, geothermal wells will be directionally drilled in general southeast and northwest directions from the six multi-well wellpads shown in Figure E-4. As stated above, geothermal exploration wells have already been drilled from Wellpads A and B. The proposed sites for the four additional wellpads (Wellpads C, D, E and F) were selected on basis of proximity to the power plant, current knowledge of reservoir extent, optimal drilling targets, directional drilling experiences, and injection needs. In order to optimize wellfield production with low surface area requirements, these proposed wellpad locations may require relocation within the proposed 500-acre PGV Project area after additional drilling, production, injection, or other information becomes available.

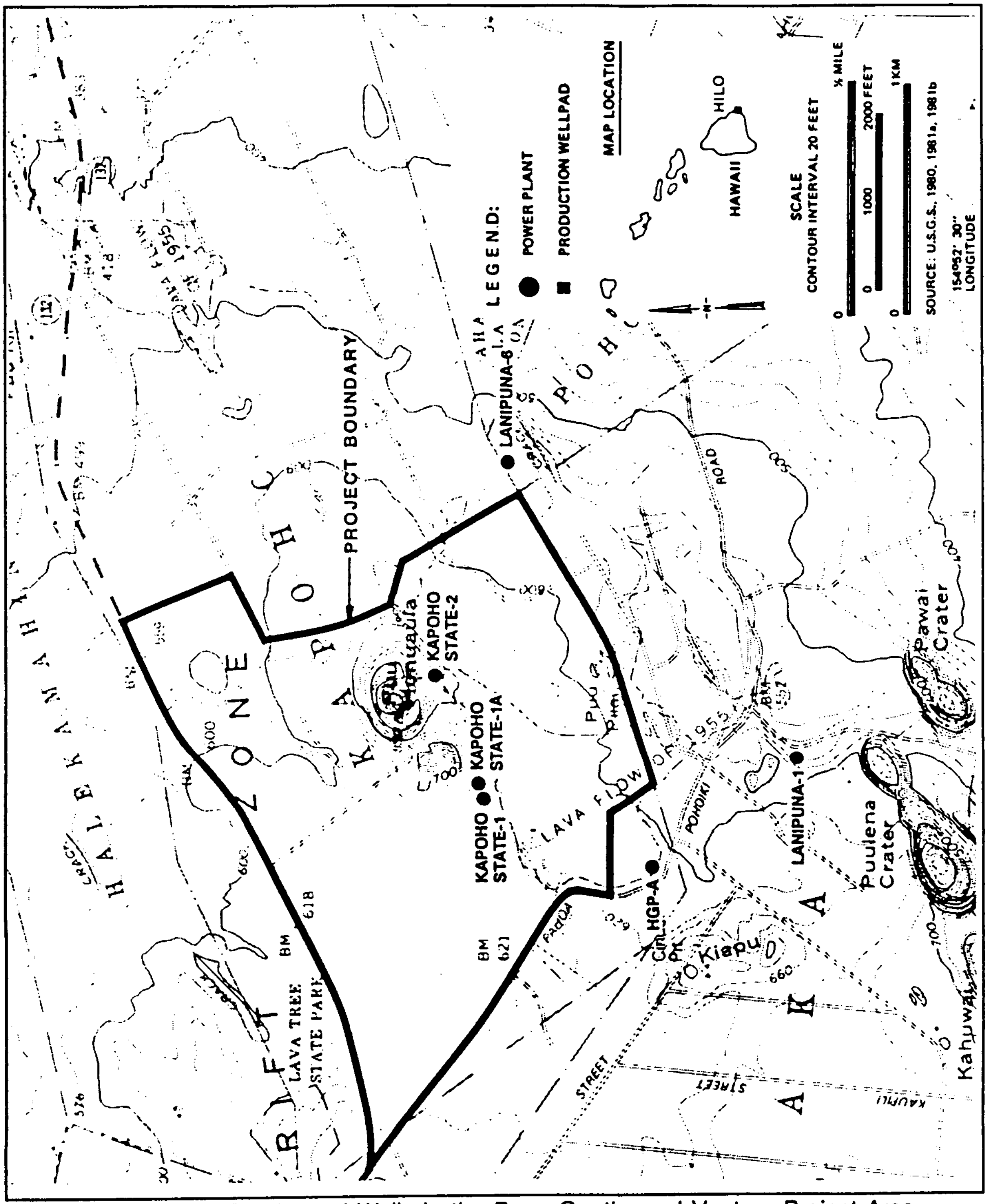


Figure E-3. Existing Geothermal Wells in the Puna Geothermal Venture Project Area

