EMERGENCY RESPONSE PLAN

Puna Geothermal Venture Geothermal Facility

January 1, 2023

Geothermal Resource Permit: GRP 87-2

TMK: 1-4-01: por. 2, 3, por. 19 & 58

Puna, Hawaii

Island of Hawaii

Puna District

Puna Geothermal Venture

P.O. Box 30

Pahoa, Hawaii 96778

808.965.6233

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INTRODUCTION

Puna Geothermal Venture (PGV) is a geothermal powered electric generating project within a designated area of about 500 acres located on State Highway 132 and Pahoa-Pohoiki Roads (Figure 1-1 and Figure 1-2). The project occupies about 25 acres of surface area consisting of production and injection wells and a power plant. A detailed description of the project facilities and operations is presented in Appendix A.

1.1 Objective

This Facility Emergency Response Plan (ERP) has been developed to comply with Condition #26 of Geothermal Resource Permit GRP 87-2, approved by the County of Hawaii Planning Commission on October 3, 1989, and in conformance with discussions with the County of Hawaii Civil Defense Agency (CDA), Hawaii Department of Health (HDOH), and the staff of the Hawaii State Emergency Response Commission (ERC). This ERP is specifically required to provide a plan of action to deal with facility emergency situations which may threaten the health, safety, and welfare of the employees and other persons in the vicinity of the project site. This plan is the basis of all actions by PGV's personnel and management staff in responding to these situations and is updated appropriately when necessary. Site personnel also follow related site Safety, Environmental and Operating Procedures.

Any change to the plan is the responsibility of:

Puna Geothermal Venture
P.O. Box 30
Pahoa, Hawaii 96778

1.2 Scope

The required Scope of the ERP, as in Condition #26 of the GRP, items a through k, requires that the following elements be included as a minimum:

a. A description of the project facilities and operations, with site plans identifying areas of potential hazards, such as high pressure piping and the presence, storage and transportation of flammable or hazardous materials, such as lubrication or fuel oil, pentane, hydrogen sulfide, and sodium hydroxide;

b. A description of emergency services available off-site to respond to any emergency.

c. A description of the current on-site chain-of-command and responsibilities of project personnel in the event of an emergency; and,

d. A description of potential project emergency situations, such as loss of well control, chemical spills, hydrogen sulfide exposure, pipeline rupture, fires, contaminated solids, etc. identifying;

(i) technical data on the nature of the hazard (for example, the concentrations of hydrogen sulfide in the various areas and the hazard associated with these concentrations, the corrosive characteristics of the abatement chemicals), or any data regarding the possible aerial extent of each potential emergency situation;

(ii) the warning systems (such as hydrogen sulfide detectors) used to alert personnel of the hazard;

(iii) the location and use of equipment used to control the hazard (such as fire protection equipment or isolation valves) or repair hazardous equipment (such as welding equipment or casing sleeves), and safety equipment for personnel (such as respiratory packs), including identification of the personnel trained in the use of that equipment; and

(iv) provisions for the monitoring, detection, and inspection of wells and plant facilities for the prevention of emergency situations.

e. Provisions to address natural hazards (such as lava flows, earthquakes, and storms) that identify warning systems, control options, steps for securing and shutting down the facility, personnel evacuation, and notification to appropriate agencies.

f. The location and capabilities of available medical services and facilities and plans for treating and transporting injured persons.

g. Evacuation plans, including meeting points, personnel rosters, and escape routes.

h. Training requirements for personnel, including procedures for emergency shutdown, handling of emergency equipment, spill prevention, first aid and rescue, fire fighting procedures, and evacuation training.

i. Provisions for periodic emergency preparedness drills for personnel.

j. Detailed procedures to be used to facilitate coordination with appropriate federal, state, and county officials during and after any emergency; and,

k. Procedures to be used to identify and inform all residents within applicable distances of the project of the possible emergency situations, warnings, and responses in advance of commencement of project operation and the methods by which all individuals affected by a given emergency will be notified and evacuated, as necessary.

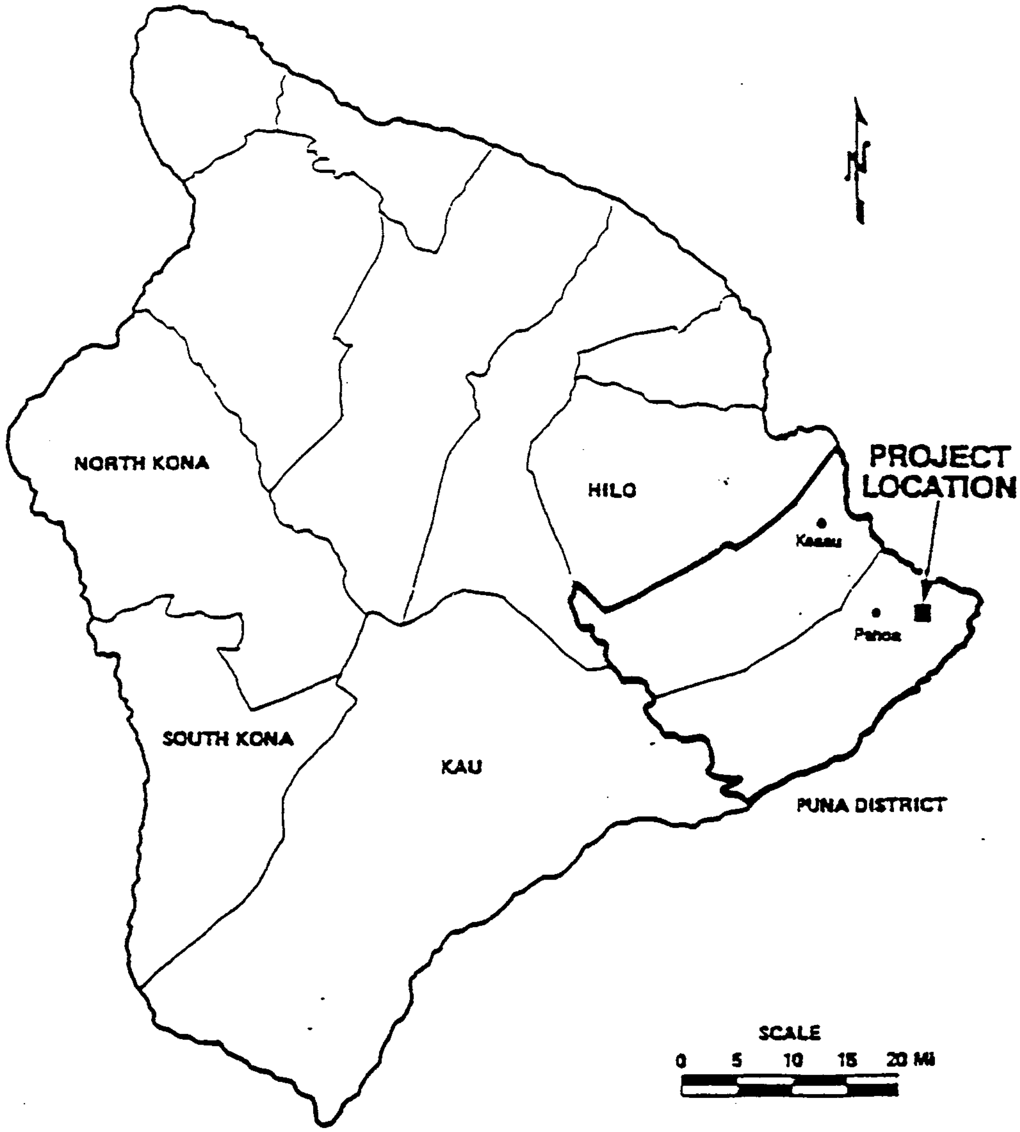
Table 1-1 identifies where the components of each of these GRP requirements are located in this document.

Table 1-1 Index of GRP Condition #26 Requirements in the Emergency Response Plan

a	A description of the project facilities and operations, with site plans identifying areas of potential hazards, such as high pressure piping and the presence, storage and transportation of flammable or hazardous materials such as lubrication or fuel oil, n-pentane, hydrogen sulfide, and sodium hydroxide;	Appendix A (A.1 - A.10.1) Section 4.2
b	A description of emergency services available off-site to respond to any emergency;	Section 4
c	A description of the current on-site chain-of-command and responsibilities of project personnel in the event of an emergency; and	Section 3
d	A description of potential project emergency situations, such as loss of well control, chemical spills, hydrogen sulfide exposure, pipeline rupture, fires, contaminated solids, etc. identifying;	Section 8
	(i) technical data on the nature of the hazard (for example, the concentrations of hydrogen sulfide in the various areas and the hazard associated with these concentrations, the corrosive characteristics of the abatement chemicals), or any data regarding the possible aerials extent of each potential emergency situation;	Section 8, Appendix F, Appendix G, Appendix H, Attachments 1-3
	(ii) the warning systems (such as hydrogen sulfide detectors) used to alert personnel of the hazard;	Section 4 Section 5 Section 6 Section 8 Appendix A
	(iii) the location and use of equipment used to control the hazard (such as fire protection equipment or isolation valves) or repair hazardous equipment (such as welding equipment or casing sleeves), and safety equipment for personnel (such as respiratory packs), including identification of the personnel trained in the use of that equipment; and	Section 4 Section 8
	(iv) provisions for the monitoring, detection, and inspection of wells and plant facilities for the prevention of emergency situations.	Appendix A Section 4
e	Provisions to address natural hazards (such as lava flows, earthquakes, and storms) that identify warning systems, control options, steps for securing and shutting down the facility, personnel evacuation, and	Section 5 Section 8

	notification to appropriate agencies;	
f	The location and capabilities of available medical services and facilities and plans for treating and transporting injured persons;	Section 4
g	Evacuation plans, including meeting points, personnel rosters, and escape routes;	Section 5
h	Training requirements for personnel, including procedures for emergency shutdown, handling of emergency equipment, spill prevention, first aid and rescue, fire fighting procedures, and evacuation training;	Section 6, Appendix B, C
i	Provisions for periodic emergency preparedness drills for personnel;	Section 6 Section 7
j	Detailed procedures to be used to facilitate coordination with appropriate federal, state, and county officials during and after any emergency; and,	Section 3, Appendix D
k	Procedures to be used to identify and inform all residents within applicable distances of the project of the possible emergency situations, warnings, and responses in advance of commencement of project operation and the methods by which all individuals affected by a given emergency will be notified and evacuated, as necessary.	Section 3.3

Figure 1.1 Site Location Map



ISLAND OF HAWAII

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

2 REGULATORY AUTHORITY AND DEFINITIONS

2.1 Regulatory Authority

As discussed above in Chapter, this ERP has been developed specifically to satisfy Condition No. 26 of GRP 87-2, which requires a plan of action to deal with emergency situations which may threaten the health, safety, or welfare of the employees and other persons in the vicinity of the proposed project site. GRP 87_2 presents fifty other conditions of approval which, among other things, set limits on the amount of several pollutants that PGV may emit into the environment, and also set limits on the ambient (environmental) concentrations of these pollutants which result from PGV's operations. So that the PGV Project will not become a nuisance to the community, these permitted emission limits and ambient concentrations are intentionally set at very low levels.

PGV has also been issued three permits by the Hawaii State Department of Health (HDOH). They limit the emissions of several pollutants, principally hydrogen sulfide, and limit the concentration levels that these pollutants can reach in the ambient environment because of PGV's operations. The operation of the PGV well field is regulated by the Permit to Operate, (PTO) # P833-1524, issued by the HDOH. PTO # P834-1582 has been issued by HDOH to regulate the operation of the Project Power Plant. Well construction, when underway, is regulated by a Non-covered Source Permit (NSP) # 0008-01-N issued by HDOH.

Exceeding either the emission limits or ambient concentrations set in these permits, either during otherwise permitted operations or during upset conditions, would be considered a violation of the permits and would subject the permit holder (PGV) to the penalties described in the permits and applicable laws and regulations. PGV is generally also required to immediately respond to exceedances of the permitted emission limits or ambient concentrations by reducing or eliminating the source of the exceedance, so that the project permitted operations are reduced to within permitted limits.

Some upset conditions, although they do not result in the emission or ambient concentration of any pollutant above the permitted level and do not pose any threat to the health, safety, or welfare of the persons in the vicinity of the community, may nonetheless result in the need for one or more of the County normal emergency response organizations (police, fire department, etc.) to respond to the site. The County of Hawaii Plan for Emergency Preparedness, Vol. III, Disaster Preparedness and Response recognizes these as "everyday" emergency situations, the type of emergency situations which frequently arise in a community and which are handled routinely by normal emergency services. However, should the exceedance of the permitted limits or concentrations during an upset or accident be so great as to endanger, or potentially endanger, the public health, safety, or welfare, an emergency response by the Hawaii County Civil Defense Agency (CDA) and/or other County emergency response organizations would likely occur.

2.2 Definitions

Normal Plant Operations	As defined in the Non-covered Source Permit (NSP), a condition when both the power plant and geothermal well field are operating normally, that is, when the power plant is operating without any upsets, equipment failure, malfunction or which is otherwise operating normally and when no well drilling, flow testing, or venting activities are occurring and where the completed wells are not experiencing any equipment failure or malfunction and are either shut-in, being used as an injection well, or connected to a sound geothermal resource distribution system.
Routine Operations	Those operations over and above normal operations, including, but not limited to, periods of well drilling, well flow testing, well or pipe clean out, but not including periods of well or power plant upset, failure or malfunction.
Upset Conditions	Those situations which are not normal or routine operations.
Permitted Operations	Those normal, routine, and upset operations and/or conditions which are permissible under permits granted by the Hawaii County Planning Commission (Geothermal Resource Permit GRP 87-1) and the Hawaii Department of Health (Permit to Operate Permits No. P-833-1524 and No. P-834-1582), whether by explicit statement or through producing impacts which do not exceed stated limits.
Permitted Upset Conditions	Those situations which are not normal or routine operations, but which are otherwise anticipated and approved by the appropriate regulatory agencies, such as steam release through the emergency steam release facility; or those circumstances, such as turbine trips, minor leaks, component malfunctions, etc., which are not expressly approved in any permits, but the impacts of which fall within permitted limits and do not have the potential to produce emergency situations which could threaten the health, safety, or welfare of the employees and other persons in the vicinity of the proposed project site.
Ambient Level	That concentration of a pollutant, such as hydrogen sulfide, or level of an environmental factor, such as noise, which is measured or predicted at a specified point or points in the air or environment.

Emission Level	That quantity of a pollutant or environmental factor which is, or could be, discharged into the environment.
Facility Emergency Situation	An upset condition which results in the need for immediate action by facility operation personnel to restore normal or routine operations.
Everyday Emergency Situation	As defined by the County of Hawaii Plan for Emergency Preparedness, Vol. III, Disaster Preparedness and Response, those emergency situations which are handled routinely by project personnel and/or normal emergency services such as police, fire, emergency medical service, public works, or utilities.
Hazard	Any situation that has the potential for causing damage to life, property, or the environment.

1 NOTIFICATION AND CHAIN-OF-COMMAND

1.1 Notification Lists

Table 3-1 provides phone contacts for County, State, and Federal government agencies, PGV staff, and the project 24-hour information line.

1.2 PGV Emergency Response Organization

Table 3-2 illustrates the chain of command and emergency response team that is in effect to deal with site emergencies and summarizes the responsibilities of the site staff during an emergency.

TABLE 3-1 EMERGENCY NOTIFICATION CONTACT LIST

INTERNAL

POSITION	ADDRESS	BUS. PH.	AFTER HOURS	MOBILE PH.
1. Plant Manager Jordan Hara	17-4487 Huina Road Kurtistown, HI 96760	808-965-2835	808-494-8882	808-494-8882
2. Director, Electricity Segment, International Ezra Zemach	Ormat Technologies, Inc.	1-775-313-5519	-775-313-5519	-775-313-5519
3. Director of Hawai'i Affairs Michael Kaleikini	1134 Ainalako Road Hilo, HI 96720	808-965-2838	808-959-1422	808-936-8161
4. Operations Supervisor Zachery Adachi	17-102 N Ipuaiwaha Keauu, HI. 96749	808-965-2842	808-494-8876	808-936-3242
5. Safety & Environmental Manager Ronald Quesada	15-1643 Lokelani Street Kea'au, HI. 96749	808-965-2828	808-982-3948	808-430-8679
6. Maintenance Supervisor Jeff Hintson	16-2109 Silversword Dr. Pahoa, HI. 96778	808-965-2829	808-765-9590	808-765-9590

PGV EMERGENCY EXTERNAL CALL LISTS

EXTERNAL (PRIMARY)

POSITION	BUS. PH.	AFTER HOURS	MOBILE PH.
1. Civil Defense Agency	935-0031	935-3311	
2. Department of Health David Wong Honolulu Clean Air (Darin Lum) Drinking Water (Norris Uehara) Noise (James Toma) Haz Evaluation/Emergency Resp. 24 Hour - Operator	808-586-4200 1-808-586-4200 1-808-586-4258 1-808-586-4700 933-9921	1-808-734-2161 1-808-247-2191	
3. Fire Department/Emergency 4. Fire Department/Pahoa	911 965-2708		
5. Police Department Pahoa	935-3311 966-7432	935-3311 966-7432	
6. Dept. of Land & Natural Resources Hilo Honolulu (Suzanne Case)	961-9588 808-587-0266 808-587-0227	961-6586	987-9184

EXTERNAL (SECONDARY)

POSITION	BUS. PH.	AFTER HOURS	MOBILE PH.
1. Security: Ron Quesada	808-965-2848	808-965-2848	808-430-8679
2. Monitoring: Joseph Chaney	1-808-640-2566		
3. HELCO	969-0411	969-0411	
4. *PGV Response Line	965-8843		
5. **PGV Information Line	934-9072	934-9072	
6. For reportable quantities: ($H_2S \geq$ 100 lbs; caustic $\geq$ 1,000 lbs.) a. Hawaii State Emergency Response Commission (HSERC) b. Hawaii County Fire Department c. Hawaii County Division of Industrial Safety (LEPC) d. National Response Center	1-808-586-4249 961-6022 936-0858 1-800-424-8802	1-247-2191 961-6022 1-800-424-8802	

*   Call this number to give current information to the operators at the response line answering service.
**   PGV Information Line: CSC will change message to update situation.
*** For emergencies, call 911

3.3 EMERGENCY RESPONSE TEAM

	PRIMARY	ALTERNATES
Incident Commander (Emergency Coordinator)	**Jordan Hara Fire Department**	**Zach Adachi Ron Quesada**
Hazardous Materials Specialists	**Ron Quesada Jordan Hara Zach Adachi**	**Guy Ha Gary Dahl Jeff Hintson**
Hazardous Material Technicians	**Zach Adachi Jack “Kaliko” Lee Paul Fernandez Guy Ha Alberto Velazquez Mark Nakasato Lyle Olivar Todd Gaskin Joseph Andrade Jose Morales Rey Moreno**	**Gary Dahl Isaac Zervigon Shanon Costa**
Media Coordinator/Spokesperson	**Mike Kaleikini**	
First Responder Awareness Level	**All Personnel**	
Post Emergency Responder	**Ron Quesada Jordan Hara**	**Outside Contractors Environmental Firms**
Safety Official	**Ron Quesada**	

TABLE 3.3.1 PUNA GEOTHERMAL OPERATIONS STAFF RESPONSIBILITIES DURING EMERGENCY SITUATIONS

Should an emergency occur, specific management personnel will assume leadership roles in the emergency response scenario. These key positions and basic responsibilities are as follows:

PLANT AND WELL FIELD OPERATIONS: (No Well Drilling)

MANAGEMENT POSITION	EMERGENCY TITLE
Plant Manager	**Incident Commander**

RESPONSIBILITIES:

- Will oversee broad implementation of the Emergency Plan.
- Will oversee effective and timely communications with Government Agencies, Civil Defense, and other key personnel.
- Assures site personnel are prepared and trained to respond to emergency situations as identified in the plan.
- Reviews assessments of response action and assures modification of plan as necessary.
- Manages the site emergency response activities and related personnel/responders.
- Implements the Emergency Response Plan
- Will assess danger/situation and account for personnel.
- Assures first aid/medical attention is given.
- Will establish command center
- Will assure all non-essential personnel are out of danger zone.
- Coordinates and directs response actions and response personnel.
- Coordinates actions, as applicable, with outside support groups (fire, police, ambulance/medical, cleanup teams etc.)
- Advises VP International Electricity Segment.
- Arranges transportation of personnel.
- Confirms reporting/notifications are implemented timely.
- Directs contractor support
- Assures shut off of all unnecessary electricity, flammable fluid pipes etc.
- Directs removal, control, or relocation of at risks chemicals.
- Directs security forces and assures traffic and property control.
- Arranges removal of equipment, records etc.
- Assures only trained and qualified personnel respond and conduct themselves in accordance with safety and environmental procedures.
- Determines when emergency is under control.
- Arranges and directs additional air monitoring, where pertinent.
- Assesses response actions and modifies procedures as needed.

MANAGEMENT POSITION	EMERGENCY TITLE
Operations & Maintenance Supervisors	**Support to Incident Commander**

- Manage personnel actions within in their departments and Manager assures they follow incident directives.

- Serve as an alternate Incident Commander, if pre-qualified.

Hazardous Material Specialists/Technicians

- Providing ongoing monitoring of local environmental conditions during Task Force operations.
- Providing an initial and ongoing survey for and identification of the presence of hazardous materials at search and rescue sites.
- Implementing defensive mitigation practices when indicated.
- Directing emergency decontamination procedures for any Task Force member or victim.
- Provides assistance to medical personnel for information regarding chemical exposure and injuries.
- Documenting all related information.
- Adhering to all safety procedures.
- Providing accountability, maintenance, and minor repairs for all issued equipment.
- Performing additional tasks or duties as assigned during a mission.
- Ensuring Safety Data Sheets (SDS) are provided for all hazardous materials carried or used by the Task Force; and
- Ensuring all specialized equipment is maintained and calibrated according to the manufacturer’s specifications.

Safety and Environmental Manager

- Assure required government notifications have been made and aid.
- Conduct response actions as directed by IC.
- Assist incident commander.
- Direct actions to mitigate spills or releases of chemicals/hazardous substances.
- Direct decontamination procedures.
- Assists IC with level of response determination.

MANAGEMENT POSITION EMERGENCY TITLE

Selected Maintenance **First Responders**

- Follow the emergency plan as trained.

Operations Personnel **Operations Level or HazMat. Technicians**

- Follow directives of the IC and Haz Mat Specialist
- Assure all Personal Protection Equipment is inspected prior to use and donned as required.
- Conduct additional monitoring as requested and make initial verbal notifications as plan designates

<u>FOR DRILLING EMERGENCY RESPONSE</u>

During drilling activities, designated Well field personnel will take the required actions as directed by the emergency plan, drilling plans, procedures and as per technical training. The General Manager and Site Manager will assure drilling personnel are informed and trained.

Drilling Site Manager (DSM) -

- Assure response procedures are current and relevant.
- Assure personnel are trained and assigned to response tasks.
- Supervise drilling response.
- Coordinate drilling crew response.
- Initiate additional monitoring as appropriate.
- Assure all required notifications are made immediately.
- Assure personnel don appropriate personal protective equipment.
- Inspect wells and related equipment for damage.

Well field Management Consultant

- Coordinate plan activities with Drilling Superintendent.

6.1.3 PLANT PERSONNEL MEDICAL DUTIES

All PGV response team members are trained to provide CPR/AED and basic first aid in a medical emergency up to their level of training while awaiting arrival of emergency medical service (EMS) personnel.