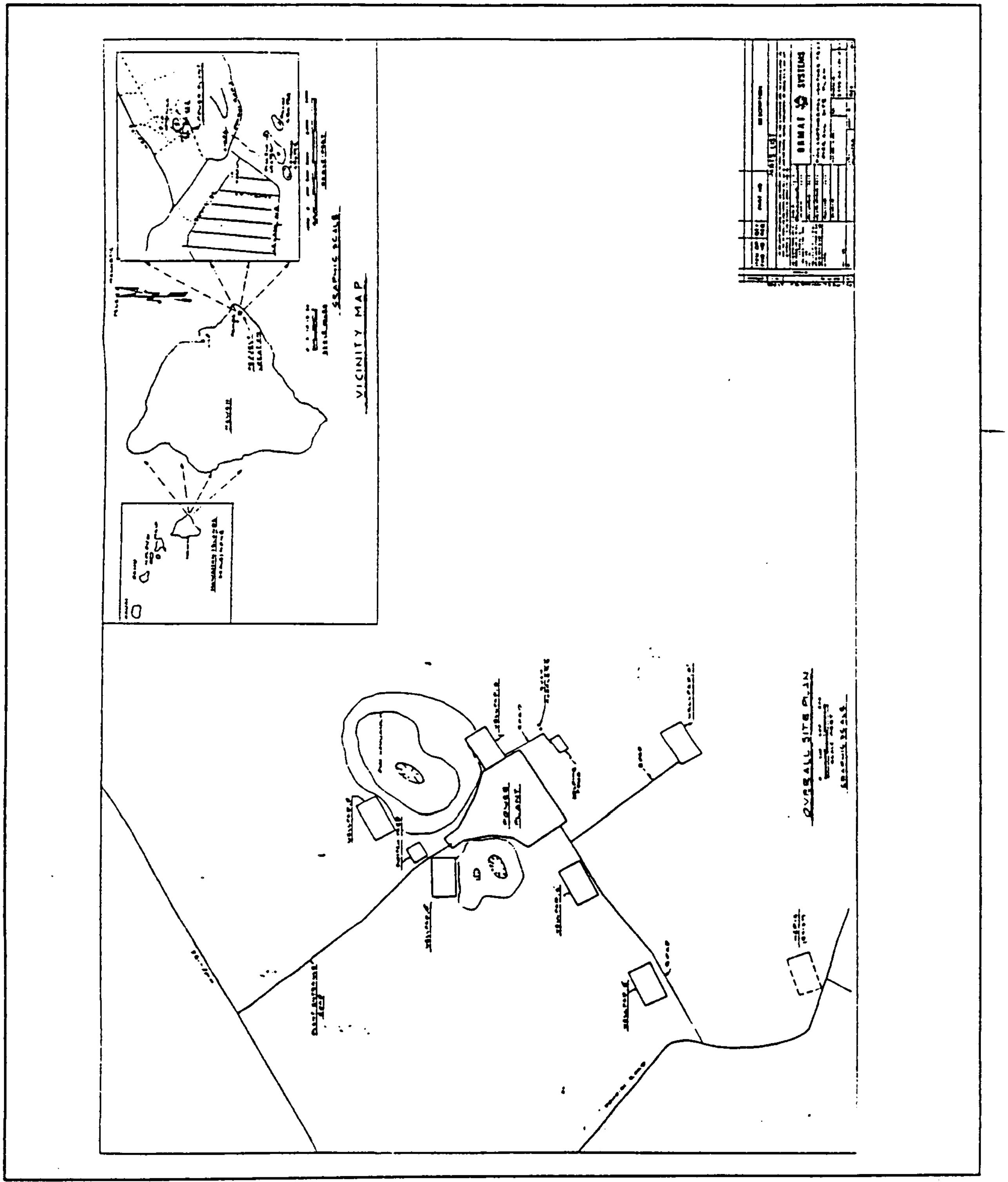


Figure E-4. Puna Geothermal Venture Project Overall Site Plan

Table E-3 presents the current initial geothermal well development plan for the PGV Project. Based upon drilling and flow testing experience to date, and projections of future performance, PGV has designed its wellfield for wells that produce approximately 62,500 lb/hr steam, with any individual well producing between 55,000 and 90,000 lb/hr steam. Thus, PGV anticipates that eight (8) production wells will be needed to supply the anticipated steam requirements of 500,000 lb/hr for the power plant at full load, although depending on the actual production rate of the wells, seven (7) to nine (9) wells may eventually supply the steam requirements of the project.

Table E-3 Initial Well Development Plan

Type of Well	Anticipated	Range
Production Wells	8	7 - 9
Injection Wells	2	2 - 3
Allowance for Unusable Wells	0	0 - 2
Total Initial Wells	10	9 - 14

Proposed
inj.
wells

To dispose of the produced geothermal brine and geothermal steam condensate, two (2) wells have been planned as geothermal injection wells; one for ongoing use and one as a spare, although a third well may be necessary. Some wells with poor production characteristics may ultimately be used as injection wells, but it is currently anticipated that wells will be drilled specifically for the injection of geothermal fluids. Additional wells are also included in the initial geothermal well development plan to allow for the possibility of drilling unsuccessful wells which terminate in impermeable rock.

Once sufficient wells are drilled to supply the initial production and injection requirements of the power plant, additional wells will be drilled as needed to supplement or replace wells which have lost production or injection capacity, which is a normal occurrence in all geothermal fields. Over the 35-year life of the PGV Project, it may be necessary to drill as many as 30 geothermal wells, the maximum number of wells which can be drilled from the six proposed wellpads.

The specific bottom hole drilling target for each well cannot be determined precisely with the reservoir information now available but, because wells will be directionally drilled from the wellpads, the bottom hole locations may be up to 1,500 feet horizontally distant from the wellhead. However, all bottom hole locations will remain within the 500-acre PGV Project area boundary. Specific bottom hole targets will be identified for each geothermal well in the drilling permit application which is required by the Hawaii State Department of Land and Natural Resources (DLNR) to be submitted to, and approved by, the DLNR prior to commencing drilling.

E.3. Wellpads and Access Roads

Each wellpad will measure approximately 300 by 400 feet, and will be designed to accommodate the drilling of up to five wells (see Figure E-5). The wellheads will be placed in cellars approximately 10 by 10 by 8 feet deep (see Figure E-6), and will be set about 50 to 100 feet apart within the wellpad. Each wellpad will be a leveled area large enough to accommodate the drilling rig and all the drilling support equipment, structures and crews. Each site will be engineered to support the drilling equipment and to keep drilling effluent contained onsite and separate from any natural drainage. Each wellpad will have drilling mud pits; sumps with gently sloped walls used to temporarily store drilling wastes, which typically consist of rock cuttings, waste drilling mud, cement particles, lost-circulation material and other drilling mud additives, and other waste drilling liquids.

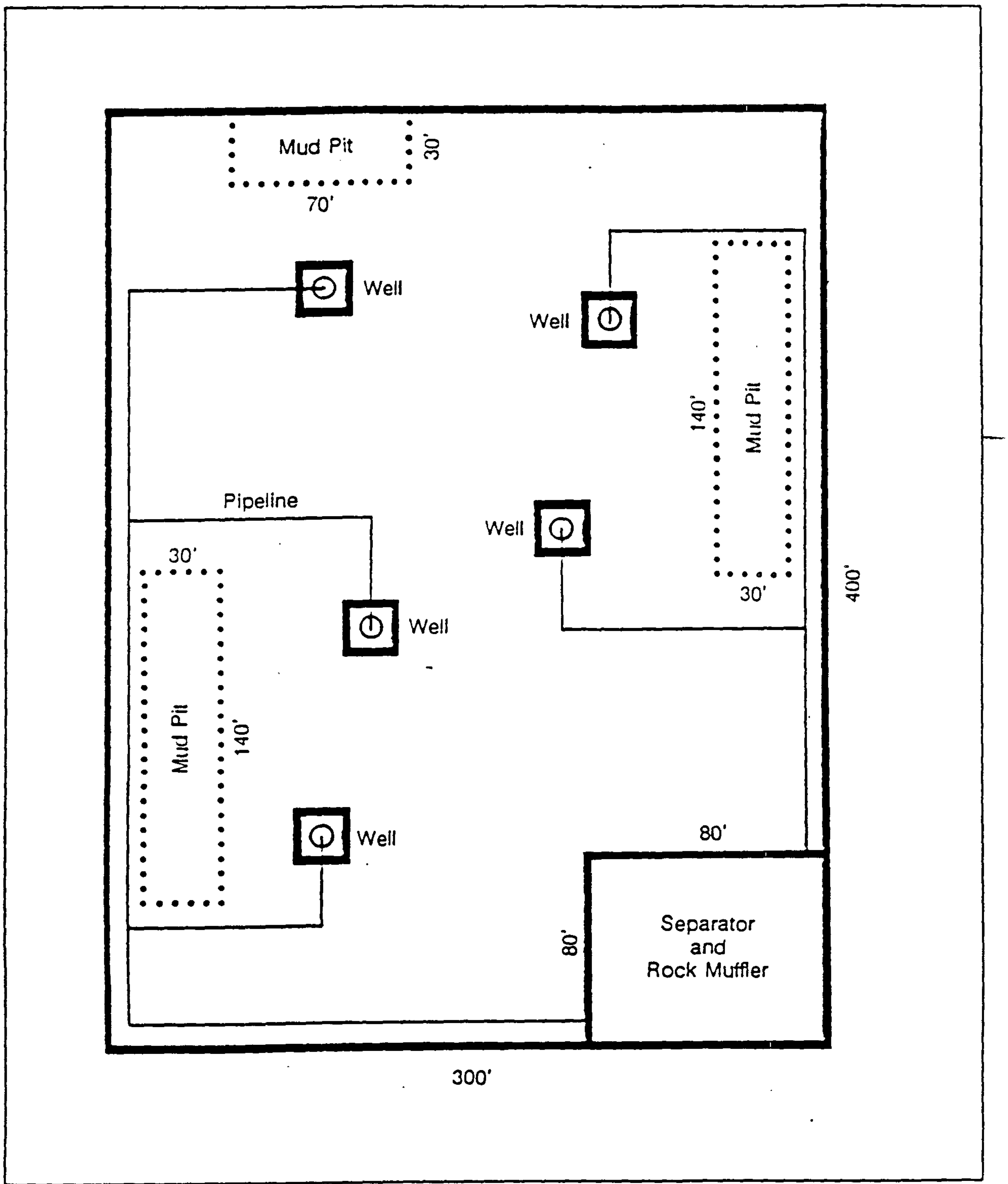


Figure E-5. Proposed Puna Geothermal Venture Project Wellpad Layout

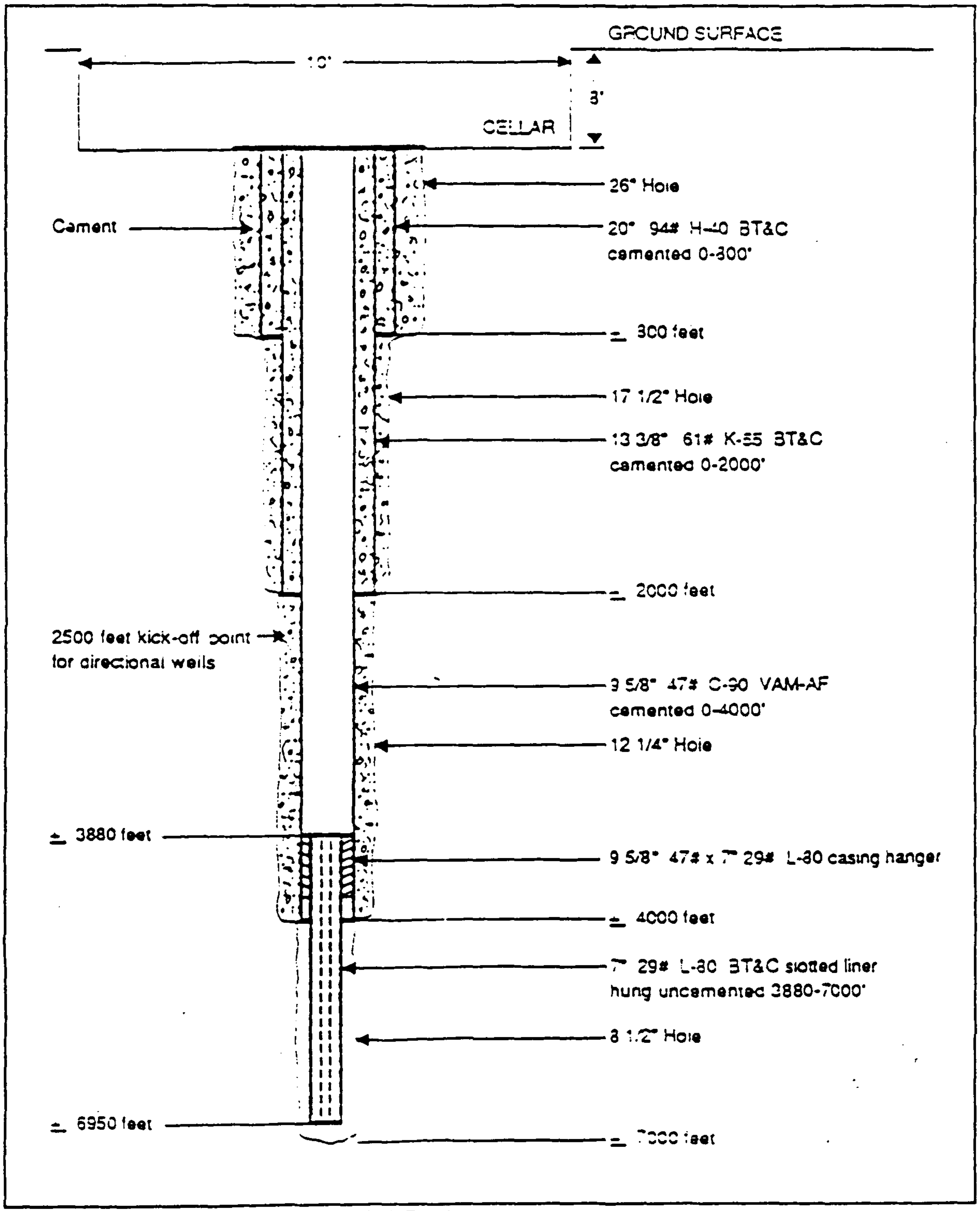


Figure E-6. Typical Production Well Design

Once drilling and initial testing of the wells on a wellpad is complete, the drilling rig will be removed and only the rock muffler, a brine/steam separator, and associated piping will remain on the pad. However, the wellpad area must be maintained to allow the return of the drilling rig should any of the wells need to be worked over or new wells drilled from the wellpad.

E.4. Well Drilling

Figure E-7 shows how the equipment required to drill the geothermal resource wells might appear during drilling operations. This equipment consists of the mast or derrick, pipe racks and drill pipe, mud mixing tanks, mud pumps and air compressors, diesel engines, blowout prevention equipment, a muffler or separator for well testing, fuel and drilling water storage water tanks, hydrogen sulfide abatement equipment, and a trailer office, change house, and restrooms for the crews.

The drilling rig will consist of a rig floor with draw works and a rotating table on a steel base structure to raise the rig floor about 20 feet off the ground to allow space for the wellhead and well-control equipment used in drilling. The rig floor is topped by a mast, or derrick, about 130 feet high. The entire rig will be powered by electricity generated by onsite diesel engines. A tank of approximately 11,000 gallons will store the No. 2 diesel fuel oil.

Drilling operations will be conducted on a 24-hour a day, 7-day per week basis until each well is completed. During drilling the wellhead is equipped with a set of control valves which collectively compose the blowout prevention equipment (BOPE). The BOPE is capable of closing (shutting) in a well during drilling operations to contain underground fluids inside the well and prevent any uncontrolled release of geothermal fluids at the wellhead. The BOPE is frequently tested to ensure its proper operation in an emergency.