3.4 Notification to Public

GRP Condition #26 (k) requires PGV to outline:

1. "Procedures to be used to identify and inform all residents within applicable distances of the project of the possible emergency situations, warnings, and responses, in advance of commencement of the project, and,"

2. "The methods by which all individuals affected by a given emergency will be notified and evacuated, as necessary."

PGV considers that within the context of this condition that:

1. The applicable distances from the project to be the 3,500 feet from the Project's 500 acres leasehold boundary, as specified in the GRP.

2. Commencement of project operation is considered as the beginning of drilling of the first geothermal well on the site,

3. The CDA will have the responsibility for, and be in charge of, any notification and evacuation of the public arising from emergency conditions existing at the site,

4. This ERP identifies the possible emergency situations, warnings and responses and the methods by which all individuals affected by a given emergency will be notified and evacuated, as necessary, and,

5. Informing all residents within applicable distances of the project of the presence of the ERP constitutes compliance with Condition #26 (k), and,

6. The public will be informed of the presence of the ERP by (1) announcement in the local newspapers, and (2) receipt of written letters to all residents within the applicable distance as noted above.

7. These notification events will occur within one week after the CDA has provided approval of this ERP in advance of commencement of project operation.

3.4.1 Public Notification During Nuisance/Disturbance Situations

PGV, in conformance with conditions of the GRP and the Power Plant and Well Field PTOs, has established a 24-hour information line for use by the public. PGV recognized that, at times, nearby residents may have questions or concerns related to facility activities. In some situations, these conditions could be perceived by the public as potentially related to an emergency condition. In these instances, individuals may call the PGV 24-HOUR INFORMATION LINE. The caller will hear recorded information on current plant activities. If this information is not sufficient the individual may call PGV’s 24-hour response line. The caller will be asked to provide the following information:

1) The general description of the situation, location, and any other relevant information.
2) The caller's name and contact phone number and/or address.

All calls and their respective conversations will be logged. The PGV person-in-charge will be immediately notified of an inquiry or complaint that could be related to a facility emergency. Corrective actions, if any, will be taken to appropriately rectify any condition which is in violation of the GRP or NSP conditions or could potentially magnify into an emergency.
Table 3-3 identifies the response PGV will take to deal with requests for information and complaints when they come from the public either in writing or over the 24-hour response line.

PGV will not contact CDA when a complaint is received unless there is a potential emergency condition at the site.

4.0 Response Facilities

4.1 Emergency Facilities Available Off-Site

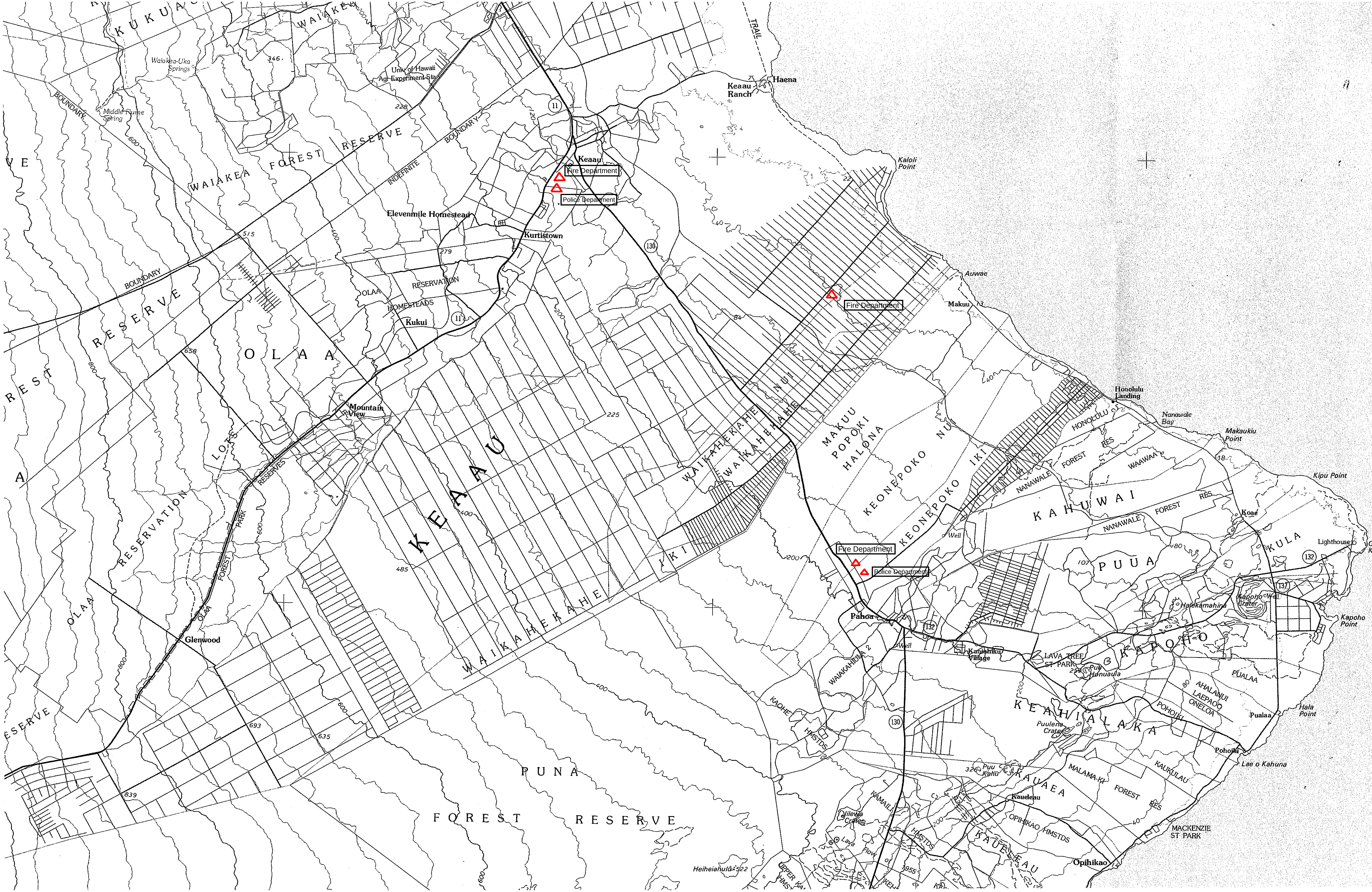
Figure 4-1 shows the location of facilities available in Pahoa, Keaau, and Hilo that can respond during on-site or off-site emergencies. Table 4-1 lists the emergency response and medical facilities that could reasonably be expected to provide support if a facility emergency arose.

4.2 On-Site Safety Facilities

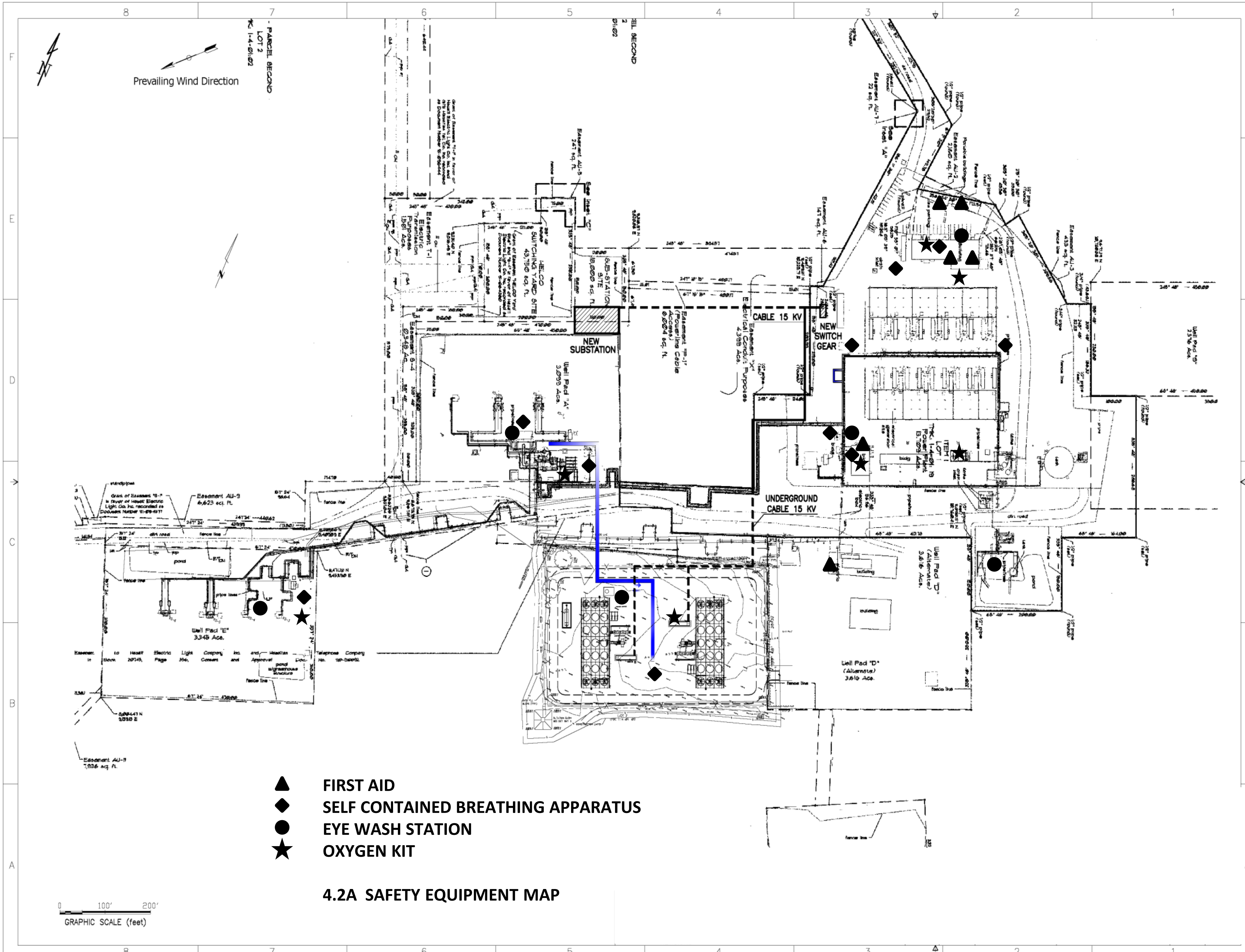
Figures 4-2 and 4-3 show the power plant and wellpad potential hazard areas, respectively. Locations of on-site safety equipment relative to the hazard areas are clearly marked. All response and safety facilities have been located so as to be close to the potential hazard area yet isolated from the immediate impact of the hazard during a facility emergency situation (such as placing air packs in elevated areas where H_2S would not collect). Table 4-2 lists the types and numbers of safety and first aid equipment located in the wellpad, power plant and staging areas of the project. Table 4-3 lists the on-site hydrogen sulfide detection equipment. More detailed descriptions of the on-site safety equipment are presented in Appendix A.

4.3 On-Site Meeting Points

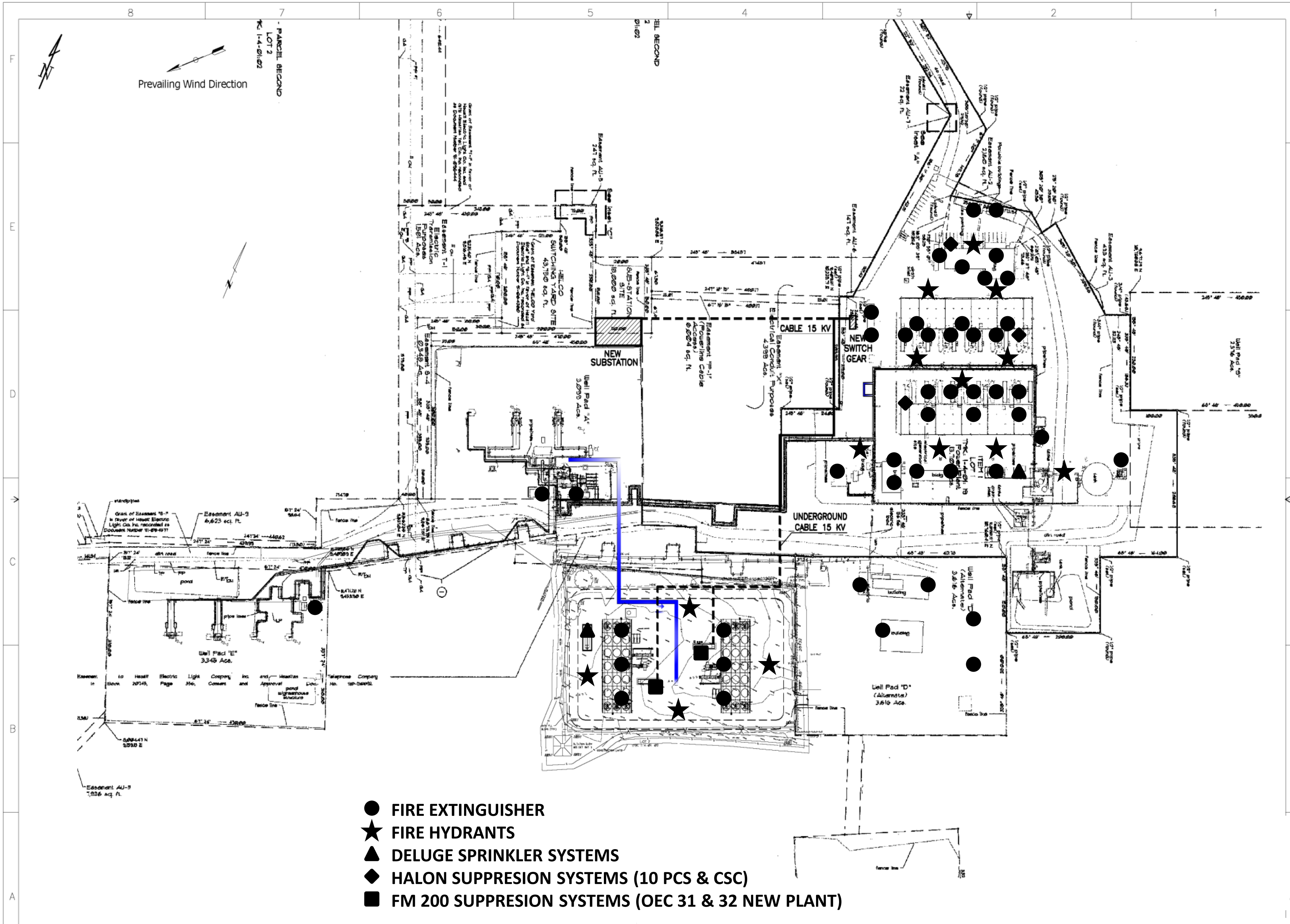
On-site meeting points are described in Section 5.1 and shown in Figure 5-1. The primary on-site meeting place will be the control building. This site is located upwind from well field and power plant operations under prevailing wind conditions. The control building will contain primary communications equipment (telephones, radio base station, etc.) and other emergency equipment along with the plant process controls. These factors make it the logical meeting area. If the control building cannot be used for any reason, site personnel will proceed along the emergency route entrance guard shack through the entrance road. If this area is inaccessible or unsafe, site personnel will proceed by way of alternate emergency route to the clearing at the intersection of Kapoho and Pohoiki Roads.



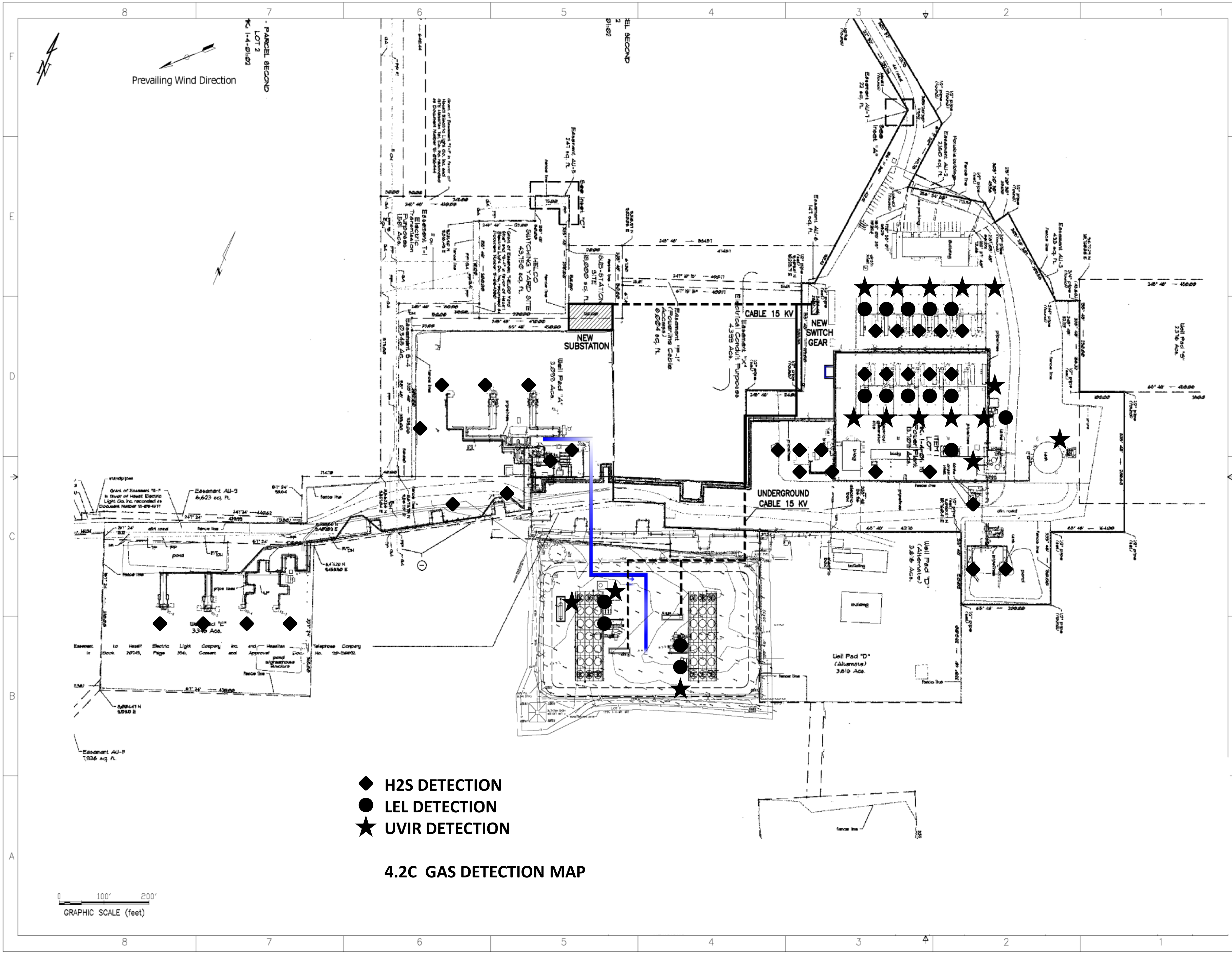
KUKUAU
WAIAKEA
TRAIL
Waiakea-Uka Springs
Univ of Hawaii Ag Experiment Sta
Middle Flume Spring
Keaau Ranch
Haena
BOUNDARY
WAIAKEA FOREST RESERVE
INDEFINITE BOUNDARY
Keaau
Fire Department
Police Department
Kaloli Point
Elevenmile Homestead
Kurtistown
OLAA RESERVATION HOMESTEADS
Kukui
Auwae
Makuu
Fire Department
RESERVE
OLAA
Mountain View
KEAAU
WAIKAHEKAHE NUI
WAIKAHEKAHE
MAKUU
POPOKI
HALONA
KEONEPOKO NUI
KEONEPOKO IKI
Honolulu Landing
Nanawale Bay
Makaukiu Point
HONOLULU FOREST RES
WAAWAA
NANAWALE FOREST RES
Kipu Point
KAHUWAI
NANAWALE FOREST RES
Koae
LOTS RESERVES
RESERVATION
FOREST PARK
OLAA
Fire Department
Police Department
Well
KULA
Lighthouse
Cape Kum
PUUA
IKI
WAIKAHEKAHE
Pahoa
Kapoho Crater
Kapoho Point
Halekamahina
KAPOHO
Glenwood
Kaniahiku Village
Well
WAIAKAHIULA 2
LAVA TREE ST PARK
Puu Hanuaula
PUALAA
AHALANUI
LAEPAOO
ONELOA
Hala Point
Pualaa
KAOHE
HMSTDS
Puulena Crater
KEAHIALAKA
POHOIKI
Pohoiki
Lae o Kahuna
PUNA
Puu Kahu
KAUAEA
MALAMA-KI FOREST RES
KAUKULAU
Kaueleau
KAMAILI
FOREST RESERVE
Ilewa Crater
HMSTDS
OPIHIKAO HMSTDS
KAUELEAU
MACKENZIE ST PARK
Lava Flow
Heiheiahulu
Opihikao



4.2A SAFETY EQUIPMENT MAP



4.2B FIRE SYSTEM MAP



4.2C GAS DETECTION MAP

SAFE BRIEFING AREAS

In the event that the CSC siren sounds, evacuate the area and proceed to 1 of the 3 safe briefing areas.

NOTE: If you detect a hazardous release notify CSC, identify the wind direction and evacuate crosswind and upwind towards 1 of 3 safe briefing areas.

1. Outside of Admin 1

2. Guard Shack Lay Down Yard

3. HWY 132 Lava Tree Triangle

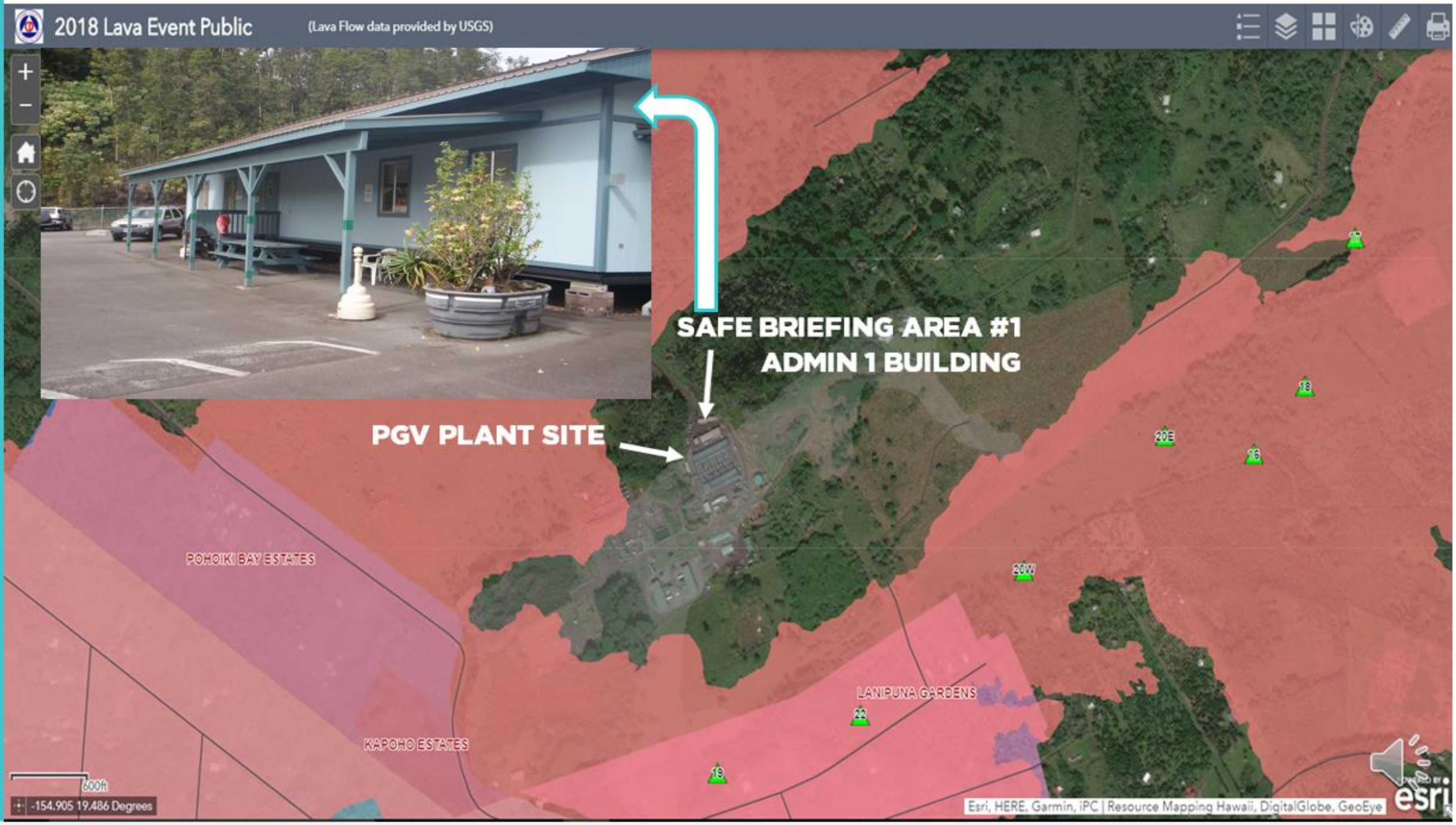
Wait there until you receive further instructions. Do not leave the area until you have been accounted for and have been granted permission to leave by the emergency coordinator or authorized PGV personnel.

NOTE: Remember all safe briefing areas are dependent on wind direction.

PUNA GEOTHERMAL VENTURE
An ORMAT Company

ORMAT

SAFE BRIEFING AREA #1 – ADMIN 1

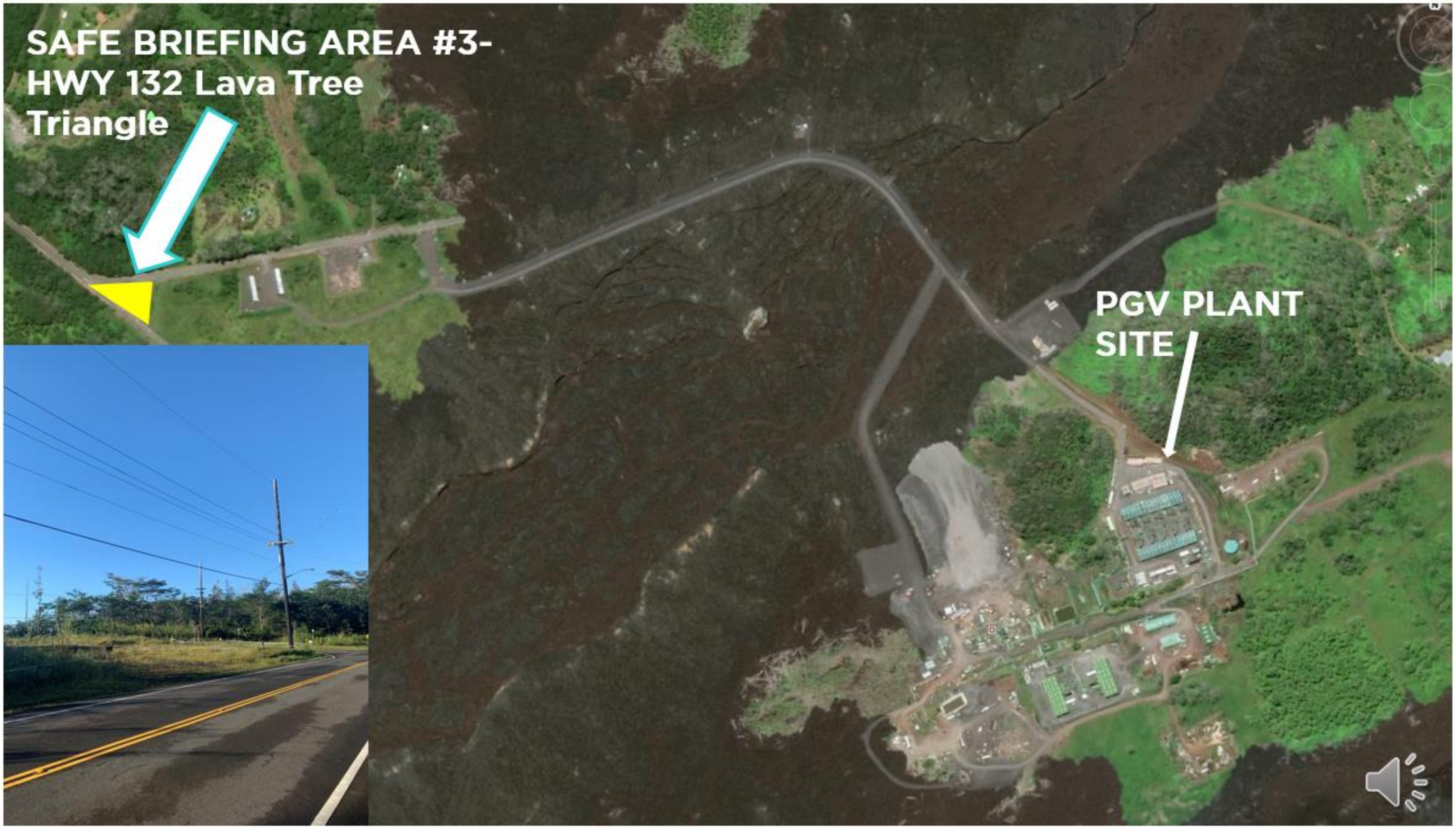


ORMAT

SAFE BRIEFING AREA #2-Guard Shack Entrance

ORMAT

SAFE BRIEFING AREA #3 – HWY 132 Lava Tree Triangle



5.0 PGV EVACUATION PLAN

This section outlines what will be done to prepare for and implement the evacuation of people from the site and the surrounding area, as necessary, and equipment from the site, if an evacuation is necessary.

5.1 Evacuation of Persons On-site

The following are the on-site features which will be in place in preparation for evacuating persons that are on site at the time that an evacuation is required from the site:

- *PGV Chain-of-Command*:
  The PGV chain-of-command (Chapter 3) will be implemented when an emergency response condition exists at the site.

- *On-site Warning*:
  A loud siren is located on top of the Control Building. This siren alarm will sound continuously in the event that a facility emergency situation exists requiring evacuation of the site. The alarm will be turned off after all personnel are accounted for and control measures have been initiated.

- *On-site meeting points (see Figure 5-1)*:
  In the event of a facility emergency at the site requiring evacuation, all on-site PGV, staff, contractor, personnel, and visitors, except those designated to deal with an emergency response at the site, are to proceed to one of three possible meeting points. The first response meeting point will be in front of Admin I. If that site has been compromised, the second meeting point will be at the entrance area on the Pahoa-Kapoho Road HWY 132, the third meeting point will be, the lava tree triangle.

- ***On-site Personnel:***
  All personnel entering the site are logged in by the security guard, lead operator, or the automated security access system. In an emergency, these logs will allow head counts to determine if all personnel have been accounted for.

- ***Evacuation Routes:***
  Primary and secondary evacuation routes from the active wellpad and the power plant will be posted and clearly marked. There are two main entries into the site (Figure 5-1). These routes will be clearly marked as the primary evacuation routes away from the power plant and wellpad areas. The two secondary alternative evacuation routes will be marked from both the wellpad and the power plant according to the road access on the site.

- ***<u>Orientation of PGV, Contractor Staff, and Other On-site Persons</u>:***
  All persons entering the site will be given an orientation regarding safety at the site, and the location of facility emergency response evacuation routes and meeting points.

- ***<u>Site Command Post</u>:***
  A command post will be established at one of the designated meeting areas to deal with a facility emergency. Additional details related to the command post are in Section 8.

5.2 Evacuation of Nearby Residents

The Civil Defense Agency (CDA) has the responsibility of providing the warning to, and to affect the implementation of, the evacuation of any residents or other members of the public from the appropriate hazard area surrounding the site, as necessary. Warning to these residences is also provided by the CDA. PGV will provide assistance if directed by the CDA. PGV anticipates no project created situation which would not provide sufficient time for the CDA to warn or evacuate the public, as appropriate.

PGV has prepared for, and submitted to, the Hawaii County Planning Department, a map showing residences located within 3,500 feet of the project boundary as specified by the Geothermal Resource Permit. PGV has updated this map and previously submitted a copy to CDA.

5.3 Removal of Equipment

Should any of the natural hazards discussed in Section 8.1 threaten project facilities, PGV may elect to remove portable construction and drilling rig equipment or other critical equipment from the project site, providing adequate time exists for this to be done without endangering the health or safety of staff undertaking the actions. In general, the equipment to be removed and the procedures to be used will be like those presented in Table 5-1.

TABLE 5-1 EQUIPMENT REMOVAL ACTIVITIES AND PROCEDURES

<u>During Well Drilling</u>

- Place 100 foot cement plug at bottom of well casing, remove drill pipe and laydown.
- Shut-in Blow-Out Preventer (BOP), including master valve.
- Evacuate all mobile and portable equipment (drill pipe, trailers, air compressor, mud logging trailer, etc.).
- Remove BOP and install blind flange on wellhead valve.
- Fill well cellar with cinders.
- Laydown rig, remove engine-generators, Silicon Control Rectifier (SCR) unit, tool shed and mud house.
- Disassemble and remove mast and sub-structure, mud tanks, fuel tanks, tracking system and other rig equipment from site.

During Plant Construction or Operation

WELLPADS

- Shut off well flow by closing the electro-pneumatic control valve that supplies geothermal fluid to the wellpad separator.

- Close the manual upper and lower master valves on production wells KS-14, KS-17, KS-18, and KS-19 and injection wells KS1A, KS3, KS-11, KS-13, KS-15, KS-20 and KS-21.

- Remove pipes around the wellhead.

- Disassemble wellhead down to the top of the upper master valve.

- Place a blind flange on top of the master valve.

- Fill the well cellar with cinders to the surface.

POWER PLANT

- Remove all other portable and construction equipment as time permits.

- Drain tanks holding chemicals into chemical tanker trucks (one tanker per caustic tank) and remove from site.

- If access to the site is cut off or if there is insufficient time to complete removal of caustic, drain tanks into ESRF pit and fill tanks with water to prevent vaporization of residue caustic solution.

In case of a lava threat to the power plant, drain all pentane from Ormat Energy Converters (OECs) units 11-15 and 21-25 and Bottoming Unit OEC's 31 and 32 to their designated pentane storage tanks. If deemed necessary, remove pentane from C storage tank and into portable tankers and locate them to the upper power plant. If there is a lava threat to the upper plant, remove pentane from A and B storage tanks and into portable tankers and remove all portable tankers from site to a designated safe area.

6.0 PGV PERSONNEL TRAINING

PGV personnel and subcontractors will be trained and educated on the relevant elements of the facility emergency response plan and on emergency equipment and related procedures. During any shift, there will be at least three PGV employees on-site familiar with the facility emergency plans and the use of the emergency rescue equipment (i.e., Self-Contained Breathing Apparatus (SCBA), fire extinguisher, etc.) and trained to administer first aid in case of injuries.

All contractors at the site have the responsibility to ensure that their staff has had adequate training and orientation related to the safety and potential hazards associated with conditions and potential conditions at the site. PGV will provide all site contractors with a copy of the Emergency Action Plan for their own use in orientation and training of their staff. PGV will consult with contractors/consultants to assure they are familiar with emergency response and evacuation procedures.

6.1 Drilling

There will be at least three (3) persons fully trained in the handling of hydrogen sulfide (H_2S) emergencies during each shift of drilling work.

6.1.1 H_2S Safety Training

All drilling staff and contractor personnel are required to be trained and knowledgeable in H_2S hazards and emergency response action. H_2S safety training will be provided, if they are not currently trained and certified, to PGV drilling staff and drilling contractor personnel prior to the start of drilling operations. All Plant operators and maintenance personnel will be trained, and the training will be administered by a certified H_2S safety instructor. The course content is described in Appendix B. The course will cover the following topics:

- DESCRIPTION OF H_2S SOURCES DURING DRILLING OPERATIONS
- PHYSIOLOGY OF H_2S TOXICITY
- USE OF DETECTION EQUIPMENT
- USE OF BREATHING APPARATUS
- EMERGENCY PROCEDURES
- FIRST AID FOR H_2S POISONING

In addition, all drilling staff and drilling contractor personnel will be trained in the importance of vertically directing and abating (for H_2S and brine particulates and aerosols) any releases of geothermal steam or brine, and in use of breathing apparatus as personal protection against any ambient brine particulates or aerosols.

6.1.2 H_2S Emergency Response Drills

Unannounced H_2S emergency response drills will be executed monthly during drilling operations. The drilling superintendent, certified in H_2S safety, will administer the drills. The drills will include:

- SIMULATE DRILLING OPERATION SHUT DOWN PROCEDURES
- EVACUATION PROCEDURES
- USE OF SCBA'S
- USE OF DETECTION EQUIPMENT TO IDENTIFY SOURCE
- SIMULATE REMEDIAL ACTIONS TO ELIMINATE SOURCE
- USE OF H_2S AND GEOTHERMAL BRINE PARTICULATE AND AEROSOL ABATEMENT PROCEDURES AND EQUIPMENT

6.1.3 Blowout Prevention Training

Drilling personnel, drilling contractor's tool pushers and drillers will be trained in “well control equipment and procedures.” The course content is shown in Appendix C. The training will include the following main topics:

- DESCRIPTION OF TYPES OF WELL CONTROL LOSS
- EARLY DETECTION OF INCIPIENT LOSS OF WELL CONTROL
- WELL CONTROL EQUIPMENT
- WELL CONTROL PROCEDURES
- TRAINING USING WELL CONTROL SIMULATOR

In addition, all drilling staff and drilling contractor personnel will be trained in the importance of vertically directing and abating (for H_2S and brine particulates and aerosols) any releases of geothermal steam or brine.

6.2 Blowout Emergency Response Drill (Drilling Operations Only)

A function test of hydril and pipe ram blow out prevention (BOP) equipment in use on the rig will be performed on a daily basis during drilling operations. A function test for blind rams will be executed during trips with drill pipe out of hole.

The drilling superintendent, certified in well control, will administer monthly blow out prevention and well control drills. These drills will consist of:

- IDENTIFICATION OF INCIPIENT BLOW OUT INDICATORS
- EMERGENCY DRILLING OPERATIONS IN PREPARATION FOR OPERATION OF BLOW OUT PREVENTION EQUIPMENT
- OPERATION OF BLOW OUT PREVENTION EQUIPMENT
- SIMULATION OF PROCEDURES TO KILL WELL
- USE OF H_2S AND GEOTHERMAL BRINE PARTICULATE AND AEROSOL ABATEMENT PROCEDURES AND EQUIPMENT
- AT LEAST ONE PERSON ON EACH SHIFT WILL BE TRAINED TO ADMINISTER FIRST AID IN CASE OF INJURIES.

6.3 Power Plant Construction

During any power plant construction or modification activities, there will be at least three (3) persons on-site that are trained to respond to H_2S releases.

During a facility emergency requiring on-site evacuation, a siren (one located at drill rig and one at the power plant staging area) will sound. Employees will be evacuated to the meeting point. Once at the meeting point, the situation will be assessed by trained supervising personnel. If the situation worsens, all non-essential personnel will be sent out of the area and only authorized, trained personnel will remain.

6.4 Power Plant Operation

During each shift of plant operations, there are at least three (3) people fully trained in handling hydrogen sulfide emergencies. A power plant personnel will be trained on the Emergency Response Plan. Additionally, plant personnel assigned to the Emergency Response Team will be trained in the use of all required personnel protection equipment and procedures. Plant Operators and Maintenance personnel will be trained on fire system and monitoring equipment as well as appropriate First Aid and CPR training.

7.0 PGV EMERGENCY DRILL

In addition to the H_2S emergency response and blowout emergency response drills described in Chapter 6, the facility operations and maintenance personnel will participate in a general drill at least semi-annually to respond to emergency situations. More frequent drills will be conducted where observations of the semi-annual drill response activities indicate a need. Drills will focus on response to all possible scenarios as outlined in this plan.

8.0 PGV HAZARD ANALYSIS AND PGV RESPONSE PROCEDURES TO POTENTIAL EMERGENCY SITUATIONS

The purpose of this section is to evaluate the hazards which could occur or develop at the project site and could cause an emergency response to be taken at the site and to generally describe PGV's planned responses. These are presented in three parts. The first part (8.0) discusses the 9 natural hazards that could affect the PGV project site. The second part (9.0) describes potential hazards which could arise from upset conditions at the site. The third (10) are special upset conditions which could arise from site equipment malfunction or power grid interruptions.

PUNA GEOTHERMAL VENTURE

An ORMAT Company

NATURAL HAZARDS

8. 1 Natural Hazards

Notification:

The Hawaii Volcano Observatory (HVO) or the CDA will commonly notify the public, including PGV, that these types of hazards threaten the general area where the PGV facility is located. Immediate verbal notifications will be made by PGV to the appropriate agencies, as applicable, and as per the PGV Notification Guidelines.

PGV General Response:

Once notified that a natural hazard situation may affect or has affected the site, PGV will:

1. Turn on a battery-powered radio to listen for Emergency Broadcast Systems (EBS) announcements.
2. Notify the CDA (Table 3-1) immediately should the situation cause a facility emergency situation that could threaten public health and safety.
3. Establish a Command Post at the site.
4. Implement the Chain-of-Command (Table 3-2) including verification of the status of all on-site persons.
5. Implement the Evacuation Plan (Chapter 5), as appropriate.
6. Take the appropriate follow-up actions that are listed in detail in the following sections.

Reporting:

All reporting related to emergencies created by these types of hazards will be done as soon as possible during the emergency and afterwards according to the Post Emergency Response Procedure presented in Appendix D.

8.1.1 Volcanic Activity

Nature of Hazard:

Volcanic activity on the Big Island of Hawaii has been severe enough to have caused the loss of life and property damage due to lava flows. The majority of Hawaiian volcanic eruptions are gentle with the lava moving no more than several miles per day. There is generally adequate time for warnings of impending or actual eruptions to allow time to evacuate both people and equipment.

Potential dangers at the PGV site in the event of lava flow are explosion and fire, principally at the OEC units, pentane and diesel storage tanks, power rooms and substation areas. Refer to Section 9.2.2 for the discussion on the hazard from fire and explosion. As discussed in Section 5.3, PGV believes that essentially all of the drilling equipment (if on-site) could be removed from the site if this type of threat developed, and that any producing or drilling wells could be suspended to eliminate the possibility of any release of H_2S from a well during lava flow. However, Section 9.2. discusses the hazard from uncontrolled releases of steam should this occur.

Response Actions:

Upon notification or determination, PGV will take the following actions, as appropriate, supplemental to those listed at the beginning of Section 8.1:

1. Prepare to cease all activities at the project site.
2. Notify the CDA (Table 3-1) immediately should the volcanic activity cause a facility emergency situation that could threaten public health and safety.
3. Alert service suppliers (Appendix E) to assist with removal of supplies and equipment.
4. Shut down all facilities and secure all wells as per Chapter 5.
5. Remove equipment and materials as time permits and the situation allows, as per Chapter 5.3.
6. Await instructions from CDA.
7. Make other required notifications.

If a determination is made that there is an imminent threat to the facility, PGV will independently take the actions needed to complete the evacuation of personnel and, if time permits, to remove equipment and fluids according to the list in Chapter 5, Table 5-0.

8.1.2 Magma Intrusion

Nature of Hazard:

Magma intrusion in the immediate vicinity of the site (within 1/2 mile) could result in a well on the property acting as a conduit for lava to flow to the surface at the project site. Were this to occur, and lava flowed through the well to the surface, the hazard would be similar to the discussion under Section 8.1.1 regarding lava flows.

Response Actions:

Upon notification or determination, PGV will take the following actions, as appropriate, supplemental to those listed at the beginning of Section 8.1 to prevent any magma from entering the wellbore:

1. Determine the availability of service personnel and equipment and request stand-by of same (Appendix E).
2. Notify the CDA (Table 3-1) immediately should the magma intrusion cause a facility emergency that could threaten public health and safety.
3. Notify the State Department of Land and Natural Resources (DLNR) and Hawaii County Planning Department (Table 3-1) regarding the status of the geothermal wells.
4. Monitor the geothermal fluid pH at intervals recommended by Resource Consultant on the basis of proximity of the intrusion to the PGV wells.
5. If the fluid is being impacted by volcanic gases, drilling or power generation will be terminated.
6. Shut-in all wells immediately.
7. Inject water into the well within 48 hours of the shut-in pressure in the well declining to less than atmospheric pressure.
8. Await instructions from CDA and DLNR.
9. Make other required verbal notifications to regulatory agencies (Hawaii County, State of Hawaii and Environmental Protection Agency).

If no evidence of fluid acidification is evident, sampling will be terminated, and the facility would resume normal operations once the emergency condition had been withdrawn by the responsible agencies.

If a determination is made that there is an imminent threat to the facility, PGV will independently take the actions needed to complete the evacuation of personnel and, if time permits, to remove equipment and fluids according to the list in Chapter 5, Table 5-0.

8.1.2.1 Lava Interruption

<u>Nature of Hazard</u>:

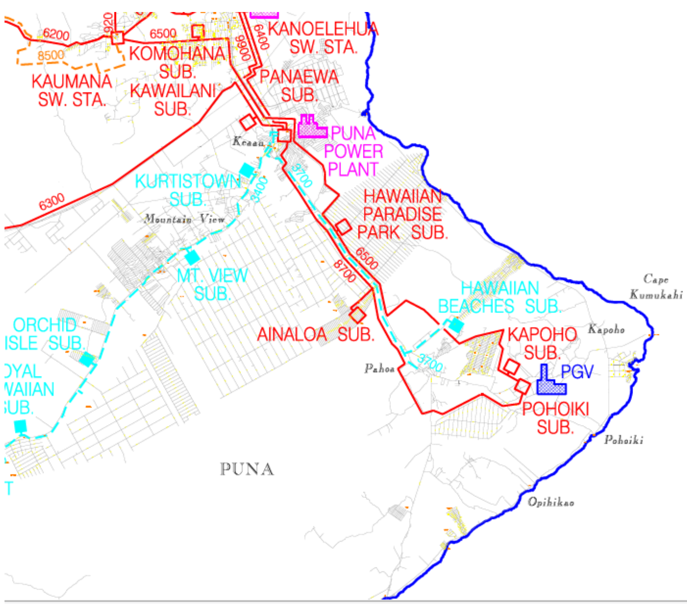
Lava interruption to electrical transmission lines 8700 and 6500 can effect power plant operation. The majority of Hawaiian volcanic eruptions are gentle with the lava moving no more than several miles per day. There is generally adequate time for warnings of impending threat to transmission lines to allow time to safely shutdown plant operation and evacuate personnel and to remove equipment according to the list in Chapter 5, Table 5-0.