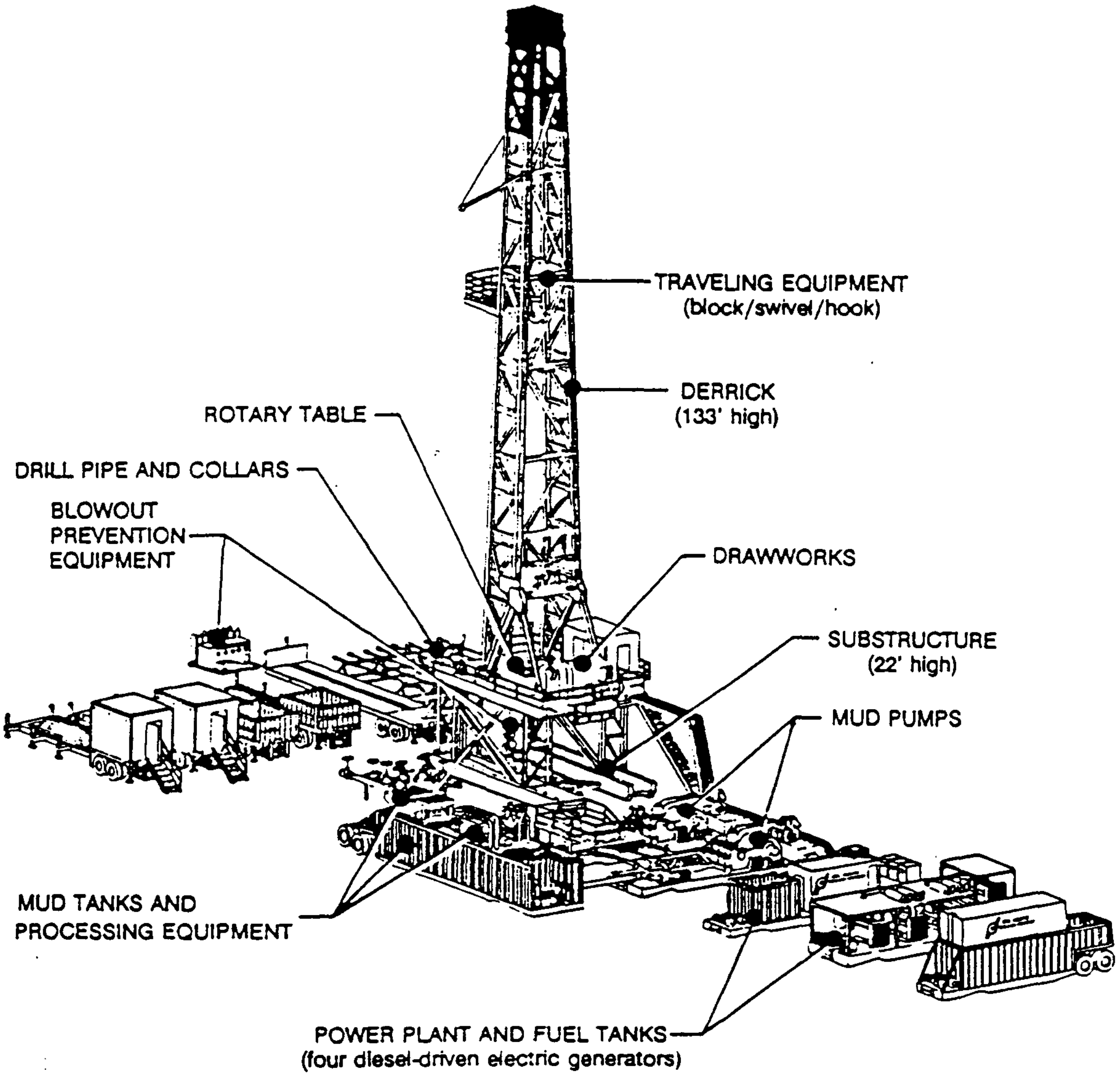


Figure E-7. View of a Typical Geothermal Well Drilling Operation

During drilling in the upper part of the hole, the circulation fluid will be drilling mud, a mixture predominantly of bentonite clay and water, with other, mostly inert, nontoxic additives included in small amounts. During the final phases of drilling in the production zone, aerated water or aerated mud may be used instead of drilling muds. Drilling muds are typically used in those portions of the well where water is expected, whereas the reservoir intervals of wells in geothermal fields containing high percentages of steam are preferably drilled with air or aerated water. Drilling typically requires up to 30,000 gallons of water per day for the preparation of new drilling fluid, washing of the rig, and other uses.

All wells will be drilled into the geothermal reservoir, which starts at a depth of approximately 4,000 feet below the surface. A series of steel casing pipes of gradually decreasing diameter will be cemented at certain depth intervals in order to: (1) maintain circulation of drilling fluids and to prevent contamination of ground waters; (2) prevent the hole from collapsing; and (3) present a clean surface to geothermal fluids. Wells drilled as production wells will consist of 20-inch, 13-3/8-inch, and 9-5/8-inch diameter casings. The 20-inch diameter casing (known as the surface casing) provides hole stability and reduces the loss of drilling mud into fractures near the surface. The 13-3/8-inch diameter casing (known as the intermediate casing) will extend from the surface down into the caprock (at approximately 2,000 feet), and 9-5/8-inch casing (known as the production casing) will extend from the surface to about 4,000 feet. This well completion design provides for a double layer of casing (13-3/8-inch and 9-5/8-inch) in the zone where the groundwater is found (from 600 feet down to the caprock).

Prior to inserting each string of casing into the hole, the hole is thoroughly flushed and cleaned by circulating fluids. Once this is done, the casing is gradually lowered in the hole and cemented in place. A 7-inch perforated liner will be installed from the bottom of the 9-5/8-inch casing to the bottom of the well at approximately 7,000 feet. This slotted casing helps to maintain well integrity, but is not cemented in place to allow for production of the geothermal fluids into the well to be brought to the surface. All casings will be steel, joined with premium threaded couplings. Figure E-6 is a diagram of a typical production well. Average drilling time for the wells will be approximately 45 days.

Directional drilling will need to be used during drilling operations to change or control the direction the drilling is proceeding. This expensive procedure is necessary because more than one well is to be drilled from each wellpad, and the bottom-hole location of each well must be far enough away from each of the other well production zones to avoid unwanted interference between wells. Directionally drilled wells are first drilled vertically to a selected depth and are then gradually deviated in specific directions using down-hole directional drilling equipment.

The following mitigation measures will be taken to ensure the integrity of the geothermal wells and to prevent blowouts:

- Use blowout prevention equipment that can rapidly choke off the flow of fluids from the well during drilling;
- Use conservative safety factors in designing wells and wellhead equipment;
- Install two strings of steel casing cemented in place from the surface into the reservoir caprock;
- Use premium grade casing materials and connections to strengthen the wellbore;
- Specify cement mixtures with high strength and insulating properties;
- Follow correct procedures during cementing of well casing;
- Inspect and test the wellhead equipment regularly; and

- Periodically survey the casing to inspect its condition.

E.5. Well Cleanout and Testing

Each well will need to be cleaned out after drilling to ensure maximum well productivity. During initial cleanout, each well will be vented vertically to remove dust and drilling debris.

After initial cleanout, the wells will be flow tested to determine the quality, flow, composition and pressure of the fluid and the capacity of the reservoir feeding the well. Each well is anticipated to have a flow rate of between 55,000 and 90,000 lb/hr of steam; 14,000 to 22,000 lb/hr brine; and 50 to 120 lb/hr H_2S.

Initially, well testing may require up to 20 days per well; however, testing durations are anticipated to decrease to 10 days or less as more wells are added and reservoir experience increases. Wells may be flowed continuously or intermittently during the test period. No more than one well will be tested at any one time at the PGV Project wellfield. Wells that are reworked after commencing operation may also have to be vented vertically and flow tested.

E.6. Makeup Wells

Over the lifetime of the project, individual geothermal wells may supplemented or replaced because production or injection capability has declined to a point where the well's contribution to the project is minimal. As many as 20 wells may be drilled over the 35-year economic life of the project to maintain full plant output. Wells no longer useful for production or injection may be used for reservoir monitoring or abandoned pursuant to applicable DLNR and HDOH regulations.

E.7. Monitoring Program

PGV will develop and implement a hydrologic monitoring program for the PGV Project. The program will provide for the regular monitoring of appropriate chemical species from a sample of existing wells completed within the shallow aquifer, including the Green Lake water supply, as well as from a groundwater well located within the project boundary and completed within the shallow aquifer. The program will monitor the shallow groundwater during all periods of PGV Project well injection activity.

[illegible]

The groundwater monitoring well will be drilled and used to verify that the injection of geothermal fluids back into the geothermal reservoir is not polluting the less geothermally influenced groundwater found east of the project boundary in the Kapoho region. This well, likely a 6-inch cased hole also used for the intermittent production of groundwater for project operations, will be located within the project area, preferably downgradient of the planned injection wellpad, Wellpad F. The well will be drilled into and completed in the zone of geothermally-influenced groundwater, at a depth not expected to be greater than 800 feet. The final location of the groundwater monitoring well will be determined after the injection wells have been drilled, and the monitoring well will be completed before injection operations begin.

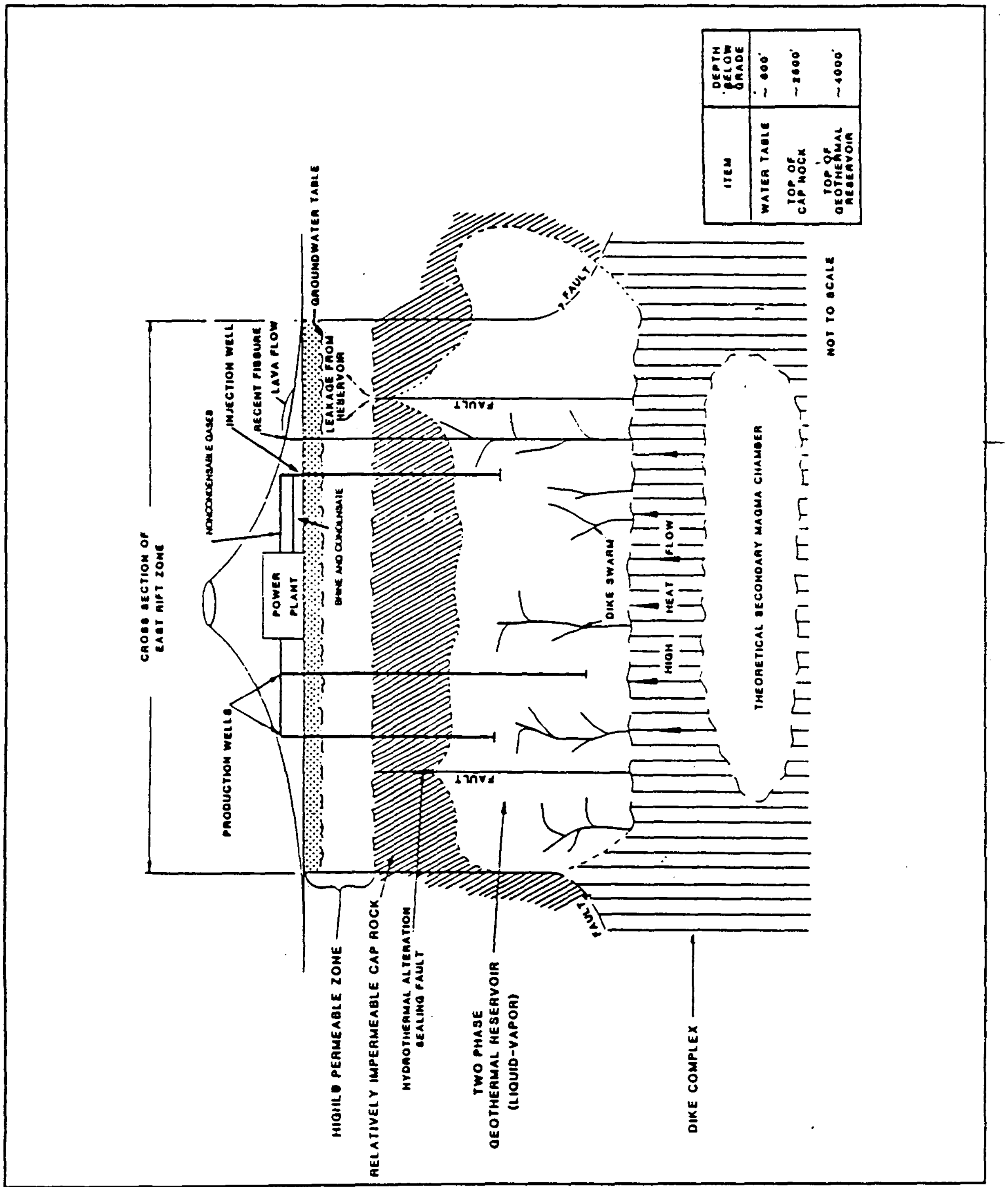
ATTACHMENT F

Hydrology

The PGV Project area is located in the LERZ on the eastern flank of Kilauea Volcano, one of the world's most active volcanoes. The LERZ is a conduit for lateral migration of basaltic magma flowing east-northeast from the caldera at the summit. The magma in this subsurface conduit provides the heat source for the high temperature Puna geothermal reservoir, which in turn affects the groundwater resources in the area.

Underground injection at the PGV Project will essentially be a reinjection of the geothermal fluids which are withdrawn from the geothermal reservoir and used in the production of electricity. The produced geothermal fluids will be reinjected into the geothermal reservoir at depths below approximately 4,000 feet, beneath an impermeable caprock which separates the geothermal reservoir from an upper groundwater zone (see Figure F-1). This groundwater zone extends from the top of the impermeable caprock to the water table, approximately 600 feet below the surface. The groundwater in this upper aquifer in the vicinity of the PGV Project is thermally and chemically influenced by natural leakage of geothermal fluids through the caprock from the geothermal reservoir below. Recharge for the groundwater aquifer is from rainwater; as much as 120 inches a year fall at the site and percolate downward through porous volcanic soil and rock. The dikes and faults of the LERZ affect the flow of the groundwater, and natural leakage of geothermal fluids and heat from the geothermal reservoir affects its quality and temperature.