<u>System Description:</u>

Highway 130 provides a road connection between PGV and upper Puna. Electrical transmission lines 8700 and 6500 are located on each side of HWY 130, each line is critical to transmit PGV power to the HELCO grid.

The PGV electrical transmission consists of the following components:

- PGV Switchyard
- Pohoiki substation
- Kapoho substation
- 8700 transmission line
- 6500 transmission line



Response Actions:

Upon notification or determination, PGV will take the following appropriate actions in the event lava interruption is imminent, supplemental to those listed at the beginning of Section 8.1:

Loss of Transmission Lines

1. If one transmission line is lost or removed from service due to lava interruption, contact the HELCO/System dispatcher for status of the grid.
    a. Reduce Main Steam Pressure (MSP) to 120psi approximately 5-7 MW.
    b. If HELCO/System is working on putting the line back in service, continue plant status.
        i. Contact HELCO/System dispatch every 30 minutes for line status.
    c. If HELCO/System is UNABLE to work on returning the line back into service and lava continues to flow to second transmission line, a controlled shutdown of the plant in coordination with HELCO/System will be performed.

Controlled Plant Shutdown

NOTE: If possible, the following steps will be done prior to losing plant operation.

1. Prepare to cease all activities at the project site.
2. Notify the CDA (Table 3-1) immediately should the volcanic activity cause a facility emergency situation that could threaten public health and safety.
3. Alert service suppliers (Appendix E) to assist with removal of supplies and equipment.
4. Shut down all facilities and secure all wells as per Chapter 5.
5. Ensure all production wells are under layup/recirculation per PGV procedures.
6. Maintain communication with CDA and await instruction.
7. Make other required notifications.

8.1.2.1 Lava Interruption

Nature of Hazard:

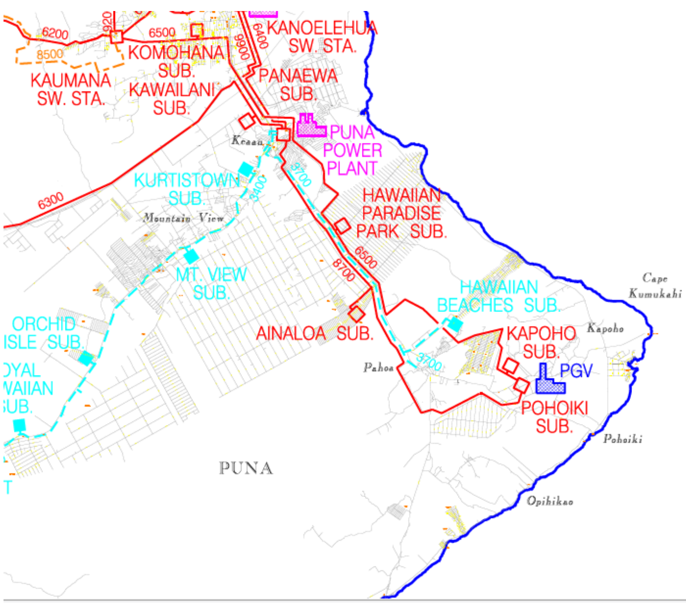
Lava interruption to electrical transmission lines 8700 and 6500 can effect power plant operation. The majority of Hawaiian volcanic eruptions are gentle with the lava moving no more than several miles per day. There is generally adequate time for warnings of impending or actual eruptions to allow time to evacuate both people and equipment.

System Description:

Highway 130 provides a road connection between PGV and upper Puna. Electrical transmission lines 8700 and 6500 are located on each side of HWY 130, each line is critical to transmit PGV power to the HELCO grid. This plan will provide guidelines on manning and maintaining the power plant, layup of the plant and receiving consumables if vehicle access and electrical transmission are lost.

The PGV electrical transmission consists of the following components:

- PGV Switchyard
- Pohoiki substation
- Kapoho substation
- 8700 transmission line
- 6500 transmission line



Response Actions:

Upon notification or determination, PGV will take the following appropriate actions in the event lava interruption is eminent, supplemental to those listed at the beginning of Section 8.1:

Loss of Transmission Lines

- If one transmission line is lost, contact the HELCO/System dispatcher for status of the grid.
    a. If HELCO/System is working on putting the line back in service, continue idling at 120 psi MSP approximately 5-7MW.
        i. Contact HELCO/System dispatch every 30 minutes for line status
    b. If HELCO/System is UNABLE to work on returning the line back into service and lava continues to flow to second transmission line, a controlled shutdown of the plant in coordination with HELCO/System will be performed.
        i. Start water well 10-P-5 with portable diesel generator to maintain water supply for bleeds.
- Ensure all production wells are under layup/recirculation per PGV procedures.

Lava Intrusion Near Plant

Controlled Plant Shutdown

NOTE: If possible, the following steps will be done prior to losing plant operation.

1. Prepare to cease all activities at the project site.
2. Notify the CDA (Table 3-1) immediately should the volcanic activity cause a facility emergency that could threaten public health and safety.
3. Alert service suppliers (Appendix E) to assist with removal of supplies and equipment.
4. Shut down all facilities and secure all wells as per Chapter 5.
5. Ensure all production wells are under layup/recirculation per PGV procedures.
6. Maintain communication with CDA and await instruction.
7. Make other required notifications

If a determination is made that there is an imminent threat to the facility, PGV will independently take the actions needed to complete the evacuation of personnel and, if time permits, to remove equipment according to the list in Chapter 5, Table 5-

<u>PGV PLANT USE ONLY</u>

SHUTDOWN OF PGV POWER PLANT:

- Follow written Operation Procedure OP-15 Plant Startup and Shutdown.

PROCESS CLEARANCE OF POWER PLANT

- **NOTE: <u>Secure OEC's with air seals first and ensure they switch over to H/R mode. When securing the OEC's without the air seals, isolate the main steam stop first and let the unit trip on their own, then go to off in CSC. By letting the OEC trip on its own, it will process steam and gas through the unit with little residual.</u>**
- **STEAM HEADER-**Open bypasses on #1 #2 #21, #24 and #25 steam traps and open 2" gate valve on steam trap header to KS- 11 injection header (located south of KS10 separator). This process will be slow, it will take a couple of hours. Back up will be the newly installed cross-connect between the old venturi line to Sulfatreat.
- **OEC-**We have no planned maintenance scheduled during this outage, but we need to drain all accumulated water in the unit.
- **NCG-**Purge both NCG #1 and #2 to Sulfatreat.
- **CONDENSATE HEADER-**Place Raw water pump in service if not in service already, open 2" ball valve and 2" globe valve at end of upper plant CPR, located in front of OEC# 25. Flush throughout the night.
- **KS11 SEPERATOR-**When using raw water to flush the condensate header, back flush the separator by manually closing 1117 to fill and dump the separator to KS-13.
- **KS9 and KS10 SEPERATOR-**Open both 4" gate valves in back of separators and dump to KS11 injection header.
    - **NOTE: This fluid will be hot, so this will take some time**.
- **BRINE INJECTION PUMPS-**When raw water is flushing the condensate header, leave open inlet and outlet valves to the BIP's for flushing to injection.

PRODUCTION WELLS:

Prior to the lava intrusion of HWY 130 and if all options are not feasible, production wells will be routed to injection wells to maintain a minimal flow or placed on a nitrogen layup per operations procedure. These production well layups will be monitored four times a day and as needed.

<u>PRODUCTION WELL BLEEDS:</u>

WELLPAD E

- KS-14 bleed to KS-20
- KS-18 bleed to KS-20
- ALTERNATE BLEED will be to KS-3/ may need to bleed to multiple wells

WELLPAD A

- KS-18- bleed to KS-20
- ALTERNATE BLEED- May need to bleed to multiple wells

VEHICLE ACCESS TO PGV:

First Option: Access Road from Nanawale through Hawaiian Beaches to Hawaiian Paradise Park.

Second Option: Beach Road and or Railroad can be resurfaced to allow access for lower Puna residence if needed. This access will be used by PGV employees for transportation to the plant. This may not be an option if the lava flow continues its path to the ocean.

Third Option: Fly employees into the plant via helicopter, this will not be a daily commute and will be for essential personnel only.

EMPLOYEE STAFFING:

Operations will be working 12 hour shifts 7 days on 7 days off, mechanics will be working 8 hour days and on call daily for 7 days on 7 days off, admin will rotate weekly. PGV will provide living accommodations and transportation to and from the plant if your commute to your home in inaccessible.

Week 1 on shift:

Operations: Crew A and B
Mechanics: Mechanic 1 and 2
Wellfield: Tech 1
EI&C: Tech 1
Admin: Tech 1
Management: TBD

Week 2 on shift:

Operations: Crew C and D
Mechanics: Mechanic 3 and 4
Wellfield: Tech 2
EI&C: Tech 2
Admin: Tech 2
Management: TBD

PLANT CONSUMABLES:

Liquid nitrogen
Oils

Sulfuric Acid
Diesel
Gas
Equipment parts
Employee consumables

If roads are inaccessible to PGV, plans will be made to fly these consumables in via helicopter.

OEC 31 and 32 Pentane De-inventory

Due to the elevation of the bottoming units and the unpredictability of lava flow, PGV will take steps to de-inventory pentane from OEC 31 and 32 (approximately 12,000 gallons each) if needed. Both units will be secured and all pentane will be transferred to the upper plant storage tanks. Both storage tanks hold 9000 gallon each and will be maximized to 90% capacity (8100 gallons). Three Oec's in the upper plant will be secured and used as storage.

Wellfield Preparation

Base coarse rock will be used to fill production and reinjection well cellars to recover future wellhead access.

8.1.2.1 Lava Intrusion

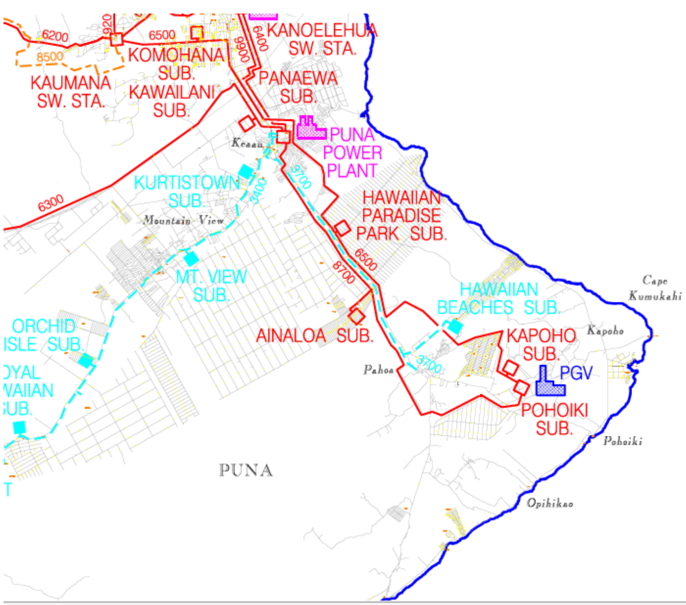
PGV LAVA INTRUSION PROCEDURES

PURPOSE
Provide a contingency plan if lava affects transmission lines or plant operation.

SYSTEM DESCRIPTION
Highway 130 provides a road connection between PGV and upper Puna. Electrical transmission lines 8700 and 6500 are located on each side of HWY 130, each line is critical to transmit PGV power to the HELCO grid. This plan will provide guidelines on manning and maintaining the power plant, layup of the plant and receiving consumables if vehicle access and electrical transmission are lost.

The PGV electrical transmission consists of the following components:

- PGV Switchyard
- Pohoiki substation
- Kapoho substation
- 8700 transmission line
- 6500 transmission line



Loss of Transmission Lines

1. If one transmission line is lost, contact the HELCO/System dispatcher for status of the grid.
    a. If HELCO/System is working on putting the line back in service, continue idling at 120 psi MSP approximately 5-7MW.
        i. Contact HELCO/System dispatch every 30 minutes for line status
    b. If HELCO/System is UNABLE to work on returning the line back into service and lava continues to flow to second transmission line, a controlled shutdown of the plant in coordination with HELCO/System will be performed.
        i. Start water well 10-P-5 with portable diesel generator to maintain water supply for bleeds.
2. Ensure all production wells are under layup/recirculation per PGV procedures.

Lava Intrusion Near Plant

NOTE: If possible, the following steps will be done prior to losing plant operation.

Controlled Plant Shutdown

1. Prepare to cease all activities at the project site.
2. Notify the CDA (Table 3-1) immediately should the volcanic activity cause a facility emergency that could threaten public health and safety.
3. Alert service suppliers (Appendix E) to assist with removal of supplies and equipment.
4. Shut down all facilities and secure all wells as per Chapter 5.
5. Remove equipment and materials as time permits and the situation allows, as per Chapter 5.3.
6. Secure wellfield and power blocks.
7. Ensure all production wells are under layup/recirculation per PGV procedures.
8. Maintain communication with CDA and await instruction.
9. Make other required notifications

If a determination is made that there is an imminent threat to the facility, PGV will independently take the actions needed to complete the evacuation of personnel and, if time permits, to remove equipment according to the list in Chapter 5, Table 5-0.

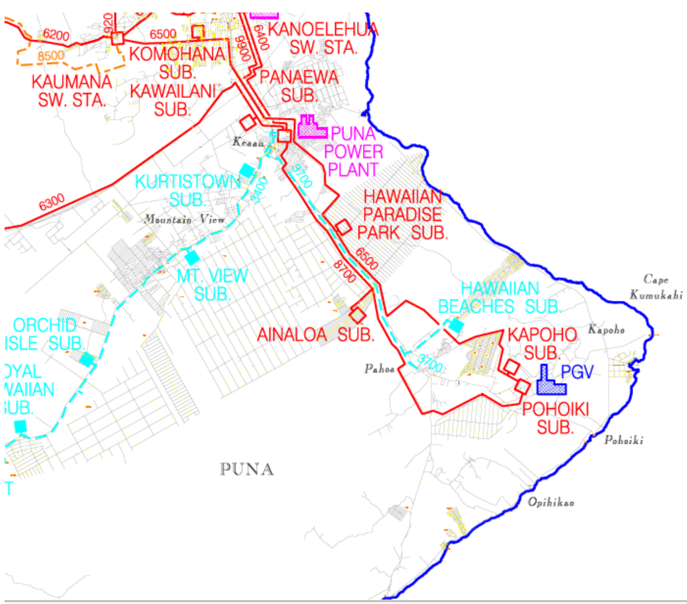
8.1.2.2 PGV LAVA INTRUSION PROCEDURES

PURPOSE
Provide a contingency plan in the event that lava affects transmission lines or plant operation.

SYSTEM DESCRIPTION
Highway 130 provides a road connection between PGV and upper Puna. Electrical transmission lines 8700 and 6500 are located on each side of HWY 130, each line is critical to transmit PGV power to the HELCO grid. This plan will provide guidelines on manning and maintaining the power plant, layup of the plant and receiving consumables if vehicle access and electrical transmission are lost.

The PGV electrical transmission consists of the following components:

- PGV Switchyard
- Pohoiki substation
- Kapoho substation
- 8700 transmission line
- 6500 transmission line



Scenario #1
Loss of Transmission Lines

1. If one transmission line is lost, contact the HELCO/System dispatcher for status of the grid.
   a. If HELCO/System is working on putting the line back in service, continue idling at 120 psi MSP approximately 5-7MW.
      i. Contact HELCO/System dispatch every 30 minutes for line status
   b. If HELCO/System is UNABLE to work on returning the line back into service and lava continues to flow to second transmission line, a controlled shutdown of the plant in coordination with HELCO/System will be performed.
      i. Start water well 10-P-5 with portable diesel generator to maintain water supply for bleeds.
2. Ensure all production wells are under layup/recirculation per PGV procedures.

Scenario # 2
LAVA INTRUSION NEAR PLANT:

NOTE: If possible, the following steps will be done prior to losing plant operation.

Controlled Plant Shutdown

1. Notify the Civil Defense Agency (CDA) per PGV notification procedures immediately should the lava flow cause a facility emergency situation.
2. Start water well 10-P-5 with portable diesel generator to maintain raw water supply for bleeds.
3. Maintain communication(s) with CDA on plant updates and lava intrusion update.
4. Make all other required verbal notifications.
5. Secure wellfield and power blocks.
6. Ensure all production wells are under layup/recirculation per PGV procedures.

PGV PLANT USE ONLY

SHUTDOWN OF PGV POWER PLANT:

- Follow written Operation Procedure OP-15 Plant Startup and Shutdown.

PROCESS CLEARANCE OF POWER PLANT

- **NOTE: Secure OEC's with air seals first and ensure they switch over to H/R mode. When securing the OEC's without the air seals, isolate the main steam stop first and let the unit trip on their own, then go to off in CSC. By letting the OEC trip on its own, it will process steam and gas through the unit with little residual.**
- **STEAM HEADER-**Open bypasses on #1 #2 #21, #24 and #25 steam traps and open 2" gate valve on steam trap header to KS- 11 injection header (located south of KS10 separator). This process will be slow, it will take a couple of hours. Back up will be the newly installed cross-connect between the old venturi line to Sulfatreat.
- **OEC-**We have no planned maintenance scheduled during this outage, but we need to drain all accumulated water in the unit.
- **NCG-**Purge both NCG #1 and #2 to Sulfatreat.
- **CONDENSATE HEADER-**Place Raw water pump in service if not in service already, open 2" ball valve and 2" globe valve at end of upper plant CPR, located in front of OEC# 25. Flush throughout the night.
- **KS11 SEPERATOR-**When using raw water to flush the condensate header, back flush the separator by manually closing 1117 to fill and dump the separator to KS-13.
- **KS9 and KS10 SEPERATOR-**Open both 4" gate valves in back of separators and dump to KS11 injection header.
    - **NOTE: This fluid will be hot, so this will take some time**.
- **BRINE INJECTION PUMPS-**When raw water is flushing the condensate header, leave open inlet and outlet valves to the BIP's for flushing to injection.

PRODUCTION WELLS:

Prior to the lava intrusion of HWY 130 and if all options are not feasible, production wells will be routed to injection wells to maintain a minimal flow or placed on a nitrogen layup per operations procedure. These production well layups will be monitored four times a day and as needed.

PRODUCTION WELL BLEEDS:

WELLPAD E

1. KS-14 bleed to KS-20
2. KS-18 bleed to KS-20
3. ALTERNATE BLEED will be to KS-3/ may need to bleed to multiple wells

WELLPAD A

4. KS-17- bleed to KS-20
5. ALTERNATE BLEED- May need to bleed to multiple wells

VEHICLE ACCESS TO PGV:

First Option: Access Road from Nanawale through Hawaiian Beaches to Hawaiian Paradise Park.

Second Option: Beach Road and or Railroad can be resurfaced to allow access for lower Puna residence if needed. This access will be used by PGV employees for transportation to the plant. This may not be an option if the lava flow continues its path to the ocean.

Third Option: Fly employees into the plant via helicopter, this will not be a daily commute and will be for essential personnel only.

EMPLOYEE STAFFING:

Operations will be working 12 hour shifts 7 days on 7 days off, mechanics will be working 8 hour days and on call daily for 7 days on 7 days off, admin will rotate weekly. PGV will provide living accommodations and transportation to and from the plant if your commute to your home in inaccessible.

Week 1 on shift:
- Operations: Crew A and B
- Mechanics: Mechanic 1 and 2
- Wellfield: Tech 1
- EI&C: Tech 1
- Admin: Tech 1
- Management: TBD

Week 2 on shift:
- Operations: Crew C and D
- Mechanics: Mechanic 3 and 4
- Wellfield: Tech 2
- EI&C: Tech 2
- Admin: Tech 2
- Management: TBD

PLANT CONSUMABLES:

- Liquid nitrogen
- Oils
- Sulfuric Acid
- Diesel
- Gas

Equipment parts
Employee consumables

If roads are inaccessible to PGV, plans will be made to fly these consumables in via helicopter.

OEC 31 and 32 Pentane De-inventory

Due to the elevation of the bottoming units and the unpredictability of lava flow, PGV will take steps to de-inventory pentane from OEC 31 and 32 (approximately 12,000 gallons each) if needed. Both units will be secured and all pentane will be transferred to the upper plant storage tanks. Both storage tanks hold 9000 gallon each and will be maximized to 90% capacity (8100 gallons). Three Oec's in the upper plant will be secured and used as storage.

Wellfield Preparation

Base coarse rock will be used to fill production and reinjection well cellars to recover future wellhead access.

8.1.3 Earthquake

Nature of Hazard:

Earthquakes occur suddenly, without warning, and can cause numerous casualties, severe damage, and loss of public and private property. The actual movement of the ground is less hazardous than partial or total building collapse, falling objects, debris and shattering glass. After shocks are usually smaller than the main quake but may be large enough to cause additional damage to structures weakened during the main shock.

Although by PGV choice, all PGV project facilities are being constructed to the Seismic Zone 4 criteria of the Uniform Building Code, which is more conservative than the required Seismic Zone 3, major earthquakes near the project site could cause buildings and tall structures to collapse (e.g., drilling rig), utility poles to collapse (creating loss of power and/or setting fires), pipeline cracks, breaks above and below ground, and loss of well integrity. Resulting hazards, with a potential to produce situations which could threaten the health, safety, or welfare of the public, are H_2S releases and fire, which are discussed in Sections 8.2.1 and 8.2.2, respectively.

Response Procedures:

Upon notification, or if an earthquake could be felt strongly at the project site, PGV will take the following actions supplemental to those listed at the beginning of Section 8.1:

1. Check for injuries and render first aid as appropriate.
2. Notify the CDA immediately should the earthquake cause a facility emergency that could threaten public health and safety, notify the CDA immediately.
3. Depending on the size of the earthquake, the power plant may be tripped. If so, emergency steam may be released through the rock muffler and abatement of hydrogen sulfide would start simultaneously. Respondents to an emergency will approach the site from an upwind direction and have air rescue packs, resuscitators and monitors as a precaution for failure of the H_2S abatement system. Notify both CDA and HDOH, Clean Air Branch (Table 3-1) if steam is released to emergency steam release facility.
4. Check water and electrical lines.
5. Switch off electrical power if there is damage to power sources or wiring.
6. Check buildings, pipelines and tanks for cracks and damage.
7. Inspect the rig (if applicable) and all wells.
8. Move diesel water pump to any damaged wellpad and notify DLNR (Table 3-1).

9. Request stand-by of well drilling contractors and suppliers (Appendix E).
10. Await instructions from CDA.
11. Make other required verbal notifications.

8.1.4 SEVERE WEATHER SYSTEMS

Nature of Hazards:

Hurricanes (winds of 74 miles per hour or more) and Tropical Storms (winds of 39-73 miles per hour) can cause death, extensive damage to lightly-built buildings and tall structures, uproot trees, snap utility poles, and make destructive missiles of flying debris. However, because of the design and construction of the PGV project, there is little potential for severe weather systems to produce facility emergency situations which could threaten the health, safety, or welfare of the public. Flooding produced by severe weather system rainfall and storm surf generated by high wind should not pose a threat to the project facilities since the project site is on high ground.

PGV General Preparedness:

Once notified that a natural hazard situation may affect or has affected the site, PGV will:

1. Turn on a battery-powered radio to listen for Emergency Broadcast Systems (EBS) announcements.
2. Notify HELCO and CDA immediately should the situation cause a facility emergency situation that could threaten public health and safety.
3. Establish a Command Post at the site.
4. Implement the Incident Command System, including verification of the status of all on-site persons.
5. Implement the Evacuation Plan, as appropriate.