Groundwater wells within the East Rift Zone have been classified as producing fresh, geothermal, or mixed waters (Iovenitti, J. "Thermal Power Plant LERZ Geotechnical Report", July 10, 1989). Physical and water quality data for geothermal, mixed, and fresh water wells located in the LERZ (see Figure F-2) are shown in Table F-1 through Table F-4. These data show the strong geothermal influence on groundwaters located within the LERZ. Groundwaters immediately within the PGV Project area are classified as geothermal



ITEM	DEPTH BELOW GRADE
WATER TABLE	~ 600'
TOP OF CAP ROCK	~2600'
TOP OF GEOTHERMAL RESERVOIR	~4000'

Figure F-1. Conceptual Model of the Puna Geothermal Reservoir

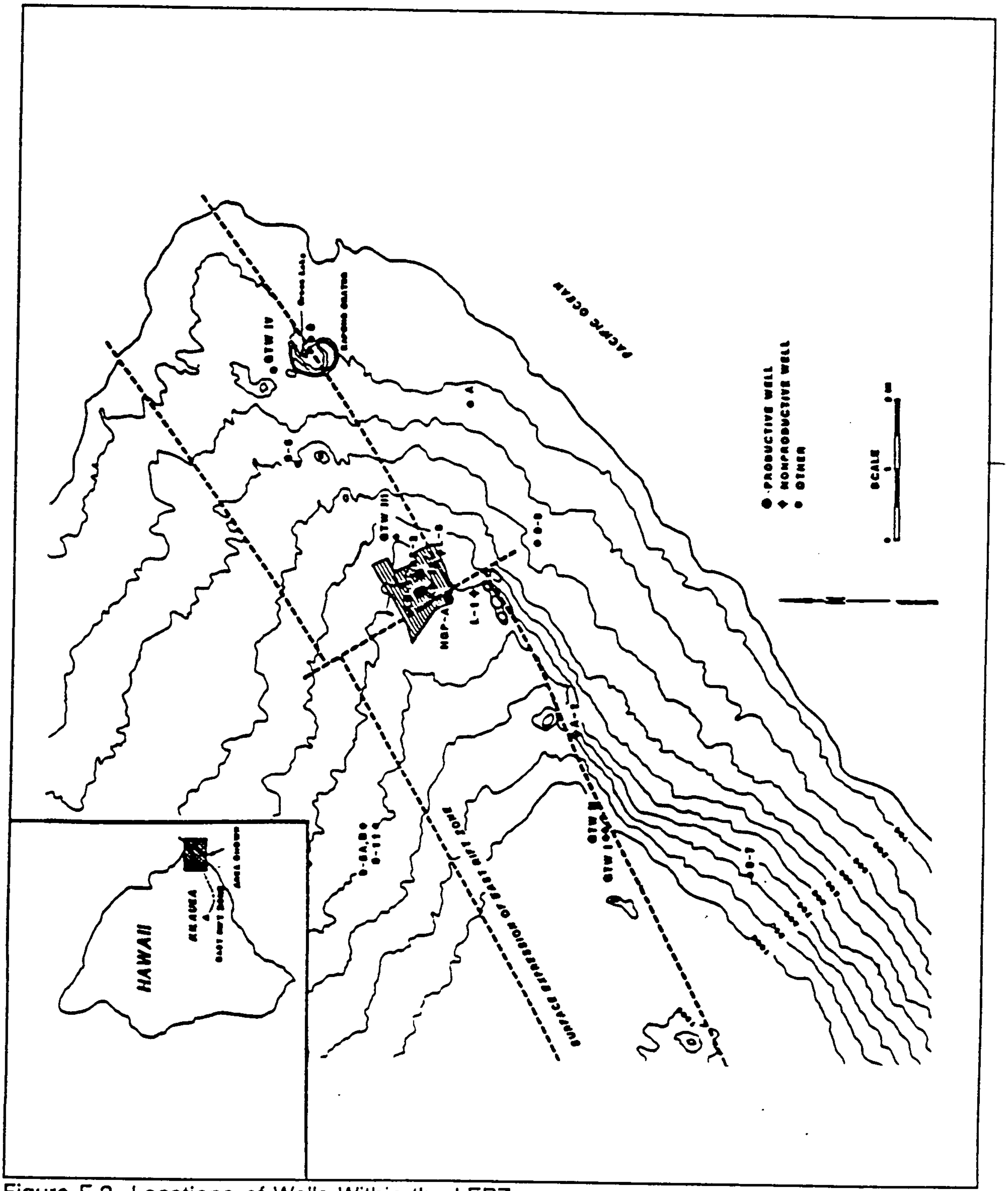


Figure F-2. Locations of Wells Within the LERZ

Table F-1 Physical Data on Wells in the LERZ Region

Well	ELEVATION (ft., AMSL[1])	DEPTH (ft.)	WATER LEVEL (ft., AMSL[1])	MAXIMUM TEMP (°F)
9-5a	705	754.7	17.8	72
9-11	402	446	11.6	72
9-7	752	801.9	2.94	73
GTW-I	1009	178	N/A	156
GTW-II	1035	556	N/A	207
KS-1	617	782[4]	11	113
KS-1A	617	586[4]	38[3]	N/A
KS-2	718	732[4]	10	N/A
9-9	274	316	0.7	131
GTW-III	563	690	4.9	199
9-6	287	337.15	3.3	98
A	129	140	4.9	102
GTW-IV	250	290	N/A	109
9	38	41	2.6	77

[1] Above Mean Sea Level

[2] N/A - Not Available

[3] The significant differential in water level between KS-1 and KS-1A is in part thought to result from a data collection error.

[4] Depth of well when formation water was intercepted.

Source: Iovenitti, J. "Thermal Power Company LERZ Geotechnical Report", July 10, 1986.

Table F-2 Water Chemistry for Geothermally Influenced Wells in the LERZ Region

	Well											
Parameter[1,2]	KS-1	KS-1A	KS-2	GTW-IIIa	GTW-IIIb	GTW-IIIc	9-9a	9-9b	9-9c	9-9d	9-9e	A
Temp (°F)	113	>100	>100	199	N.A.	165	126	N.A.	N.A.	128	N.A.	99.5
pH	N.A.	8.5	9.5	6.85	N.A.	1.4	7.02	7.45	6.92	7.1	6.92	7.35
Na	614	921	1000	2050	2000	1740	2105	2890	2935	2695	3090	216
K	46.1	26.0	94	190	195	158	109	149	155	129	N.A.	10.8
Ca	53.2	65.8	65.0	76.8	81.0	71.0	66.8	117	182	122	182	13.4
Mg	30.2	2.71	0.5	52.0	59.0	62.5	210	293	324	267	324	15.0
Cl	1150	1098	1600	3274	3410	2980	3811	5120	5850	6887	5850	281
SO_4	169	74	210	314	335	317	471	598	681	583	681	69.2
HCO_3	N.A.	N.A.	N.A.	30.0	N.A.	20.0	144	128	262	173	N.A.	132
SiO_2	80.0	104.6	93.0	96.6	N.A.	N.A.	100.7	N.A.	59.0	83.2	59.0	24.1
P	N.A.	N.A.	N.A.	0.006	0.076	0.053	0.006	0.013	N.A.	N.A.	N.A.	<0.002
Fe[3]	15.0	N.A.	70.0	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	3.16	3.16	N.A.
TDS	2158	2292	3140	6084	6080	5349	7018	9295	10450	10949	11700	762
Cl/Mg	38.08	405.17	3200	62.96	57.8	47.68	18.15	17.47	18.06	25.79	18.06	18.73
Date	1983	1985	1984	1-75	7-75	7-75	1-75	7-75	9-62	N.A.	9-62	1-75

[1] Parameters shown in mg/l.
[2] N.A. - Not Available
[3] Total Fe

Source : Iovenitti, J. "Thermal Power Plant LERZ Geotechnical Report", July 10, 1986.

Table F-3 Water Chemistry for Mixed Water Wells in the LERZ Region

	Well							
Parameter[1,2]	9-6a	9-6b	9-6c	GTW-IV	9a	9b	9c	9d
Temp (°F)	91	92	96	N.A.	77.9	71.8	N.A.	N.A.
pH	7.42	7.75	7.1	7.9	7.8	7.1	7.7	7.2
Na	238	223	231	49.2	85.8	86.5	97.0	139
K	13.6	16.8	15.2	N.A.	6.6	6.2	14.0	25.0
Ca	23.0	12.5	16.5	16.2	42.4	23.2	47.7	14.0
Mg	28.0	27.2	24.1	7.5	37.0	25.7	26.5	17.0
Cl	303.5	316	450	72	16.9	95.7	125	331
SO_4	204	211	106	18.4	20.0	22.7	5.5	65.4
HCO_3	48.0	44.0	46.0	N.A.	372	328	283	61
SiO_2	71.3	N.A.	63.0	44.0	53.6	N.A.	44.0	70.5
P	0.04	0.076	N.A.	N.A.	0.233	0.268	N.A.	N.A.
Fe[3]	N.A.	N.A.	0.2	0.1	N.A.	N.A.	N.A.	0.2
TDS	929	851	1006	220	635	588	643	723
Cl/Mg	10.8	11.6	18.67	9.6	0.46	3.72	4.7	19.47
Date	1-75	7-75	1979	6-61	1-75	7-75	3-68	N.A.

[1] Parameters shown in mg/l.
[2] N.A. - Not Available
[3] Total Fe

Source: Iovenitti, J. "Thermal Power Plant LERZ Geotechnical Report", July 10, 1986.

Table F-4 Water Chemistry for Fresh Water Wells North and South of the LERZ Region

	Well				
Parameter[1,2]	9-5a[4]	9-5b[4]	9-11[5]	9-7a	9-7b
Temp (°F)	75	74	75	83.3	69.4
pH	7.3	6.65	8.5	7.68	7.05
Na	36.0	19.3	16.0	89.6	78.8
K	2.72	2.7	3.3	5.2	5.0
Ca	1.58	1.6	19.0	5.3	5.9
Mg	2.7	1.9	5.1	6.6	5.6
Cl	13.5	9.8	4.0	132.2	120
SO_4	48.0	44.0	11.0	37.6	38.6
HCO_3	21.1	27.3	71.0	N.A.	N.A.
SiO_2	50.0	N.A.	62.0	44.5	N.A.
P	0.08	0.13	N.A.	0.056	0.194
Fe[3]	N.A.	N.A.	8.8	N.A.	N.A.
TDS	176	107	120	359	291
Cl/Mg	5.0	5.16	0.787	20.0	21.43
Date	1-75	7-75	10-85	1-75	N.A.

[1] Parameters shown in mg/l.
[2] N.A. - Not Available
[3] Total Fe
[4] 9-5a/9-5b - Pahoa Station (PSa/PSb)
[5] 9-11 - Pahoa Village Fresh Water (PVFW)

Source: Iovenitti, J. "Thermal Power Plant LERZ Geotechnical Report", July 10, 1986.

because of significant natural geothermal fluid leakage into the groundwater zone. Geothermally influenced waters are also found south of the LERZ, downgradient from the project area as shown in Well A. The high temperatures, and high chloride and total dissolved solids in the groundwater encountered in these wells makes it economically and technically impractical to render these waters fit for human consumption.

An area of mixed waters is also located to the east, within the rift zone, downgradient from the region of upwelling geothermal fluids. The mixed waters in this area may be less geothermally influenced from LERZ dikes and faults and may contain fresh waters from Green Lake located within the Kapoho Crater. Green Lake is the only standing body of water in the LERZ, and its existence is attributed to an ash layer acting as an aquitard. It is about three miles east-northeast of the project area. The geothermal influence on groundwaters appears to decrease with distance from the proposed project area.

The East Rift Zone physically separates fresh water areas from geothermally influenced areas. Fresh waters are present north of the rift zone, south of the rift zone, and west of the PGV Project area. A chemical analysis for the fresh water supply well located nearest to the PGV Project area is provided in Table F-5. This well is the Pahoa Station well located about 3 miles west-northwest from the project area.

Table F-5 Chemical Composition for Nearest PGV Project Supply Well

(all concentrations are in mg/l)