PGV Response Actions:

Upon notification or determination, beginning 72 hours prior to a hurricane and/or severe weather system making landfall, PGV will take the following actions supplemental to those listed above.

1. Secure loose objects around project site and, if appropriate, cease drilling or plant operations.
2. (4-3) hours prior to the severe weather system making landfall, notify HELCO and CDA prior to reducing Main Steam Pressure (MSP) to 180 psi and communicate to CDA all safety protocols and PGV's plan for the severe weather systems.
3. Depending on the size and strength of the severe weather system, the power plant may be tripped. If so, steam is released through the rock muffler and abatement of hydrogen sulfide should start simultaneously. Responders to an emergency should approach the site from an upwind direction and have personal monitors and self-contained breathing apparatus (SCBA). Notify both CDA, HDOH (Clean Air Branch), County, and DLNR, if steam is released to the emergency steam release facility.
4. Ensure Monitoring Stations are recording meteorological data. Check propane tanks and top off if necessary.

72-60 Hour Off-Peak

1. One at a time, cycle shut and open all production well control valves.
2. Ensure there is a positive shut off on each well head control valve.

60 Hours

1. Ensure hydraulic actuator units are fueled up and attached to KS-14, KS-17 and KS-18 Velan isolation valves.
2. Operationally test the emergency diesel generator (EDG).
3. Check status of all emergency generators.

48 Hours

1. Call all off shift operators and notify them that they are on standby call in.
2. Review plant trip procedures.
3. Ensure all on shift personnel know the location of the STOP button on the CITECT screen.
4. Walk down production well bleed system.

The following will be contingent on landfall and severity of the severe weather system.

24 Hours

1. Call system (HELCO) and let them know that depending on landfall of the hurricane or severe weather system, we will need to reduce MSP to 180 psi. Estimate power loss for HELCO.
2. Place emergency generator in standby for water well MW-4. This well water will be used for the injection wells for bleeding

8 Hours

1. Evaluate wells if needed for bleed systems with current weather conditions.

4-3 Hours

1. Call in standby operators for operational support (minimum 3), 1 mechanic, 1 EI&C, and 1 well technician.
2. All production wells go down from two legs to one leg in service.
3. If needed, take one or two reinjection wells (KS-3, KS-11) out of service and set up well(s) with minimal bleeds from production wells.
4. Reduce MSP below 180 psi, give net power estimate net for HELCO.
5. Ensure heat removal mode settings are in place for all other operational OEC's.
6. Have all CSC shutdown procedures available for review

2-1 Hours

1. Station one operator on Wellpad A and another on Wellpad E.
2. Minimal bleed of production wells KS-14 and KS-18 will bleed to KS-17 production well. This will assist with bleeding the wells in the event the WHCV's are isolated.
3. Have all notification documents in standby.

Landfall

1. Notify system that you are reducing load to 120 psi MSP, which is approximately 5-7MW.
2. Throttle shut production wellhead control valves to maintain 120 psi MSP.
3. Make all attempts to keep as many OEC's online to reduce MSP and consume steam if plant trips.

Single Transmission from PGV

1. If one transmission line is lost, contact the HELCO/System dispatcher for status of the grid.
    a. If HELCO/System is working on putting the line back in service, continue idling at 120 psi MSP approximately 5-7MW.
        i. Contact HELCO/System dispatch every 30 minutes for line status
    b. If HELCO/System is UNABLE to work on returning the line back into service and weather conditions continue to worsen, perform a controlled shutdown of the plant in coordination with HELCO/System.

Plant Trip

1. Notify the CDA immediately should the severe weather system cause a facility emergency situation.
2. Start water well MW-5 with portable diesel generator to maintain raw water supply for bleeds.
3. Monitor communications on emergency radio channel from CDA.
4. Make other required verbal notifications.
5. Secure wellfield and power blocks.
6. Ensure all production wells (KS-14, KS-17 and KS-18) are bleeding per chart below.

PRODUCTION WELL BLEEDS:
WELLPAD A and E
KS-14 bleed to KS-17
KS-18 bleed to KS-17
ALTERNATE BLEED any injection well available.

7. Once the severe weather system has passed, if needed, perform testing on all auxiliary, wellfield, and powerblock systems prior to plant startup.

8.1.5 Lightning

Nature of Hazard:

The power plant is designed to operate in all types of weather conditions, even in severe thunderstorms. Grounding is provided in the power plant, wellpads, substation, and switchyard. There is also a grounded lightning rod on top of the drilling rig. Though the plant is equipped with lightning protection systems lightning could trip the whole plant and activate the emergency steam release system with power coming from the emergency diesel generator. There is little potential for lightning to produce any facility emergency situations which could threaten the health, safety, or welfare of the public, although ignition of a fire within the plant is a remote possibility (see Section 8.2.2).

Response Action:

In this instance, there may not be advance notification to PGV regarding this hazard. In the event that a lightning storm should threaten the project facilities, PGV will take the following supplemental actions in addition to those listed at the beginning of Section 8.1:

1. Assess the conditions.
2. Notify the CDA immediately should lightning cause an facility emergency situation that could threaten public health and safety.
3. Prepare to extinguish small fires and cut (or reduce) all power sources.
4. If there is a fire, implement Brush Fire Response actions as outlined in Section 8.1.6 or the actions in Section 8.2.2 if it is in the plant site.
5. Depending on the nature of the lightning strike, the power plant may be tripped. If so, steam may be released through the rock muffler and abatement of hydrogen sulfide would start simultaneously. Respondents to an emergency should approach the site from an upwind direction and have personal monitors and SCBAs. Notify both CDA and HDOH, Clean Air Branch (Table 3-1), if steam is released to the emergency steam release facility.
6. Await instructions from CDA.

8.1.6 Brush Fire

Nature of Hazard:

A runaway brush fire reaching the power plant could cause an explosion or fire at the OEC Units, pentane and diesel storage tanks, power rooms, and substation areas. Similar dangers could also exist in the vicinity of the well pads and could threaten the rig and support facilities. PGV's responses to fires involving actual project components are presented in Section 8.2.2.

Response Actions:
In this instance, the CDA may not provide advance notification to PGV regarding this hazard. In the event that a brush fire should threaten the project facilities, PGV will take the general actions outlined at the beginning of Section 8.1 and the following supplemental actions:

1. Call Fire Department and the CDA (Table 3-1).
2. Notify the CDA immediately should the fire hazard cause a facility emergency situation that could threaten public health and safety.
3. Instruct on-site personnel to proceed immediately with fire fighting using the existing on-site fire protection systems (see Section 4 and Appendix A, Section A-8-3).
4. Prepare to cease all activities at the project site.
5. Prepare to shut down facilities and secure wells as outlined in Table 5-1.
6. If time permits, remove drilling equipment as per Evacuation Plan (Chapter 5).
7. Establish temporary blockades for all access roads leading into the fire.
8. Await instructions from the Fire Department and CDA.

8.1.7 PGV General Response:

Once a facility emergency situation occurs or is indicated which could threaten the health, safety, or welfare of the persons in the vicinity of the project site, PGV will:

1. Immediately notify CDA and other appropriate agencies of the nature and anticipated impacts and duration of the emergency situation in accordance with Table 3-1.
2. Turn on a battery-powered radio for Emergency Broadcast Systems (EBS) announcements, if appropriate.
3. Establish a Command Post at the site.
4. Implement the Chain-of-Command (Tables 3-1, Table 3-2), including verification of the status of all on-site persons.
5. Implement the Evacuation Plan (Chapter 5), as appropriate.
6. Provide environmental monitoring data to the Department of Health and to the County Civil Defense.
7. Take whatever follow-up appropriate actions are necessary to deal with the facility emergency situation.

<u>Reporting:</u>

All post-notification reporting related to these type of emergencies will be done as soon as possible during the emergency, and afterwards according to the Post Emergency Response Procedure identified in Appendix D.

The following sections describe the specific actions that will be followed if the following upset conditions requiring emergency response arise:

1. Geothermal steam and fluid releases from the reservoir or power plant.
2. Fire that threatens the site facilities and has the potential for moving off-site.
3. Any event creating very high continuous noise levels.
4. Chemical spills which could move off-site.

PUNA GEOTHERMAL VENTURE

An ORMAT Company

OFF SITE HAZARDS

9.0 UPSET CONDITIONS

Upsets

<u>Notification:</u>

Upsets can occur during the life of the project, whether caused by natural or man-made events. Table 9-1 presents a summary of the specific routine and upset conditions that could occur at the project site. PGV will immediately notify the CDA when any facility emergency situation occurs or is indicated which could threaten the health, safety, or welfare of persons in the vicinity of the project site. In addition, PGV will notify the CDA (and appropriate other governmental agencies) when the routine and upset conditions indicated in Table 9-8 occur at the site so that these governmental agencies are kept informed of the site status. Finally, PGV has the responsibility under its permits and other regulatory authorities to notify various regulatory agencies related to the operation of the project and when certain upset conditions occur at the site.

TABLE 9-1 SITE RELEASES UNDER ROUTINE AND UPSET CONDITIONS

TABLE 9-1. SITE RELEASES UNDER ROUTINE AND UPSET CONDITIONS

		CHEMICAL/ MATERIAL	SOURCE	QUANTITY (lb/hr)	ESTIMATED DURATION	NOTICE TO CDA	MITIGATION AND OTHER ACTIONS
1.	WELLPAD ACTIVITIES						
1.1	ROUTINE ACTIVITIES						
1.1.1	DRILLING						
A	DRILLING	H2S	MUD PIT	NONE	N/A		MAINTAIN pH 11 IN TANK
B	TRIPPING	H2S	WELL	NONE	N/A		KEEP HOLE FILLED WITH MUD
C	RUNNING CASING	H2S	WELL	NONE	N/A		KEEP HOLE FILLED WITH MUD
D	CIRCULATING	H2S	MUD PIT	NONE	N/A		MAINTAIN pH 11 IN TANK
1.2.1	WELL TESTING						
A	PIPED DISCHARGE	H2S	RESERVOIR	13	10 DAYS-1x/WELL	YES	ABATE TO 95% THRU FLOW LINE
		BRINE	RESERVOIR	100,000	10 DAYS-1x/WELL		
B	WELL SHUTIN	H2S	RESERVOIR	<1	1 TO 2 DAYS	YES	BLEED H2S THRU CAUSTIC BUILDUP OVER MONTHS
1.2	UPSET CONDITIONS						
1.2.1	DRILLING						
A	WELL BLOWOUT	H2S	RESERVOIR	448	HOURS OR WEEKS	YES	KILL THRU SIDE VALVES OR DRILL OFFSET WELL
		BRINE	RESERVOIR	100,000	HOURS OR WEEKS	YES	
B	CASING BLOWOUT	H2S	RESERVOIR	448	SECONDS TO DAYS	YES	SHUTIN PIPE OR BLIND RAMS AND
		BRINE	RESERVOIR	100,000	SECONDS TO DAYS	YES	KILL WELL THRU SIDE VALVES
C	STRING BLOWOUT	H2S	RESERVOIR	448	SECONDS TO MINUTES	YES	USE FAST-COUPLING SHUTOFF
		BRINE	RESERVOIR	100,000	SECONDS TO MINUTES	YES	VALVE ON STANDBY
D	TANK RUPTURE	DIESEL	TANK	11,000 GAL	<2 HR TO CONTAIN		PUMP REMAINING TO FRAC TANK
		CAUSTIC	TANK	3,000 GAL	<2 HR TO CONTAIN		PUMP REMAINING TO FRAC TANK
E	SITE SPILL	DIESEL	TANK/LINE	11,000 GAL	<2 HR TO CONTAIN		SHUT VALVE AND CLEANUP
		CAUSTIC	TANK/LINE	3,000 GAL	<2 HR TO CONTAIN		SHUT VALVE AND CLEANUP
F	TRANSPORTATION SPILL	DIESEL	TRUCK	8,000 GAL	@ DAY<6 HR-SURFACE		TRANSFER AND CLEANUP SPILL
		CAUSTIC	TRUCK	5,000 LB	@ MON<6 HR-SURFACE		TRANSFER AND CLEANUP SPILL
G	FIRE	FUEL	VARIOUS	N/A	<12 HR	YES	SITE FIRE PROTECTION SYSTEM

TABLE 9-1. SITE RELEASES UNDER ROUTINE AND UPSET CONDITIONS

		PARTS		N/A	<12 HR	YES	SITE FIRE PROTECTION SYSTEM
1.2.2	WELL TESTING						
A	CAUSTIC SYSTEM FAILURE						
	POWER FAILURE	H2S	RESERVOIR	448	<5 MIN	YES	BACKUP GENERATORS/STOP TESTING
	TANK/LINE FAILURE	H2S	RESERVOIR	448	<15 MIN	YES	BYPASS TO BACKUP CIRCUIT/STOP
B	PIPE FAILURE	H2S	RESERVOIR	448	<5 MIN	YES	BYPASS TO BACKUP CIRCUIT/STOP
C	VALVE FAILURE	H2S	RESERVOIR	448	<15 MIN	YES	BACKUP/THROTTLE VALVE>SHUTIN WELL
D	CASING FAILURE	H2S	RESERVOIR	448	HOURS TO DAYS	YES	KILL AND CEMENT THRU SIDE VALVES

TABLE 9-1. SITE RELEASES UNDER ROUTINE AND UPSET CONDITIONS (continued)

		CHEMICAL/ MATERIAL	SOURCE	QUANTITY (lb/hr)	ESTIMATED DURATION	NOTICE TO CDA	MITIGATION AND OTHER ACTIONS
2	POWER PLANT						
2.1	ROUTINE ACTIVITIES						
A	OPERATIONS	H2S	FUGITIVES	<1	CONTINUAL		SITE SURVEYS/ROUTINE MAINTENANCE
2.2	UPSET CONDITIONS						
A	PLANT SHUTDOWN						
	ABATED-ALL WELLS	H2S	RESERVOIR	22	MINUTES TO HR	YES	ABATEMENT TO 96% THRU ESRF
		BRINE	RESERVOIR	114,000	MINUTES TO HR	YES	DISPOSAL THRU HOLDING POND
B	MAIN PIPE FAILURE	H2S	RESERVOIR	560	MINUTES TO HR	YES	CLOSE VALVES/SHUTIN WELLS
		BRINE	RESERVOIR	114,000	MINUTES TO HR	YES	
C	WELL PIPELINE	H2S	RESERVOIR	448	MINUTES TO HR	YES	CLOSE VALVES/SHUTIN WELLS
		BRINE	RESERVOIR	100,000	MINUTES TO HR	YES	
D	TANK RUPTURE	PENTANE	TANKS	35,600 GAL	<2 HR TO CONTAIN	YES	TRANSFER AND CLEANUP SPILL
		PENTANE	TURBINES	17,500 GAL	<2 HR TO CONTAIN	YES	TRANSFER AND CLEANUP SPILL
		CAUSTIC 50%	TANK	14,700 GAL	<2 HR TO CONTAIN		TRANSFER AND CLEANUP SPILL
		CAUSTIC 10%	TANK	13,200 GAL	<2 HR TO CONTAIN		TRANSFER AND CLEANUP SPILL
		DIESEL	TANK	1,500 GAL	<2 HR TO CONTAIN		TRANSFER AND CLEANUP SPILL
E	SITE SPILL	PENTANE	TANKS	35,600 GAL	<2 HR TO CONTAIN	YES	SHUT VALVE/TRANSFER AND CLEANUP
		PENTANE	TURBINES	17,500 GAL	<2 HR TO CONTAIN	YES	SHUT VALVE/TRANSFER AND CLEANUP
		CAUSTIC 50%	TANK	14,700 GAL	<2 HR TO CONTAIN	YES	SHUT VALVE/TRANSFER AND CLEANUP
		CAUSTIC 10%	TANK	13,200 GAL	<2 HR TO CONTAIN	YES	SHUT VALVE/TRANSFER AND CLEANUP
		DIESEL	TANK	1,500 GAL	<2 HR TO CONTAIN	YES	SHUT VALVE/TRANSFER AND CLEANUP
F	TRANSPORTATION SPILL	PENTANE	TRUCK	10,000 GAL	1x/YR-<6 HR		TRANSFER AND CLEANUP SPILL
		CAUSTIC	TRUCK	5,000 LB	1x/YR-<6 HR		TRANSFER AND CLEANUP SPILL
		DIESEL	TRUCK	8,000 GAL	1x/YR-<6 HR		TRANSFER AND CLEANUP SPILL
G	FIRE	PENTANE	TANK/LINES	44,600 GAL	<12 HR	YES	SITE FIRE PROTECTION SYSTEM

TABLE 9-1. SITE RELEASES UNDER ROUTINE AND UPSET CONDITIONS (continued)

	CHEMICAL/ MATERIAL	SOURCE	QUANTITY (lb/hr)	ESTIMATED DURATION	NOTICE TO CDA	MITIGATION AND OTHER ACTIONS
	LUB. OILS	CANS	<50 GAL	<12 HR		SITE FIRE PROTECTION SYSTEM
	DIESEL	TANK	1,500 GAL	<12 HR	YES	SITE FIRE PROTECTION SYSTEM
	PLANT	EQUIPMENT	N/A	<12 HR	YES	SITE FIRE PROTECTION SYSTEM
	PLANT	BUILDING	N/A	<12 HR	YES	SITE FIRE PROTECTION SYSTEM

FOOTNOTES:

1 H2S RELEASE IS ABATED OR UNABATED
ABATED RELEASE IS BASED ON 95% ABATEMENT OF 448 LB/HR WITH A RELEASE CONCENTRATION OF 31 PPM.
UNABATED RELEASE IS 448 LB/HR/WELL WITH A 1,120 PPM CONCENTRATION IN THE STEAM.

2 BRINE RELEASE IS NOT CONSIDERED AN EMERGENCY CONDITION.

3 QUANTITIES ARE ESTIMATED AS MAXIMUMS IN LB/HR OR AS DESIGNATED IN COLUMN.

4 DURATIONS ARE ESTIMATED AT RANGES BASED ON SITUATION AT SITE.

5 TRANSPORTATION SPILLS ARE ALSO PROVIDED WITH FREQUENCY OF DELIVERY: @DY-DAILY, @MO-MONTHLY.

6 THE TWO PENTANE TANKS HOLD 18,000 GAL BUT ARE AT MOST 50% FULL.

7 THE TURBINE PENTANE VOLUME IS BASED ON 10 x 3,560 gal

8 MAXIMUM DESIGN FLOW THROUGH PLANT IS 570,000 LB/HR.

9 DESIGN MAXIMUM WELL FLOW IS 400,000 LB/HR STEAM AT 650 PPM H2S CONCENTRATION.

9.2 Geothermal Steam and Fluid Releases

Nature of Hazard:

The geothermal resource produced from the reservoir through the wells drilled by PGV consists principally of high-temperature steam. When produced to the surface, the wells also bring geothermal "brine", consisting of numerous chemical and metallic salts, and "noncondensible" gases, such as carbon dioxide, hydrogen sulfide (H_2S), nitrogen and hydrogen. Appendix H contains a discussion of the chemistry of the geothermal fluids contained in the geothermal reservoir. During an uncontrolled release of steam from the reservoir, the geothermal brine and noncondensible gases would most likely also be released from the reservoir and into the environment.

Because of its toxicity and concentration, of all the components of the geothermal resource the H_2S gas is the component of most significant concern. H_2S gas is a colorless gas with a "rotten egg" odor which is slightly heavier than air. H_2S is acutely toxic in high concentrations (in the range of 400,000 to 700,000 ppb). H_2S at 10,000 ppb is considered the acceptable limit for worker exposure for 8 hours per day, 40 hours per week. At 10,000 ppb, H_2S is documented to be an eye irritant. It is readily detectible down to levels of about 5 ppb.

GENERAL CHARACTERISTICS OF HYDROGEN SULFIDE

Concentration (ppb)	Characteristics
400,000 to 700,000	Acutely toxic
10,000	Acceptable worker exposure for 40 hours per week - documented eye irritant
1,000	Hawaii Department of Health concentration limit for required evacuation to protect public health and defined "Warning" level (one-hour average)[1]
25	Hawaii Department of Health concentration limit for routine PGV project operations and defined "Watch" level (one-hour average)
5	Generally recognized level of odor delectability

1. The decision to actually order an evacuation is typically made in the field by the appropriate responsible agency(ies) based not on waiting on field measurements to document that the established one-hour average "Warning" level has been exceeded, but on the professional judgement of the agency(ies), based on all the data available at that time, as to whether or not the incident has the potential to exceed the established one-hour average "Warning" level.

HDOH has set a one-hour average ambient air concentration of 25 ppb H_2S as the lower limit for requiring notification to the CDA, and set a one-hour average ambient air concentration of 1,000 ppb H_2S as the lower limit for requiring evacuation. For the purposes of this PGV ERP, these levels have been designated as follows: 25 ppb = "Watch" and 1,000 ppb = "Warning". The decision to actually order an evacuation is typically made in the field by the appropriate responsible agency(ies) based not on waiting for field measurements to document that the established one-hour average "Warning" level has been exceeded, but on the professional judgement of the agency(ies), based on all the data available at that time, as to whether or not the incident has the potential to exceed the established one-hour average "Warning" level.

As stated above, because of its toxicity and concentration in the geothermal fluid, H_2S is the component of the geothermal fluid of greatest significance. Other components, such as acidic aerosols and total particulates which may be formed in the atmosphere once the geothermal fluid is discharged during a well uncontrolled flow event, may also be potential health hazards if produced in sufficiently high concentrations, as may other components which are typically associated with geothermal fluids but which have not yet been quantified from samples of the PGV geothermal fluid. The HDOH-established "Watch" and "Warning" levels for H_2S have been set at levels to protect public health from H_2S and all other non-H_2S components of the geothermal fluid. Appendix H contains a more complete discussion of the current understanding of the chemistry of the PGV geothermal resource, including these other components.

The release of high temperature steam containing H_2S gas into the atmosphere may occur under different scenarios. To determine the "worst case" conditions under which such emissions could occur during an uncontrolled flow event at any wellpad, or during specified power plant upset conditions, PGV conducted a simplified hazard analysis of the possible well-related uncontrolled flow event and power plant upset scenarios to determine the range of credible situations under which hydrogen sulfide and other contaminants could be released from any well or the power plant (see Appendix H). On the basis of the available existing information, the "worst case" credible parameters of the geothermal resource (geochemistry [hydrogen sulfide and other chemical constituents], likely maximum credible productivity [flow rate], temperature [enthalpy], etc.) which would be used as the emitted (released) constituents in conducting a hazard analysis for these emissions (see Appendix H).

In order to determine the maximum ("worst case") impacts which could result from each of these 12 different emission scenarios, PGV conducted an impact analysis utilizing a standard air dispersion model (ISCST) accepted by the U.S. Environmental Protection Agency using a standard screening set of 33 different meteorological conditions to ensure that the "worst case" meteorological conditions for each emission scenario and receptor point was evaluated (see Appendix H). The results of this air dispersion modelling are presented in Appendix H. Table 9-2 summarizes the results of the modelling for each of the 12 release scenarios, organized on the basis of the air dispersion modelling are presented in Appendix H. Table 9-2 summarizes the results of the modelling for each of the 12 release scenarios, organized on the basis of the maximum distance at which each of the HDOH-specified threshold levels are predicted to be exceeded under the "worst case" meteorological conditions, and the point and concentration of maximum impact. Table 8-2 has further categorized each release scenario by which, if any, of the HDOH-specified threshold levels is exceeded by the maximum predicted concentration, thus ensuring that each release scenario is categorized by the highest estimated modelling impact.

TABLE 9-2. SUMMARY OF MODELED H_2S EMISSIONS

TABLE 6: SUMMARY OF MODELED HYDROGEN SULFIDE IMPACTS				
RELEASE SCENARIO	MAXIMUM OFF-SITE (>0.3 km) DISTANCE FROM SOURCE (km) TO IDENTIFIED ACTION LEVEL		POINT OF MAXIMUM PREDICTED OFF-SITE IMPACT (>0.3 km)	
	WATCH" LEVEL (25 ppb)	"WARNING" LEVEL (1,000 ppb)	CONCENTRATION (ppb)	DISTANCE FROM SOURCE (km)
TYPE "1" (EVENTS (EXCEED ONLY THE "WATCH" ACTION LEVEL)				
1. Abated vertical flow through diverter/muffler	0.9 km	N/A	40.3	0.4
9. Abated vertical flow from the mud sump	2.8 km	N/A	57.1	0.4
8. Abated vertical flow from the mud tanks	4.5 km	N/A	253.1	0.4
11. Unabated noncondensible gas flow	5.5 km	N/A	935.7	0.4
4. Unabated vertical flow through 13-3/8" casing	25. + km	N/A	146.0	0.6
5. Unabated vertical flow through 9-5/8" casing	25. + km	N/A	146.0	0.6
12. Unabated vertical flow through power plant steam release facility	25. + km	N/A	150.6	0.8
6. Unabated vertical flow through drill rig subbase	25. + km	N/A	246.8	0.5
2. Unabated vertical flow through diverter/muffler	25. + km	N/A	403.4	0.4
7. Unabated vertical flow through area of fractured rock	25. + km	N/A	789.4	0.4
TYPE "2" EVENTS (EXCEED THE "WATCH" AND "WARNING" ACTION LEVELS)				
10. Unabated horizontal flow through a 4" choke	25. + km	3.7 km	6,395[1]	0.4
3. Unabated horizontal flow through diverter	25. + km	6.7 km	12,786[1]	0.4

[1]Note that these scenarios can and will be quickly controlled through closing valves to shut in the well, resulting in a significantly reduced emission rate over any one hour period. The decision to actually order an evacuation is typically made in the field with the appropriate responsible agency(ies) based not on waiting for field measurements to document that the established one-hour average "Warning" level has been exceeded, but on the professional judgement of the agency(ies) based on all the data available at that time, as to whether or not the incident has the potential to exceed the established one-hour average "Warning" level.

As shown in Table 9-2, ten (10) of the modelled release scenarios result in predicted ambient air concentrations in excess of the HDOH-established one-hour 25 ppb H_2S notification "Watch" action limit, but do not produce predicted results in excess of the HDOH-established one-hour 1,000 ppb H_2S "Warning" action limit. These include all of the uncontrolled well-related releases (scenarios 1-2 and 4-9) and the continuous power plant-related release (scenario 12). The short-term, or "puff", release of hydrogen sulfide and other noncondensible gases from the power plant also falls in this category. Figure 9-1 has been drawn to show the predicted maximum off-site distance to the specified ambient hydrogen sulfide concentrations from each PGV wellpad and the plant site from all of these "Type 1" scenarios; that is, Figure 9-1 shows the worst of the worst case impacts predicted from all of the scenarios which maximum impact did not exceed the HDOH 1,000 ppb one-hour average "Warning" level. Thus, Figure 9-1 serves as the single worst case emergency planning and response map for all of these ten (10) listed "Type 1" scenarios; all predicted impacts were not greater than those shown on Figure 9-1 from any of the ten (10) scenarios.

The two well-related releases (scenarios 3 and 10) which have been modelled to exceed the HDOH-established "Warning" levels for one-hour hydrogen sulfide averages ("Type 2" events) are unique from all the other well-related discharges in more than predicted maximum impacts. First, the high predicted impacts result from the horizontal nature of the discharge of the geothermal fluid; that is, the horizontal discharge of geothermal steam and noncondensible gases creates an impact significantly larger in a directly downwind direction than the same flow would if directed in a vertical direction. Second, each of these upset discharges can each be stopped or redirected vertically by either manually or remotely shutting in one of the upstream control valves even after the discharge occurs. Thus, although these two discharges have been modelled as if the discharge of geothermal steam and hydrogen sulfide would continue in a horizontal direction for more than an hour, through this modelling PGV has recognized that horizontal discharges of the geothermal fluid can produce unacceptably high impacts, and PGV can and will immediately terminate any such discharge if it occurs. Thus, any impact resulting from the short-term horizontal discharge of geothermal fluid will be short-term, and the actual hydrogen sulfide impact will be much less than that predicted in Table 9-2, and directly proportionate to the time the horizontal discharge continues.

The horizontal discharge of geothermal fluid modelled in scenarios 3 and 10 is directional (that is, the magnitude of the impact depends upon the direction of the discharge and the direction of the wind). Table 9-2 has been prepared to graphically show the focused nature of the emissions and impacts (a "Type 2" event) for scenario 3 from a single source if the emission were to continue for an entire hour under the worst case conditions. However, as stated above, PGV will immediately terminate any created horizontal discharge and the actual impact will be proportionally less.

A preliminary analysis of the possible impacts and health hazards which could result from the uncontrolled emission of the geothermal brine and noncondensible gases was also conducted by PGV and HDOH (see Appendix H). Based on this preliminary analysis, none of the non-H_2S components of the geothermal fluid appear to be released to, or formed in, the environment in concentrations high enough to significantly increase the level of health hazard created by the simultaneous emission of the H_2S. As a result, the levels of H_2S described above are used exclusively herein as the emergency response planning criterion. However, PGV, under the review of HDOH, will be undertaking a more detailed sampling and analysis program for these non-H_2S components during the first well flow test following acceptance of this revision of the ERP.

Response Actions:

PGV will immediately notify the CDA, HDOH - Clean Air Branch, and HDOH - Hazard Evaluation and Emergency Response Branch, in the event that any of PGV's operations result in an uncontrolled steam release which produces, or has the potential to produce, an exceedance of the appropriate ambient H_2S concentrations established by the HDOH - Clean Air Branch and HDOH - Hazard Evaluation and Emergency Response Branch.

In the event of an uncontrolled steam release, PGV will take the following actions to supplement the ones outlined at the beginning of Section 9.2:

1. Determine the nature (estimated duration and emissions, etc.) and "type" of release (Type "1" [Figure 8-1] or Type "2" [Figure 9-2]) and immediately communicate this information to CDA, HDOH - Clean Air Branch, and HDOH - Hazard Evaluation and Emergency Response Branch (Table 3-1).
2. Immediately implement perimeter monitoring with portable H_2S meters.
3. Maintain constant coordination with CDA, providing all assistance as requested.
4. Act to control and/or abate and vertically direct the uncontrolled source of the H_2S, as below:

   For most types of well blowouts, where control of the well is lost, the equipment and expertise will be immediately available to bring the well back under control. In parallel with any attempts to bring the well under control, PGV will work to ensure that any releases of geothermal fluid and/or steam are vertically directed and that emissions of H_2S and/or brine particulates or aerosols are abated to the extent consistent with equipment and worker health and safety. If initial attempts at well control are unsuccessful, PGV, in consultation with DLNR, will decide whether further attempts using available personnel are likely to be successful. If not, outside well control experts will be called in. This decision will be based on the severity and magnitude of the uncontrolled release, the hazard it represents to surrounding life and property, the experience and training of on-site personnel, and the availability of necessary well control equipment.

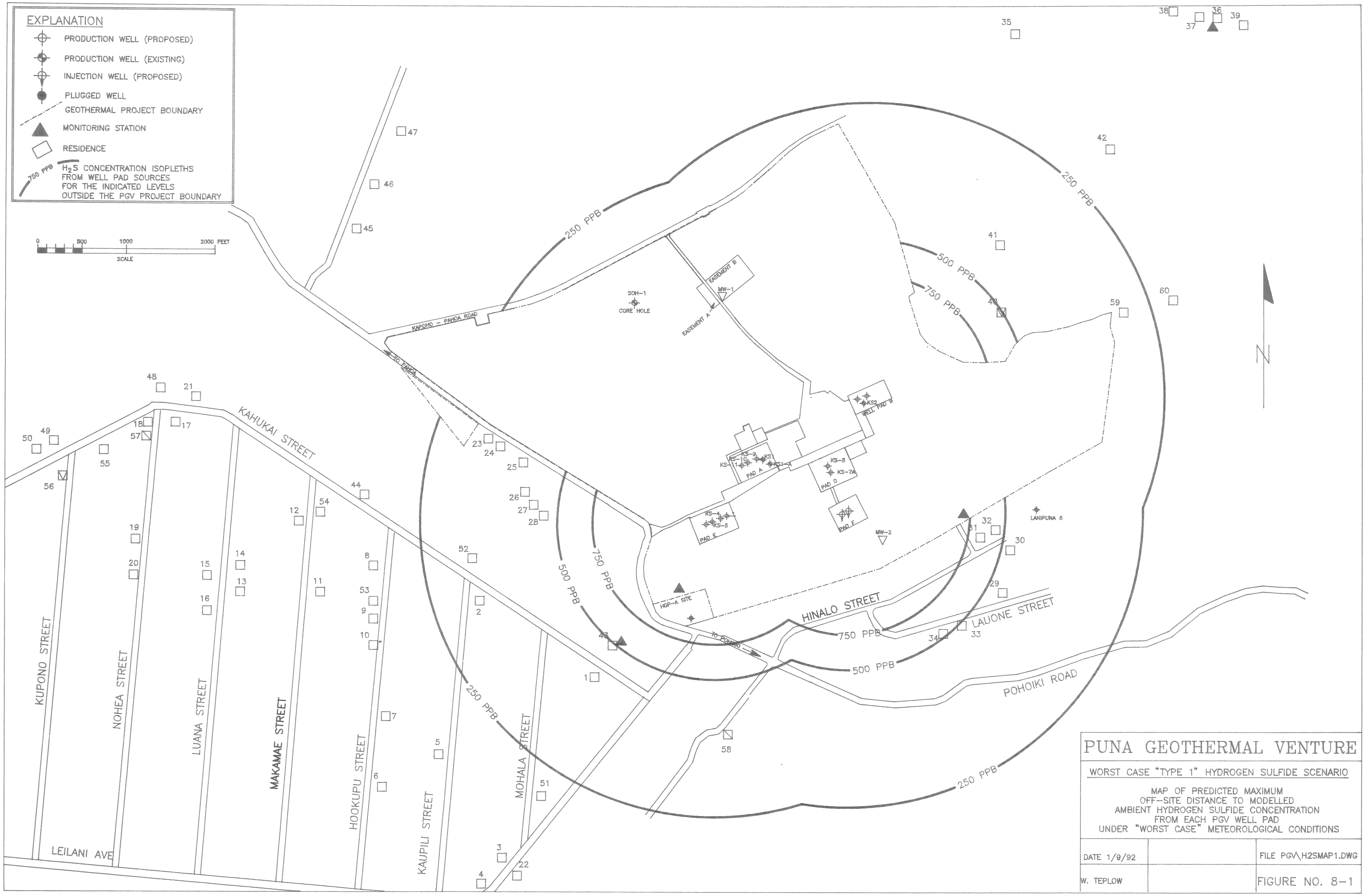
   If local expertise is unable to control the steam release, well control specialists from the mainland will be immediately contracted for assistance (see Appendix E). If it is determined that additional equipment and services are needed for the control of the steam release, PGV will obtain the required assistance and begin repair work immediately.

   As appropriate, the area around the uncontrolled well or point of discharge will be cleared of all loose materials and any unnecessary equipment and machinery. As feasible, giving first consideration to personal safety, PGV will attempt to control the release at the wellhead. Any on-site contractor personnel involved in well operations will have expertise and training in well control and should be consulted by the Project Manager.

   The well site will be immediately evacuated if there is any danger of the rig toppling. If not, water will be pumped into the well through the kill line or drilling pipe until the steam release is under control and stopped. Arrangements will then be made to pump cement into the well and plug the well as appropriate.

   An earthen berm and dikes may be constructed to divert and contain released brine in on-site well sumps and brine pits.

5. Report releases of H_2S in excess of reportable quantities (100 pounds over 24 hours) to the National Response Center, State Emergency Response Commission, and the Local Emergency Planning Committee (Table 3-1).



PUNA GEOTHERMAL VENTURE

WORST CASE "TYPE 1" HYDROGEN SULFIDE SCENARIO

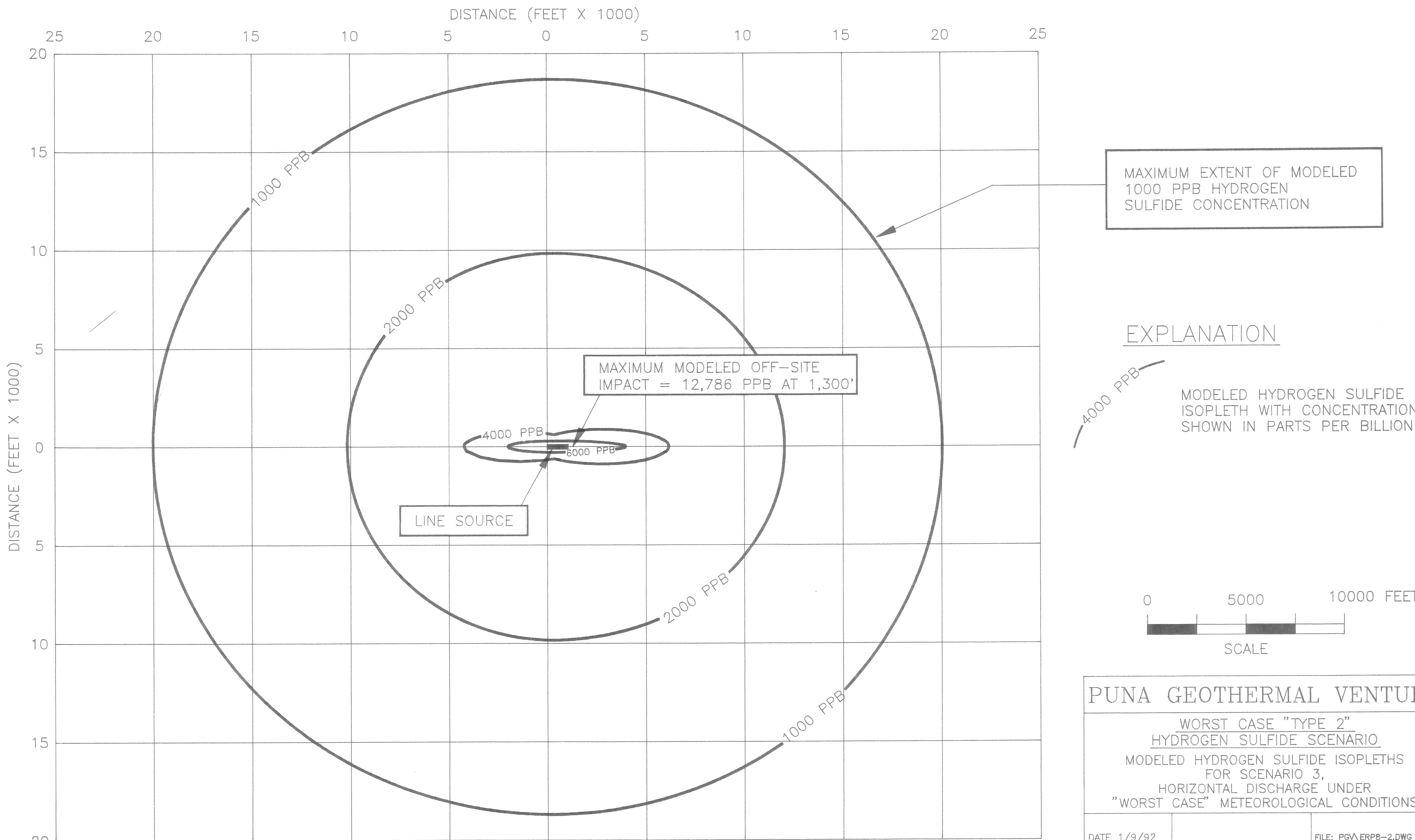
MAP OF PREDICTED MAXIMUM OFF-SITE DISTANCE TO MODELLED AMBIENT HYDROGEN SULFIDE CONCENTRATION FROM EACH PGV WELL PAD UNDER "WORST CASE" METEOROLOGICAL CONDITIONS

DATE 1/9/92

FILE PGV\H2SMAP1.DWG

W. TEPLOW

FIGURE NO. 8-1



PUNA GEOTHERMAL VENTURE

WORST CASE "TYPE 2" HYDROGEN SULFIDE SCENARIO

MODELED HYDROGEN SULFIDE ISOPLETHS FOR SCENARIO 3, HORIZONTAL DISCHARGE UNDER "WORST CASE" METEOROLOGICAL CONDITIONS

DATE 1/9/92		FILE: PGV\ERP8-2.DWG
BY W. TEPLOW		FIGURE NO. 8-2

9.2.2 Fire Hazard

Nature of Hazard:

The most probable location for a fire at the PGV plant site is within the electrical power rooms or any of the pentane heat exchangers. Fires may also occur in the control room, diesel fuel storage/or unleaded gas tanks, or the pentane storage tanks. Figures 4-2 and 4-3 show the location of most of the potential fire locations. Most fires will be limited in size and extent, identical to fires involving the same materials at any other facility or location. However, as described in Chapter 4 and Appendix A, all portions of the project which are potentially subject to a fire are protected by specific fire protection systems designed to prevent the occurrence and spread of a fire.

Of special interest is the presence of pentane on the power plant site. As indicated on Table 9-1 and Figure 4-3, a maximum of 11,000 gallons (approximately 56,000 pounds) of pentane is stored in two reserve tanks in the power block and one reserve tank with a maximum of 12,472 gallons (approximately 65,478 pounds) at the expansion plant. There are ten (10) OEC Units that hold approximately 3,560 gallons (approximately 18,700 pounds) and (2) OEC Bottom End Units located at the expansion plant that hold approximately 10,500 gallons each (approximately 55,545 pounds). Pentane is a flammable liquid (boiling point equals 97^{o}F) with flammable limits between 1.5 and 7.8 percent (by volume) in air. By comparison, because of its lower volatility, pentane is less flammable than propane.

To evaluate the hazard limits of a catastrophic fire involving pentane at the site, the fireball hazard was modelled. This modelling predicted that the maximum injury zone radius for a fireball involving 56,000 pounds of pentane would be approximately 1,350 feet. As shown on Table 9-1, this is substantially less than the 2,000-foot minimum distance from the storage tank to the project boundary/nearest residence. In addition, the catastrophic release of pentane was modelled to evaluate the possible movement offsite of a potentially flammable cloud of pentane under various meteorological conditions. As shown also on Table 9-1, the cloud of pentane was no longer flammable (that is, the concentration of pentane in the cloud was diluted below the lower limit flammability of pentane (1.5 percent) within approximately 1,000 feet of the source, again well within the boundary of the project site.

Initial Action:

PGV will immediately notify both the Fire Department and CDA (Table 3-1) in the event of a fire at the site.

<u>Response Actions</u>:

In the event that a fire threatens major components of the project facilities, PGV will immediately implement the evacuation plan (Chapter 5) and notify the CDA (Table 3-1) that site evacuation is underway and request the presence of one of their staff at the site.

The on-site fire protection system (see Appendix A) will be automatically triggered in the power plant area in the event of any fire at the site. Different kinds of fires in the site area may also require use of different manual systems for control. The following are the actions to be taken when handling different kinds of fires at the site:

(1) Electrically Caused Fire
Extinguish with a class C fire extinguisher (ABC or BC extinguisher are also sufficient).

(2) Solvent/Petroleum/Pentane Fire
Water from hydrants will be used to cool the surrounding areas. Extinguish with a Class B fire extinguisher (ABC and BC extinguisher are also sufficient).

PGV will implement the general response conditions identified in Section 9.2 above, and thereafter evaluate the situation on a case-by-case basis. PGV will also notify the Hawaii County Planning Department regarding the fire.


SCALE: 1:12,000
1/2 MILE
3 THOUSAND FEET
CONTOUR INTERVAL 20 FEET
GEOTHERMAL LEASE BOUNDARY
LOCATION OF ISOPENTANE TANKS
MAXIMUM INJURY ZONE FOR A FIREBALL
MAXIMUM LIMIT OF FLAMMABILITY FOR A CLOUD OF PENTANE
HAWAIIAN ISLANDS
PUNA
REVISIONS
HAZARD LIMITS OF A FIRE OR LEAK INVOLVING PENTANE TANKS AT THE PGV POWERPLANT
PUNA GEOTHERMAL VENTURE
NOTE: SHADED AREA IS WHERE THE HAZARD COULD BE LOWER DUE TO TERRAIN BARRIER EFFECTS
FIGURE 8-3
Kaniahiku Village
LAVA TREE STATE PARK
Puulena Crater
Pawai Crater
Kahuwai Crater
Univ of Hawaii Experimental Station
MALAMA HOMESTEADS
Pohoiki
Kapoho
Halekamahina
Kapoho O'Kanawali Crater
Puu Kii
Puu Kaliu
Puu Kepaka

9.3 Noise Hazard

Nature of Hazard:

Noise is not commonly considered a hazardous condition in any situation other than the workplace, although it is a nuisance and can, following repeated exposures at high energy levels, result in a degradation of hearing acuity. The Occupational Safety and Health Administration (OSHA) has set the permissible noise exposure at 90 dBA for an eight-hour day. The HDOH has recently suggested that a noise level of 85 dBA (1-minute L_{eq}) be used for establishing when to recommend voluntary evacuation to protect public health. For the purpose of this PGV ERP, this level has been designated as the noise "Warning" level.

The most probable sources of high level noises during upset conditions would be a steam release through a pipe or pipe rupture and/or during a well blowout. In most cases, such a high noise level would result from a short-term steam release from a pipe that had ruptured or a valve or seal that had broken. Any of these conditions could produce noise levels similar to that produced from vertical well venting or steam pipeline clean out, from 75 dBA to 125 dBA 50 feet from the source. Figure 8-4 has been prepared to show the possible noise levels which would result off of the project site from these 75 dBA to 125 dBA sources, based upon a noise level drop of 6 dBA for each doubling of the distance, as discussed in the Geothermal Noise Guidelines of the Hawaii County Planning Department. Although this assumption (6 dBA reduction for each doubling of the distance) is reasonable at the closer distances, this usually underestimates the reduction in noise levels as the distance from the source increases (that is, the predicted noise level would be too high).

Initial Action:

PGV will immediately notify the CDA, Hawaii County Planning Department, and HDOH - Noise and Radiation Branch (Table 3-1) in the event that any upset of PGV's operations leads to an exceedance of the appropriate ambient noise levels (Figure 8-4).

Response Actions:

The site situation will be continuously monitored to establish the actual noise levels, and actions will be taken at the site to stop the source of the noise. PGV will continue to coordinate with the CDA and other agencies to advise them of the anticipated duration of the upset and high noise level situation.

9.4 Spills and Leaks

Nature of Hazard:

Spills or leaks of chemicals, including hydrocarbons, at the site could occur related to transfer or storage of pentane, caustic soda, treatment chemicals, diesel fuel, or unleaded gasoline. Of these, only the catastrophic spill of pentane could result in an emergency situation off-site, and this only as a result of the potential flammability of the cloud (see Section 9.1.2). Pentane is not toxic (see Appendix F), and is not hazardous outside of its flammability characteristics. Caustic soda is considered hazardous because of its corrosivity, but is otherwise not toxic, and the quantity stored on site will not be able to move off site under any upset condition (see Appendix G).