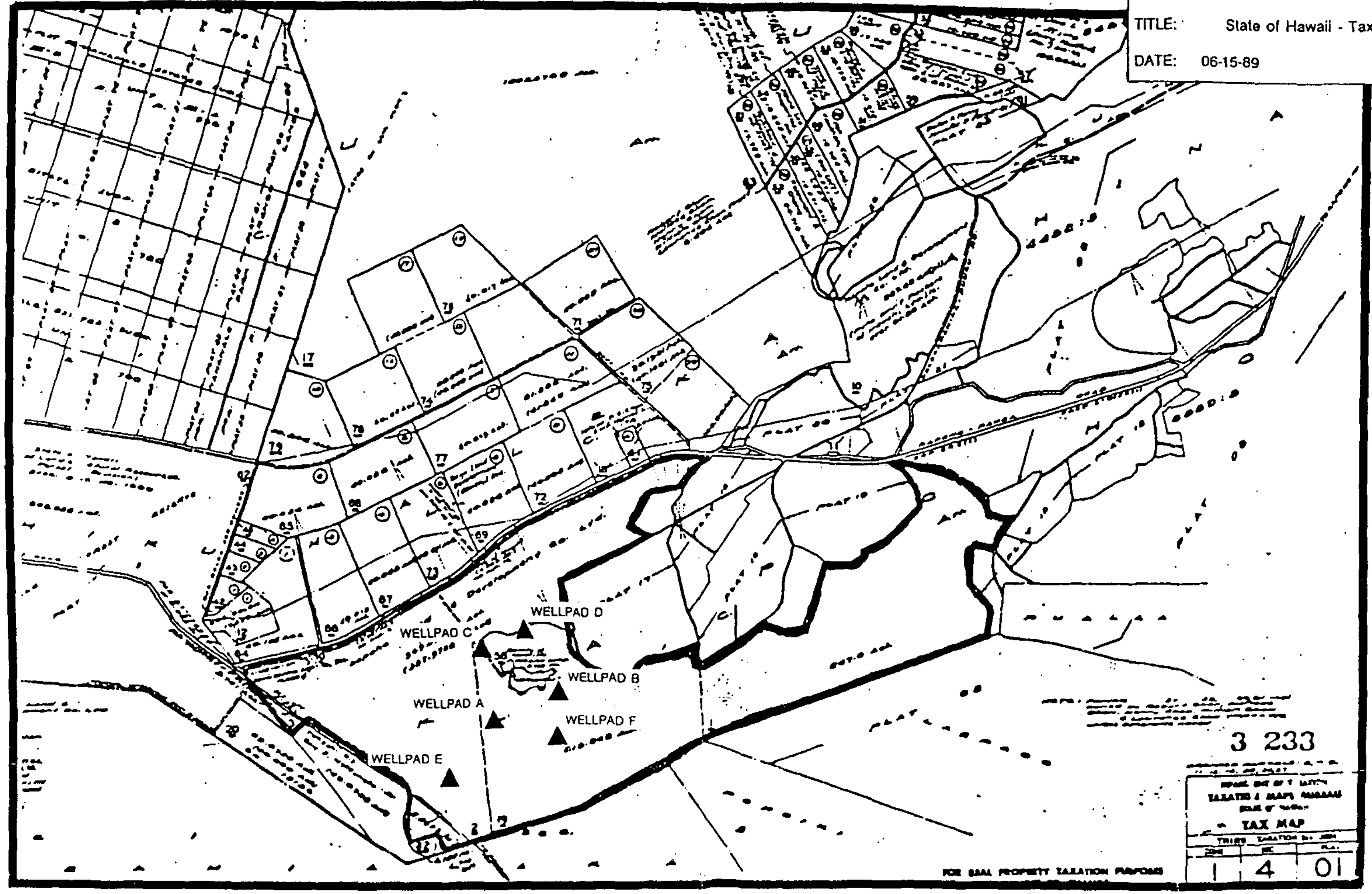
Name	Date	Temp. (°C)	pH	Na	K	Ca	Mg	Cl	HCO_3	SO_4	TDS
Pahoa Station	01-06-75	23.9	7.30	36.0	2.72	1.58	2.7	13.5	21.1	48.0	176
	07-21-75	23.3	6.65	19.3	2.7	1.6	1.9	9.8	27.3	44.0	107

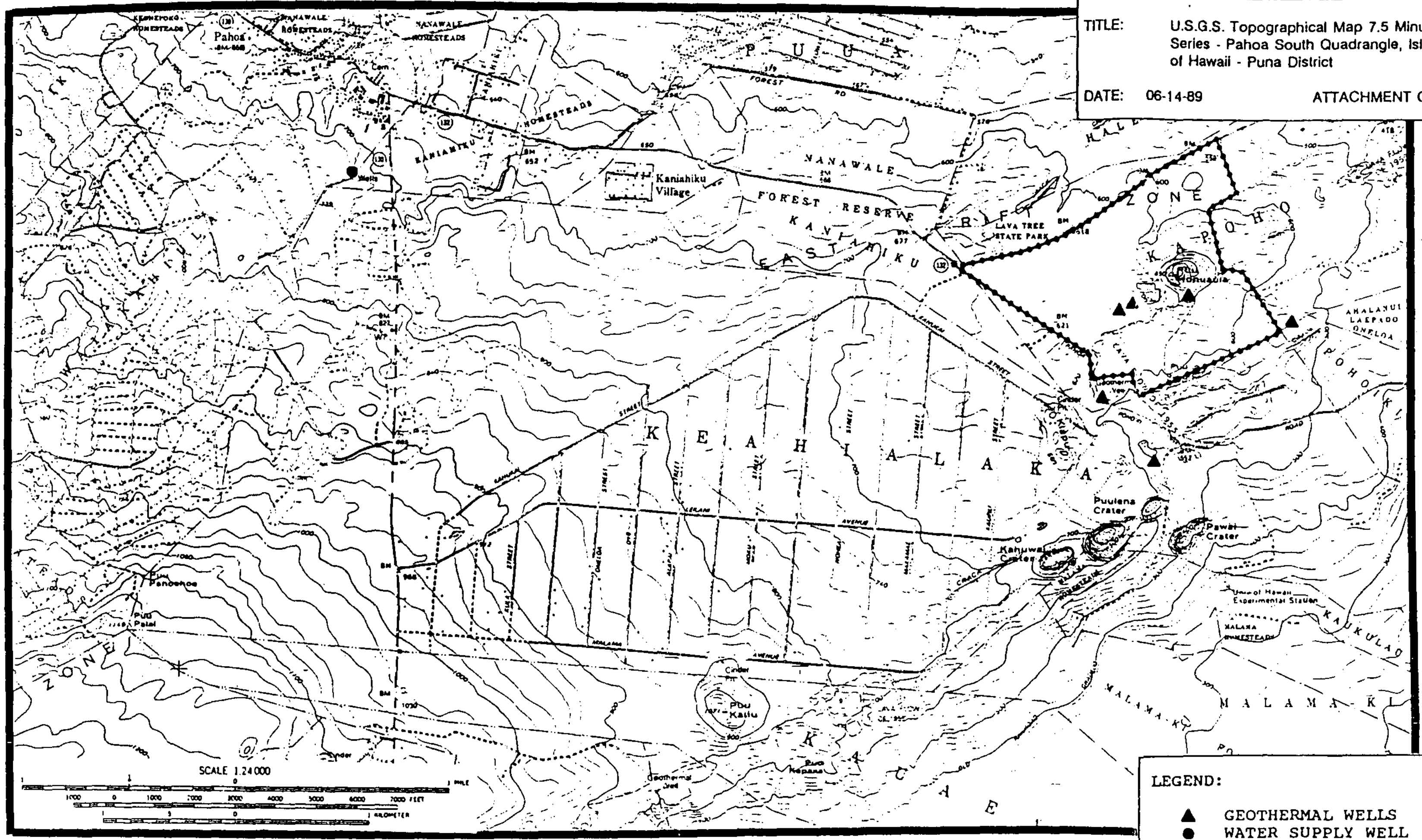
Source: Iovenitti, J. "Thermal Power Company LERZ Geotechnical Report", July 10, 1986.

ENVIRONMENTAL MANAGEMENT ASSOCIATES

TITLE: State of Hawaii - Tax Map Key Map

DATE: 06-15-89 ATTACHMENT B





ENVIRONMENTAL MANAGEMENT ASSOCIATES

TITLE: U.S.G.S. Topographical Map 7.5 Minute Series - Pahoa South Quadrangle, Island of Hawaii - Puna District

DATE: 06-14-89 ATTACHMENT C

LEGEND:

- ▲ GEOTHERMAL WELLS
- ● WATER SUPPLY WELL
- ✦✦✦✦ PGV PROJECT BOUNDARY