Spills of geothermal brine may also occur over the life of the project. However, the geothermal brine expected from the wells that will feed the PGV plant does not contain levels of constituents which necessitate its classification as hazardous waste. Brine chemistry will be evaluated analytically each year to monitor any changes in brine characteristics.

Response Actions:

The following are the general procedures that will be used to control and contain a spill:

1. Close all valves in pipelines leading to and from the source of the spill, giving first consideration to personnel safety in all attempts to control the release at its source.

2. The release should be contained within the smallest area possible. This may be accomplished by:

   - ☒ construction of an earthen berm around the spill and earthen dams across any drainage channels or swales in the spill area.
   - ☒ diversion of the spill to sump areas, if possible.
   - ☒ if needed, call an outside emergency cleanup contractor (Appendix E) according to the chemical nature and magnitude of the spill, the experience and training of available on-site personnel, and the availability of cleanup materials and equipment.
   - ☒ The facility response plan (Hazwoper) will be followed by employees when responding to spills or releases.

For small-scale spills or leaks of pentane, caustic soda or diesel fuel (less than reportable quantities), the following cleanup procedure will be followed:

1. Provide personnel with the proper protection as appropriate and according to the nature of chemicals involved. Appendices F & G have the Material Safety Data Sheets for pentane and 50% caustic soda, respectively.

2. After completion of activities that require the use of personal health and safety equipment, the equipment will be cleaned.

For spills larger than reportable quantities, actions taken will be similar to those provided above and in PGV's Hazwoper Program. Also, other reporting and on-site cleanup actions shall adhere to the direction required by agencies involved with compliance at the site. This shall include reporting any release of more than 100 pounds of pentane or H_2S per 24 hours to the National Response Center, Hawaii State Emergency Response Commission, and the Local Emergency Response Commission (Table 3-1).

For spills of geothermal brine:

1. Personnel assigned to spill containment, control, and cleanup will be provided with adequate protection equipment.

2. After completion of all activities that require the use of personal health and safety equipment as described above, the equipment will be properly cleaned.

PUNA GEOTHERMAL VENTURE

An ORMAT Company

ON SITE UPSET

CONDITIONS

10.1 GRID UPSETS

10.1.1 GRID INTERRUPTION

10.1.1.1 INITIAL INDICATIONS

INDICATIONS	COMMENTS
Control room lights flicker	Normally all lights flicker at the same time.
Noise level	Noise levels in the plant change up and down. The sound type change from normal operation sound.
Numerous audible alarms on CSC Control Board	
CSC control power indicators on the control panel will vary and go to different values.	

10.1.1.2 TYPES OF INTERRUPTIONS

TYPES	COMMENTS
Total grid loss	Both 69 KV outgoing transmission lines lose voltage. When this occurs, the plant will go black, or lose total power until the emergency generator starts and produces power.
Partial grid loss	One 69 KV outgoing transmission line loses voltage. When this occurs half the OECs will trip off the line depending on the transmission line lost.

10.1.1.3 IMMEDIATE ACTIONS TOTAL GRID LOSS

ACTIONS	COMMENTS
Maintain main steam pressure (PT-1123, A, B, C) and stabilize wellhead control valves.	When the grid is lost OECs will cease to generate and not use steam. This will cause an increase in M.S.P., wellhead valves should go closed to minimum stop. Verify correct valve action. If valves do not go closed, they may have to be closed in manual.

Verify diesel generator start. Call HELCO dispatcher and verify grid conditions and determine grid problem cause.	
After the **OECs** come to a complete stop, switch selected **OECs** to heat removal.	This will facilitate steam usage and keep the wells at a normal operating temperature until power generation can be restarted.

10.1.1.4 SUPPLEMENTARY ACTIONS FOR TOTAL GRID LOSS

ACTIONS	COMMENTS
Check electrical equipment in the field for any flags that could have occurred during grid loss.	
Check plant operation during power outage.	
Call appropriate personnel	

10.1.1.5 IMMEDIATE ACTIONS PARTIAL GRID LOSS

ACTIONS	COMMENTS
Maintain main steam pressure (PT-1123 A, B, C) and stabilize wellhead control valves.	With a partial grid loss, half the OECs will cease to generate, and not use steam. This will cause an increase in M.S.P., wellhead valves should go closed, to control M.S.P.
Call and notify HELCO dispatching.	

10.1.1.6 SUPPLEMENTARY ACTIONS FOR PARTIAL GRID LOSS

ACTIONS	COMMENTS
Check plant for proper operation.	
Call the appropriate personnel.	
Check electrical equipment in the field for any flags that could have occurred during grid loss.	
Check Cytec single line diagram for partial grid loss indications.	

10.2 AUXILIARY UPSETS

10.2.1 LOSS OF NCG COMPRESSORS

10.2.1.1 INITIAL INDICATIONS

INDICATIONS	COMMENTS
Compressor failure at CSC.	Indicator light at compressor green OFF/RUN switch will blink.
	Failure alarm will indicate on alarm print out.
NV-4145 CLOSE/OPEN/AUTO switch will activate and open-by-passing OEC NCG to mixing spool.	Valve opens at 25 psig NCG header pressure.

10.2.1.2 IMMEDIATE ACTIONS

ACTIONS	COMMENTS
Dispatch operator to the NCG compressor and attempt a restart as soon as possible.	
Lower reinjection header pressure as low as possible.	
If NV-4152 is operating, open to rock muffler, or sulfa treat system.	If NV-4152 is opened to rock muffler, abatement water, and caustic system will have to be activated.

10.2.1.3 SUPPLEMENTARY ACTIONS

ACTIONS	COMMENTS
Call HELCO and advise that power cut back may occur.	
Call management and advise of situation.	
If unable to re-establish NCG compressor operation begin cutting back plant power production.	Cut production back to a point where NCG can be handled without compressors.
Facilitate NCG compressor repair.	

10.2.2 LOSS OF PLANT AIR

10.2.2.1 SYMPTOMS/INDICATIONS

INDICATIONS	COMMENTS
Both plant air compressors running continuously for extended periods of time.	
Loud hissing noise.	
Plant air pressure low alarm. It alarms at 80 psig.	
Plant shut down sequence started. This is set in the control logic to start at 100 psig. When this occurs, the plant will begin to ramp down.	

10.2.2.2 POSSIBLE CAUSES

INDICATIONS	COMMENTS
Loss of one or both plant air compressors.	
Unauthorized use of plant air by contract labor, or personnel not familiar with the plant air system.	
Line rupture.	
Air dryer plugging.	

10.2.2.3 IMMEDIATE ACTIONS

INDICATIONS	COMMENTS
If rupture has been identified shut the appropriate component isolation valves. Before closing the valve, consult with the valve FAIL/OPEN/CLOSE list to anticipate component isolation.	

Connect portable air compressor to the plant air system and augment the system using this air. It should be noted that air from a portable compressor is not dried and could contain traces of oil. This would depend on the location chosen for connection.	
Verify that there are no unauthorized uses of the system.	
Verify proper operation of PV-6201. This valve regulates air to the service air header.	Located between OEC's 15 & 25

10.2.2.4 SUPPLEMENTARY ACTIONS

INDICATIONS	COMMENTS
Notify appropriate personnel.	PGV management, agencies etc.
Inspect the plant air system piping within the plant, including all components. If the site of the rupture is located, isolate if possible.	
If the leak is outside the power plant in the well pad areas, inspect all distribution piping, and isolate the leak if possible.	
Once located, isolate the rupture as close to the source as possible. Restore the system then start effected equipment.	

10.3 PLANT UPSETS

10.3.1 ESRF RELEASE

10.3.1.1 INITIAL INDICATIONS

INDICATIONS	COMMENTS
Rising steam pressure on main steam header	As indicated on PT-2123 A,B,C
Increasing pressure to 245 PSIG on main steam will activate ESRF. Lights at Mimic Panel in CSC for ESRF will activate.	Lights located at top section of Mimic Panel and are on valve switches.
ESRF activation will open NV-4204 Jamesbury Valve.	
At increasing steam pressure other valves in the ESRF begin to activate.	
Power plant output will increase at rising steam pressure.	

10.3.1.2 IMMEDIATE ACTIONS

ACTIONS	COMMENTS
Check main steam pressure. Reduce main steam pressure by any means.	Well control valves may have to be taken to manual and closed.
Verify correct wellhead control valve action. Correct if necessary.	
Check main steam pressure indications. Correct if necessary.	Check functions of PT-2123 A,B,C
Verify stable OEC operations. Send portable H_2S monitor downwind of ESRF to check for any H_2S release indications.	
Verify proper operation of the reinjection system.	High system pressure may cause back up of steam pressure.

10.3.1.3 SUPPLEMENTARY ACTIONS

ACTIONS	COMMENTS
Call management and appropriate government agencies.	

Verify correct and appropriate government agencies. Correct problem at ESRF system.	

10.3.2 PENTANE LEAK RUPTURE

10.3.2.1 GENERAL

INDICATIONS	COMMENTS
A Pentane rupture could result in serious personnel injuries and/or equipment damage. Pentane at high temperatures will vaporize immediately upon being released to atmosphere. This resultant vapor will make it almost impossible to distinguish the location of a rupture. Operator knowledge of system piping and component orientation will play an important role in differentiating a pentane rupture from a rupture within another high temperature, pressurized system. Extreme care should be taken to ensure personnel safety when combatting this casualty. Operator safety shall take precedence over plant operability at all times. Rapid identification and isolation of any major leak or rupture will aid in minimizing its effects on the distribution system as well as on other plant system and equipment. Pentane leaking can greatly increase the extent of the casualty by enlarging the size of The rupture. Additionally, the Pentane flow emitting from the rupture can cause serious damage to any equipment in its path. Electrical shock hazards are greatly increased due to the proximity of electrical equipment in the vapor. Subsequent to isolation of the rupture, a careful evaluation of plant conditions should be made in order to restore customer services in a timely manner. Re-entry to an evacuated area of the plant should be attempted only when deemed safe by supervisory personnel. Restore unaffected parts of the plant and realign systems as necessary to regain plant operability as soon as	

conditions permit. Additionally, the long-term effects of wetted insulation must be considered when evaluating total damage and plant recovery time.	
During a rupture of Pentane, OEC vaporizer level will be used as the controlling indicator for verifying isolation. Once the ruptured portion of the organic turbine is isolated, vaporizer level should remain constant. When any isolated portion of the organic turbine is re-pressurized, observe vaporizer level for any changes. If level decreased, the portion just isolated contains the rupture. If level remains constant, that portion may be considered intact, and remaining portions should be isolated with caution.	

10.3.2.2 SYMPTOMS/INDICATIONS

INDICATIONS	COMMENTS
Loud noise of a fluid leaving a pressurized system.	
Vapor cloud.	
Organic turbine vaporizer pressure alarm accompanied by OEC power loss.	
Vaporizer low level alarm.	
Erratic alarms and indications due to vapor loss.	
Detronics detection system in the Control Room alarms and gives location of alarm.	First alarm activates at 20% Lel Detection. Second alarm will activate at 40% Lel. Multiple alarms could be an indication of leak size.

10.3.2.3 POSSIBLE CAUSES

INDICATIONS	COMMENTS
Failure of a pipe and/or weld due to material defect or corrosion/erosion.	
Failure of a pipe and/or weld due to an overpressure condition.	

Physical damage to system piping or valves caused by external forces.	
Failure of fin fan tubes due to corrosion of fin fan malfunction.	
10.3.2.4 IMMEDIATE ACTIONS	
INDICATIONS	**COMMENTS**
Pentane vapors and liquids are very hazardous due to flammability. When the rupture or leak is identified, do the following:	Shut down all equipment around the leak. **NOTE:** The only exception would be if the leaks are in the fin tubes. In this case maintain fan operation until OEC is depressurized and vapor free.
Notify all plant personnel so that any equipment being used (tools, lifts, etc.) can be shut down.	
Flag off effected area.	
Set up all firefighting equipment for immediate response to a fire (train monitors, charge hoses, etc.)	
Isolation of Pentane leak may have to be done under a water blanket. This depends on the size of the leak. Personal protection is of utmost importance when dealing with a Pentane leak. Electrical equipment may have to be isolated if water protection is used.	
If the rupture is known to be within the plant, and can be readily located and isolated:	
SHUT down the affected OEC.	
STOP any affected OEC pumps.	
Isolate the effected piece of equipment on the OEC.	
Take supplementary actions to restore system operability.	
If the rupture location is not readily identifiable:	

Continue with attempts to locate the rupture.	
Take supplementary actions as necessary to locate and isolate the rupture, and restore system operability.	
10.3.2.5 SUPPLEMENTARY ACTIONS	
INDICATIONS	**COMMENTS**
Inspect the Pentane system piping within the plant, including all components.	If the site of the rupture is located, isolate it if possible and commence restoration of the system and its generating capabilities as necessary to provide the required service.
Inspect all Pentane distribution piping to each of the OECs in the complex to locate the rupture site.	Locate the rupture inside the plant as follows: After effected area has been isolated, and liquid Pentane removed, pressure test with Nitrogen to determine the actual point of the rupture.
Once located, isolate the rupture as close to the source as possible.	
Organize the necessary repair efforts to restore full system and service operability.	
Notify management personnel and customers of the casualty and the effects on services supplied by the plant.	
Once the rupture has been isolated and system restored, realign the system.	
Lock out or tag out the applicable parts of systems affected by the rupture.	

10.3.3 HYDROGEN SULFIDE

10.3.3.1 GENERAL

INDICATIONS	COMMENTS
An H_2S release may best be described as an unplanned leak of major proportion. It is a very serious casualty as it could result in personnel injury, equipment damage, the possibility of an extended outage of the power plant, and in the most extreme case, it may require the evacuation of all plant, personnel and area residents living in the vicinity of the plant perimeter. This procedure, therefore, does not address H_2S leaks of a minor nature which is addressed as part of the plants continuing maintenance plan. The key to reducing the effects of an H_2S release is the timely identification and isolation of the source of the release. Efforts to locate and isolate the leak must, however, not take precedence over personal safety. Only events as they occur will determine whether operators can remain and attempt to localize the source, or whether it is best to abandon the area or even whole parts of the plant.	

10.3.3.2 INDICATIONS

INDICATIONS	COMMENTS
Audible alarm in CSC coming from any of the Fixed H_2S detectors located strategically throughout the plant.	
Audible and printed alarm generated from any of the Fixed Monitoring Stations near the plants perimeter or in the residential areas surrounding the plant site.	
Abnormally high H_2S levels as reported by The Environmental Company (TEC).	

NCG Compressors failure due to loss of pressure on the discharge piping (logic control assuming a leak).	
Odor complaints from area residents.	

10.3.3.3 POSSIBLE CAUSES

INDICATIONS	COMMENTS
Failure of a pipe and/or weld due to material defect or corrosion/erosion.	
Failure of a pipe and/or weld due to an over pressurization condition.	
Failure of a sealing gasket located between flanged piping.	
Mechanical damage to system piping/valving.	
Safety/pressure relief valve fails in the OPEN position.	

10.3.3.4 IMMEDIATE ACTIONS

INDICATIONS	COMMENTS
Clear the affected area of all personnel and barricade the affected area.	
Implement the ERP guidelines.	
Notify the Civil Defense Agency.	Inform CDA of H2S levels internally and as noted on perimeter monitoring stations. CDA is the lead agency to determine community evacuation requirements.
Notify the Department of Health (Clean Air Branch)	
Notify County Planning Department Director	
Notify PGV Management.	
Notify HELCO of plant availability and status.	

If the source of the leak is isolatable, personnel must don SCBA's prior to entering the affected area to isolate the leak.	

If the source of the leak cannot be isolated while the plant is in operation, it may be necessary to shut in the Production Wells.	NOTE: It will be necessary to implement steps 1 through 8 in a safe an expedient manner.
10.3.3.5 SUPPLEMENTARY ACTIONS	
INDICATIONS	COMMENTS
If the source of the leak has been successfully isolated, carefully evaluate the effects of the release in respect to the overall operability of the plant.	
If the source of the leak has been successfully isolated, continue area monitoring of any residual H_2S levels.	Ensure that H_2S levels continue to decrease.
If the Production Wells were shut in, it may be necessary to allow minimum steam flow by bypassing the flash separators and directing steam flow directly into the reinjection header.	
Inform HELCO of the current plant status, and expected duration of the current situation.	

10.3.4 FIRE

10.3.4.1 GENERAL

INDICATIONS	COMMENTS
A Fire at any facility would be considered a very serious casualty. A Fire could result in personnel injury, equipment damage, and the possibilities of an extended outage of the power plant and in the most extreme case, it may require the evacuation of plant personnel. The key to reducing or minimizing the effects of a fire is the identification and response to the source of the fire.	PGV personnel will immediately notify both the Fire Department and CDA in the event of any fire on-site whether or not it seems to be an incipient fire response. No one shall enter a structure to fight a fire that cannot be put out with a fire extinguisher.

10.3.4.2 SYMPTOMS/INDICATIONS

INDICATIONS	COMMENTS
Fire Alarm in CSC	From Detronics panel or computer printout.
Visual indicators or report of flames or electrical arcs reported from plant personnel.	
Emergency Diesel Fire Pump running indications.	

10.3.4.3 POSSIBLE CAUSES

INDICATIONS	COMMENTS
Hotwork being performed in the plant	Smoking is prohibited around any flammable substance. A Hot Work Permit and a fire watch are required prior to any cutting, welding and grinding.

Flammable product making contact with hot surfaces	All flammables i.e.…Spray lubricants solvents shall be stored in the flammable locker located east of the maintenance shop in a approved flammable i.e.… Pentane and fuels shall be stored in approved storage container. All containers shall be grounded inside of a containment berm.
Electrical malfunctions/failures causing class "C" fire	Only trained personnel shall fight a fire at an incipient response level.

10.3.4.4 IMMEDIATE ACTIONS

INDICATIONS	COMMENTS
If a fire occurs at the facility, activate the Emergency Response Plan (ERP) and institute the Incident Command System (ICS). Once the Fire Department arrives, the PGV incident commander shall turnover the ICS duties of the IC to the Hawaii County Fire Department. PGV's Incident Commander shall act as an assistant to the HCFD.	Trained personnel shall also utilize the AFFF fire monitors to extinguish a fire as long *as* no additional PPE is required, and the Fire Department has been notified. See Organization structure in the ERP/HAZWOPER training procedures
If required, evacuate all non-essential personnel.	The Alarm Siren System is located on top of the CSC control building. This siren is tested each month at 11:45 am on the first working day. The siren is a steady tone alarm with a red beacon light attached. This alarm is to be used in the event of an emergency that requires potential evacuation of personnel or the activation of the Incident Command System (ICS).
Secure all operating equipment as required.	All Emergency Responders shall remain on-site to perform critical operations of the facility. As a rule, the CSC operator and Plant Technicians shall remain on-site to secure the operation of the facility. All other Emergency Response Personnel will report to their designated area to help with the evacuation of all non-essential personnel and with the emergency.

Shutdown all non-essential equipment adjacent to fire to prevent possible spreading of fire.	Annual training required to utilize, fire equipment. Refer to Safety training package.

10.3.4.5 SUPPLEMENATRY ACTIONS

INDICATIONS	COMMENTS
Verify that all non-essential personnel are evacuated from the plant and accounted for by name.	All plant personnel shall strictly follow the Emergency Escape Procedures which is referred to in the ERP/EAP/HAZWOPER procedures. All PGV personnel have been issued an electronic gate key that will log employees in and out. Contractors and Visitors will be logged in and out from the CSC log. In the event of an emergency, the admin 2 personnel have been trained to print out an entry report and provide it to the Incident Commander.
Assist with first aid if required.	All Operations and Maintenance personnel have been trained in CPR and basic First-aid. Employees that have been trained will provide Basic First-aid to employee in the event of an emergency. If necessary CSC operator will **immediately notify** 1011 in the event an employee is injured. All injured employees are not to be moved unless they're located in a life threatening situation. All injured employees will be transported to Hilo Medical Center for treatment.
Notify appropriate personnel.	PGV management, agencies, etc.
Inspect plant equipment when applicable.	
Restore from casualty as situation allows.	

10.3.5 EARTHQUAKE

10.3.5.1 GENERAL

INDICATIONS	COMMENTS
An earthquake, whether large or small in magnitude and duration, presents many situations requiring operator attention. It is the operator's responsibility at the onset of an earthquake to first ensure his/her personal safety is established. After the immediate physical effects of the earthquake have passed, operators can further enhance their safety through evacuation of the plant. Then, existing plant conditions are evaluated and balanced against personnel/plant safety requirements to determine if re-entry is appropriate.	
Structures that have shaken loose and falling objects (missile hazards) present the highest danger during and after an earthquake. Operators should utilize an inherently stable structure for protection from missile hazards, i.e. desk, table and doorway.	
Consideration should be given to the proximity of the protection chosen in relation to high pressure/temperature fluid systems and electrical systems. In all cases, protection should be utilized quickly and movement through the plant suspended until the earthquake cases. Once the earthquake has stopped, immediate evacuation of personnel should commence with subsequent steps taken to ensure all personnel are present and/or accounted for at this point in time.	
Attention should be directed at this point to the integrity of the plant and collateral damage suffered by systems and structures from the earthquake. Actions to restore service systems to the Power Plant may be impractical due to damage to the distribution system and the rest of the complex.	

For this reason plant restoration should take place as system integrity is verified safe for operation and as the need exists.	

10.3.5.2 SYMPTOMS/INDICATIONS

INDICATIONS	COMMENTS
Visible movement of ground and buildings.	

10.3.5.3 POSSIBLE CAUSES

INDICATIONS	COMMENTS
Geological disturbances.	

10.3.5.4 IMMEDIATE ACTIONS

INDICATIONS	COMMENTS
Take cover using the closest means available. Do not attempt to use stairways until the earthquake ends.	
Evacuate all non-essential personnel once the earthquake has stopped.	

10.3.5.5 SUPPLEMENTARY ACTIONS

INDICATIONS	COMMENTS
Verify that all personnel are evacuated from the plant and accounted for by name.	
Perform a cursory inspection of the plant without entering the building.	
Perform the following actions concurrently:	
If no visible danger exists within the plant's perimeter, ENTER the plant and inspect the components and systems for damage.	
If required, perform the applicable system casualty procedures. Do not attempt to restore electrical power at this time.	
If electrical power is not available, RESTORE electrical power. Electrical power shall be restored only after all the MCC and lighting panel supply breakers have been opened. Reenergize buses and controllers one at a time to ensure operational integrity.	

Inspect the distribution systems for leaks or other damage as well as the conditions of all control buildings.	

10.4 WELLFIELD UPSET

10.4 Loss of Mechanical Integrity Injection Wells	
INITIAL INDICATIONS	
INDICATIONS	**COMMENTS**
Loss of mechanical integrity would be indicated by loss of nitrogen pressure within the well annulus.	PGV Monitors annulus pressures 24/7 locally and remotely in CSC.
Hangdown liner failure, increase in injection pressure.	
Well casing failure, decrease in annulus pressure.	
IMMEDIATE ACTIONS	
ACTIONS	**COMMENTS**
A loss of nitrogen pressure triggers PGV to implement additional tests and possible shut in the injection well.	The injection well will be shut in when exhibiting an unacceptable loss of nitrogen pressure (10% in 5 hours) in the annulus.
Steps to perform: • Make operational changes to the plant and shut in the injection well. • Notify Wellfield Technician and the EH&S Manager. • Check surface piping and wellhead for leaks • Perform nitrogen pressure test using the procedure for annual nitrogen pressure test. • Confirm water level in the annulus with Echo meter.	

	Additional testing will include: • Temperature survey • Pressure survey • Echo meter testing • Sinker bar or feeler gauge runs • Caliper runs • Video inspection • Electric casing inspection logs
	Refer to System Operating Procedures (SOP) • 10.4.1 PGV Injection Testing of Wells • 10.4.2 PGV Mechanical Integrity Testing • 10.4.3 PGV Loss of Mechanical Integrity • 10.4.4 PGV Echo meter Testing
SUPPLEMENTARY ACTIONS	
ACTIONS	**COMMENTS**
Call management and appropriate government agencies.	

PUNA GEOTHERMAL VENTURE

STANDARD OPERATING PROCEDURE

ORMAT

Title: Injectivity Testing of Wells	Procedure: SOP-012K	Revision: 0	Page 1 of 3
		Review Date: 5/3/21	Issued: 10/14/10
	Plant Manager: Jordan Hara		Signature:

Purpose:

Possible means of monitoring injectivity of a geothermal injection well

System Description:

Wellpad A has three reinjection wells KS-1A, KS-11, KS-13 and KS-20, wellpad E has one reinjection well KS-3 and wellpad B has one reinjection well KS-15. The 8" reinjection fluid piping tees from the main 16" reinjection header and is supplied with an 8" gate valve for isolation. The 8" pipe continues to the wellhead assemblies and is supplied with the following accessories listed as installed in line:

A. A flow orifice plate for flow measurement.

B. A pressure safety valve assembly to prevent exceeding design pressure of piping. The assembly includes a 4" gate valve (normally locked in open position) for isolation when maintenance is performed, a 4" B S & B rupture disk (PSE-2410A1) with design burst pressure of 500 psig at 310'F and a J.E. Lonegran 4" pressure relief valve (PSV-2410 E 3) with a design burst pressure of 500 psig and 1394 gpm flow.

C. A globe hammer valve (8") for flow control to well and a check valve (8") to prevent back flow.

D. The wellhead assembly is comprised of a one WKM 8" wing valve (fluid inlet), two Foster 8" wellhead valves (vertical), one 3" suave valve (vent), four 3" wing valves (horizontal) for N2 injection, pressure indicators, and bleed off. All 3" wing valves are WKM (Cooper Ind.) 5000 psig gate valve.

E. A 1 ½" nitrogen (N2) line is supplied from N2 header to connect to a 3" wing valve inlet to the annulus. The N2 line is comprised of a 1 ½" gate valve header isolation, 1 ½" gate valve and a 1 ½" check valve before connecting to wellhead valve. The N2 system is supplied from the N2 storage tank and is connected to the reinjection well annulus. A pressure measurement device is installed to monitor annulus pressure. High pressure N2 is added as required to maintain pressure on the annulus.

Prerequisites:

The following systems/equipment must be operating or lined up to operate prior to initiating this procedure

Start-up Procedure:

1. If possible wellbore problems are anticipated, make a sinker bar run using a sinker bar with a larger o.d. than p/t tools.

a. Run In Hole (RIH) to logging depth to insure that well bore is open.

b. RIH @ a slow rate ~ 100'/min. to minimize the chance of getting hung up.

2. Begin cooling injection and allow operation to become stable for a few hours.
    a) Shut in well during off peak hours
    b) Start flow of raw water into well to get well under vacuum conditions
    c) After well goes into vacuum conditions, reduce the flow of water to gravity feed from the raw water system.

3. Perform pressure temperature (p/t) survey, Step rate test, and pressure fall off to desired depth ~3000' in injection area.
    a. Adjust flow rate as needed so pt tool not to interfere with flow. Recommended rate is raw water valve fully open, gravity feed.
    b. Record well head pressure, Annulus pressure, and flow rate readings every 15 minutes through out the entire test.
    c. RIH @ 120' / min, from surface to desired depth in well.
    d. Hang PT tool approximately 10' from bottom of hole, and keep flow rate constant for an additional 30 minutes.
    e. With PT tool at the same depth, adjust flow rate higher and hold constant for 120 minutes. Recommended rate is raw water valve fully open, raw water pump on with recirc valve fully open. Raw water line pressure will be between 120 and 140 psi.
    f. With PT tool at the same depth, adjust flow rate higher and hold constant for 120 minutes. Recommended rate is raw water valve fully open, raw water pump on with recirc valve partial closed. Raw water line pressure will be between 250 and 300 psi.
    g. Shut off and isolate water flow into well bore and log pressure drop off for 90 minutes
    h. POH @ 120' / min, keeping water flow into well shut in
    i. Calculation for injectivity, gpm per psi = Maximum bottom hole pressure with water flowing prior to shut in minus bottom hole pressure after well stabilizes after pressure drop off divided into flow rate at the time of shut in.

j. Rig down PTS and return well to reinjection.

4. Additional logging may be performed to obtain further information if so desired.

Note: For all logging evolutions refer to the P.G.V. procedure for "Logging Wells"

PUNA GEOTHERMAL VENTURE
STANDARD OPERATING PROCEDURE

Title: Mechanical Integrity Testing (MIT)	Procedure: SOP-012H	Revision: 2	Page 1 of 3
		Review Date: 5/3/21	Issued: 10/14/10
	Plant Manager: Jordan Hara		Signature: Jordan L Hara

Purpose:

Describe possible means of proving mechanical integrity of a geothermal well

System Description:

Wellpad A has three reinjection wells KS-1A, KS-11, KS-13 and KS-20, wellpad E has one reinjection well KS-3 and wellpad B has one reinjection well KS-15. The 8"reinjection fluid piping tees from the main 16" reinjection header, and is supplied with an 8" gate valve for isolation. The 8" pipe continues to the wellhead assemblies and is supplied with the following accessories listed as installed in line:

A. A flow orifice plate for flow measurement.

B. A pressure safety valve assembly to prevent exceeding design pressure of piping. The assembly includes a 4" gate valve (normally locked in open position) for isolation when maintenance is performed, a 4" B S & B rupture disk (PSE-2410A1) with design burst pressure of 500 psig at 310'F and a J.E. Lonegran 4" pressure relief valve (PSV-2410 E 3) with a design burst pressure of 500 psig and 1394 gpm flow.

C. A globe hammer valve (8") for flow control to well and a check valve (8") to prevent back flow.

D. The wellhead assembly is comprised of a one WKM 8" wing valve (fluid inlet), two Foster 8" wellhead valves (vertical), one 3" suave valve (vent), four 3" wing valves (horizontal) for N2 injection, pressure indicators, and bleed off. All 3" wing valves are WKM (Cooper Ind.) 5000 psig gate valve.

E. A 1 ½" nitrogen (N2) line is supplied from N2 header to connect to a 3" wing valve inlet to the annulus. The N2 line is comprised of a 1 ½" gate valve header isolation, 1 ½" gate valve and a 1 ½" check valve before connecting to wellhead valve. The N2 system is supplied from the N2 storage tank and is connected to the reinjection well annulus. A pressure measurement device is installed to monitor annulus pressure. High pressure N2 is added as required to maintain pressure on the annulus.

Prerequisites:

The following systems/equipment must be operating or lined up to operate prior to initiating this procedure

Start-up Procedure:

1. Make a sinker bar run using a sinker bar with a larger o.d. than p/t tools.
    a. Run In Hole (RIH) to ~ 3000' to insure that well bore is open.

b. RIH @ a slow rate ~ 100'/min. to minimize the chance of getting hung up.

2. Perform pressure temperature (p/t) survey to desired depth ~3000'.
   a. This will determine static fluid level in the well bore.
   b. This will also identify abnormal bottom hole pressures and temperatures.

2a. Schedule for running MIT's

a. Run tools into well at 120 feet per minute. Hang tool 10' above set down or at pre-determined setting.

b. Wait on bottom 90 minutes after all injection has been stopped after shut-in, to record pressure drop off. Pull tools out of hole at 120 feet per minute to record initial static conditions.

c. Run 2nd log 12 hours after shut-in to record temperature build up and pressure stabilization.

d. If abnormal conditions are observed on second log, run 3rd log 36 hours after shut-in

3. Perform Nitrogen (N2) pressure test on well bore casing after well is returned to service following well surveys
   a. Use specific well calculation sheet for pressure needed to depress fluid to 3000'.
   b. Use pressure gauge and chart recorder to monitor pressure losses
   c. Pump nitrogen into the annular space between the production casing and hang down liner.
   d. When calculated pressure is achieved complete 5 hour drop test per written Operations procedure
   e. Check all surface equipment for leaks during this evolution.

Note: If the above tests pass satisfactorily it may be considered by some to have acceptable integrity. If not additional testing could possibly be as follows but not limited to.

4. RIH with a gauge ring and allow ~ 1" clearance to Inner Diameter (ID) of casing.

5. RIH with a multi finger caliper to desired depth and log ID of casing while Pulling Out Of Hole (POOH).

6. Run a Bond Log to ensure the cement on the back side of the casing has good integrity.

Note: Bottom hole temperatures must be within the ratings of tools.

7. Additional logging may be performed to obtain further information if so desired.

Note: For all logging evolutions refer to the P.G.V. procedure for "Logging Wells"

PUNA GEOTHERMAL VENTURE

STANDARD OPERATING PROCEDURE

ORMAT

Title: Loss of Mechanical Integrity Injection Wells	Procedure: SOP-012J	Revision: 0	Page 1 of 3
		Review Date: 5/3/2021	Issued: 10/14/10
	Plant Manager: Jordan Hara		Signature: Jordan L Hara

Purpose:

Loss of mechanical integrity would be indicated by loss of nitrogen pressure within the well annulus. If this occurs in any or all injection wells, the following procedure should be followed.

System Description:

Wellpad A has three reinjection wells KS-1A, KS-11, KS-13 and KS-20, wellpad E has one reinjection well KS-3 and wellpad B has one reinjection well KS-15. The 8" reinjection fluid piping tees from the main 16" reinjection header and is supplied with an 8" gate valve for isolation. The 8" pipe continues to the wellhead assemblies and is supplied with the following accessories listed as installed in line:

A. A flow orifice plate for flow measurement.

B. A pressure safety valve assembly to prevent exceeding design pressure of piping. The assembly includes a 4" gate valve (normally locked in open position) for isolation when maintenance is performed, a 4" B S & B rupture disk (PSE-2410A1) with design burst pressure of 500 psig at 310'F and a J.E. Lonegran 4" pressure relief valve (PSV-2410 E 3) with a design burst pressure of 500 psig and 1394 gpm flow.

C. A globe hammer valve (8") for flow control to well and a check valve (8") to prevent back flow.

D. The wellhead assembly is comprised of a one WKM 8" wing valve (fluid inlet), two Foster 8" wellhead valves (vertical), one 3" suave valve (vent), four 3" wing valves (horizontal) for N2 injection, pressure indicators, and bleed off. All 3" wing valves are WKM (Cooper Ind.) 5000 psig gate valve.

E. A 1 ½" nitrogen (N2) line is supplied from N2 header to connect to a 3" wing valve inlet to the annulus. The N2 line is comprised of a 1 ½" gate valve header isolation, 1 ½" gate valve and a 1 ½" check valve before connecting to wellhead valve. The N2 system is supplied from the N2 storage tank and is connected to the reinjection well annulus. A pressure measurement device is installed to monitor annulus pressure. High pressure N2 is added as required to maintain pressure on the annulus.

Prerequisites:

The following systems/equipment must be operating or lined up to operate prior to initiating this procedure.

Start-up Procedure:

1. Well(s) exhibiting an unacceptable loss of nitrogen pressure (10% in 5 hours) during the annual nitrogen pressure test should be immediately shut in, and diagnostics performed. During normal operating conditions i.e. unchanged wellhead pressure and temperature, well(s) exhibiting a loss of 5% in 12 hours will flag the possibility of integrity loss. If this occurs, perform the following:

- Make operational changes to the plant and shut in the injection well.
- Notify Wellfield Technician and Environmental Manager
- Check surface piping and wellhead for leaks
- Perform nitrogen pressure test using the procedure for annual nitrogen pressure test
- Confirm water level in annulas with Echometer

Any well that meets the normal test criteria would be available for injection service.

2. Any well that fails the nitrogen pressure test should remain shut in, and down hole surveys should be conducted to assess the condition of the well and plan for repair or abandonment. These surveys could include any of the following:

- Temperature survey
- Pressure survey
- Echometer testing
- Sinker bar or feeler gauge runs
- Caliper log
- Video inspection
- Electronic casing inspection logs

There is no lead-time on temperature and pressure surveys using PGV's wireline unit. For logs requiring an electric line unit (e.g., caliper, video, or casing inspection), the minimum lead-time would be ~ 7 days.

3. If a drilling rig were required to repair or abandon the well, most of the equipment, materials, and services would have to be shipped from the mainland by barge. These could include the following:

- Workover rig, if not available locally
- Drillpipe and drill collars, if not available locally

- BOP stack (3M or 5M rating as required)
- Cementing units and cement additives
- Drilling mud components
- Drilling tools, fishing tools, bits, mills, etc.
- Tubulars: special work strings, casing, liner, hangdown liner
- Electric line logging tools

Estimated lead-time to specify, order, and mobilize the necessary equipment is in the range of 3-6 months. The critical path item is likely to be casing or the drilling rig. Therefore, the availability of a drilling rig on the island may or may not influence the lead-time.

PUNA GEOTHERMAL VENTURE

STANDARD OPERATING PROCEDURE

ORMAT

Title: Echometer testing, Mechanical Integrity Injection Wells	Procedure: SOP-012L	Revision: 0	
		Review Date: 5/3/2021	Issued: 10/14/10
	Plant Manager: Jordan Hara		Signature: Jordan L Hara

Purpose:

An annual Mechanical integrity test is a permit required procedure to confirm integrity of the hang down liner on injection wells. Loss of mechanical integrity would be indicated by loss of nitrogen pressure within the well annulus. Echometer testing confirms water levels in the annular space by generating a pressure wave in the casing annulus. The wave travels through the casing annulus gas to the liquid level and reflects the wave back to the surface. Reference material, Nitrogen Velocities1, Model M Manual

System Description:

Wellpad A has three reinjection wells KS-1A, KS-11, KS-13 and KS-20, wellpad E has one reinjection well KS-3 and wellpad B has one reinjection well KS-15. The 8" reinjection fluid piping tees from the main 16" reinjection header and is supplied with an 8" gate valve for isolation. The 8" pipe continues to the wellhead assemblies and is supplied with the following accessories listed as installed in line:

A. A flow orifice plate for flow measurement.

B. A pressure safety valve assembly to prevent exceeding design pressure of piping. The assembly includes a 4" gate valve (normally locked in open position) for isolation when maintenance is performed, a 4" B S & B rupture disk (PSE-2410A1) with design burst pressure of 500 psig at 310'F and a J.E. Lonegran 4" pressure relief valve (PSV-2410 E 3) with a design burst pressure of 500 psig and 1394 gpm flow.

C. A globe hammer valve (8") for flow control to well and a check valve (8") to prevent back flow.

D. The wellhead assembly is comprised of a one WKM 8" wing valve (fluid inlet), two Foster 8" wellhead valves (vertical), one 3" suave valve (vent), four 3" wing valves (horizontal) for N2 injection, pressure indicators, and bleed off. All 3" wing valves are WKM (Cooper Ind.) 5000 psig gate valve.

E. A 1 ½" nitrogen (N2) line is supplied from N2 header to connect to a 3" wing valve inlet to the annulus. The N2 line is comprised of a 1 ½" gate valve header isolation, 1 ½" gate valve and a 1 ½" check valve before connecting to wellhead valve. The N2 system is supplied from the N2 storage tank and is connected to the reinjection well annulus. A pressure measurement device is installed to monitor annulus pressure. High pressure N2 is added as required to maintain pressure on the annulus.

Prerequisites:

The following systems/equipment must be operating or lined up to operate prior to initiating this procedure

Start-up Procedure:

1. Echometer Operation

- Securely attach the Echometer Gas Gun to the well annulus casing valve
- Close the casing pressure bleed valve and filler bleed chamber valve
- Open the casing valve to the gas gun slowly
- Pull trigger ring, annulus pressure will be seen on the gas gun pressure gauge
- Lift the Cocking arm to close the internal gas valve
- Record Time, casing pressure, wellhead pressure, flow rate, and injection temperature
- Bleed the gas chamber by turning the Filler-bleeder valve clockwise until the gas gun pressure has decreased to around 200 psi below casing pressure
- Connect the coaxial cable from the gun to the Model M recorder
- Turn power switch on.
- Set the gain controls to Auto
- Turn chart drive ON
- When signaled on chart drive to generate pulse, pull the trigger ring
- Turn chart drive off after detecting the liquid level signal.
- Repeat the procedure to verify the result.
- Turn power switch off
- Close the casing valve and relieve pressure from the gas gun by opening the casing pressure bled valve.

2. Interpretation of Echometer chart data

- Measure echo line in seconds to second decimal
- Determine echo velocity using Acoustic Velocity in Nitrogen chart, annulus pressure and injection pressure are used for this calculation and need to be accurate.

- Multiply the Echo time in seconds to two decimal position by determined velocity and divide by two to calculate water level in the annular space. {E x V / 2}

APPENDICES
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APPENDIX A

DESCRIPTION OF PROJECT FACILITIES AND OPERATIONS

The PGV Project is located approximately 21 miles southeast of the city in Hilo in the Puna district of the Island of Hawaii (see attached map Figure 1.1 and 1.2). The Project occupies about 25 acres of surface area within a 500 acre project area in the Kapoho section of the Kilauea Lower East Rift Geothermal Resource Subzone

The PGV Project is designed to generate electrical energy from geothermal fluids produced from the Puna geothermal field. The project, which is planned for an operating life of 35 years, currently consists of:

- ☒ Ten (10) integrated back pressure steam turbine and air cooled binary cycle turbine power generating modules;
- ☒ Two (2) integrated Two Level Units (ITLU)
- ☒ Up to fourteen geothermal wells drilled from up to three or more wellpads;
- ☒ Brine, steam and other process pipelines;
- ☒ Pollution control equipment;
- ☒ Brine separators and accumulators;
- ☒ Switchyard;
- ☒ Office, warehouse, workshop, control building, visitors room, and related facilities;
- ☒ Access roads; and
- ☒ Auxiliary facilities such as air compressors, H_2S abatement, vapor recovery and chemical systems, fire protection equipment, etc.

Figure 1.2 shows the locations of the major project facilities. The Project delivers its electrical energy to the HELCO energy grid system.

A.1 Geothermal Wellfield Facilities

The PGV Project currently uses the geothermal wellpads A & E shown in Figure 1.2. Presently there are two production wells and two injection well on wellpad A and three production wells and two injection wells on wellpad E.

Each wellpad contains a wellpad piping subsystem. The subsystem begins downstream of the master shutoff valves at each wellhead and includes production, throttling, and isolation valves, and instrumentation required for local or remote monitoring and control of each well. A rock catcher is installed immediately downstream of each production wellhead. The subsystem includes a flash separator that flashes the geothermal fluids into steam and brine fractions.

A.2 Well Control and Safety Equipment During Drilling

Blowout Prevention Equipment (BOP) will be installed on the wellhead during all phases of drilling below depths of 800 - 1000 feet (i.e., below depth of surface casing). The BOP equipment will permit the remote shut-in of the well whether the drilling assembly is inside the well or not. Also, a kill line will be hooked up to the well during drilling in order to permit kill mud or water to be pumped into the well at anytime during drilling.

During drilling operations which could result in a steam or H_2S release, the BOP will be connected to a cyclonic muffler (for noise and brine particulate and aerosol abatement) and H_2S abatement equipment. This equipment will also be used during abated well clean out.

The BOP equipment will be operated and pressure tested after installation on each casing string per Hawaii State Department of Land and Natural Resources (DLNR) requirements. Subsequently, the BOP assembly will be tested daily during drilling.

H_2S emission sensors will be installed on the rig floor, well cellar, and mud outlets (shaker) during drilling. These sensors will activate an alarm in the drilling logging unit if ambient H_2S concentrations exceed 10 parts per million (ppm).

A wind sock will be erected at the rig in order to determine the wind drift direction in the event of an uncontrolled steam or H_2S release.

A total of 12 portable breathing air packs with a minimum 30-minute capacity will be maintained at the drilling rig for use by the drilling crew and supervisory personnel.

A.3 Turbine Generator System

The back pressure steam turbine and binary cycle power generating unit known as Ormat Energy Converter (OEC) is a closed system that, during normal operations, does not release any H_2S or other gases to the atmosphere. The steam, after expanding and passing through the steam turbine and OEC unit heat exchanger, respectively, will condense. The steam condensate is recombined with geothermal brine from initial separation and noncondensible gases produced from the reservoir. All of the produced fluids and gases are injected into the geothermal reservoir. Each steam turbine is equipped with a bypass system so that its binary unit can operate even during turbine upset conditions or plant start-up. When a steam turbine bypass system is actuated, the steam turbine bypass valves are opened and the binary unit, which is capable of operating with high temperature steam, will continue to operate. The steam flow from the wells is reduced as necessary to accommodate the reduced production capacity of the power plant.

Expansion Plant

The ITLU consists of two turbines, each turbine is coupled to a synchronous generator. Geothermal fluid is diverted into the unit, where the brine flows through the tube section of the vaporizer (of level 1), then through the tube section of the vaporizer (of level 2) and the tube section of the preheaters of level1 and level 2, heating the organic liquid that flows through the shell section of the preheaters and then of the vaporizer, to its boiling point.

Before entering the turbine, the motive fluid vapors pass through a liquid separator located on top of the vaporizer. In the separator, drops of liquid, which are still present in the vapors, are separated to prevent impingement on turbine blades.

The liquid level in the vaporizers is regulated by level control valves (which are controlled by a level control system.

Under normal operation, organic vapor flows through turbine main valves and injection valves and enters the turbines.

In some operational modes the turbine bypass line allows vapor to bypass the turbine assembly through turbine bypass control valves and to flow directly to the condenser.

The exhausted vapor from the level I turbine flows through a recuperator to an air-cooled condenser. In level II the exhaust vapors flow directly to an air-cooled condenser. In the condensers, the vapors are cooled and condensed into liquid.

Multistage centrifugal pumps are designed to supply motive fluid to the vaporizers at vaporizing pressure.

Under normal operation conditions the entire motive fluid system is sealed and no motive fluid is lost in the process.

A.4 Non-Condensable Gas Control

Under normal operating conditions, there are no emissions of H_2S other than negligible fugitive emissions from piping joints, which are minimized through proper design, ongoing maintenance procedures, and monitoring by plant operators.

Almost all of the noncondensible gases produced from the geothermal reservoir with the geothermal fluids are partitioned with the steam in the flash separators and will pass through the steam turbines. As the low pressure steam leaving the steam turbines is condensed in the OEC vaporizers, the noncondensible gases and residual water vapor will remain under low pressure.

These gases are piped to gas compressors which compress the gases prior to injection into the condensate. This mix is combined with the brine and ultimately, injected into the geothermal reservoir.

A.5 Steam Release Facility

Under certain relatively uncommon upset conditions of the power plant generating units, such as failure of the electrical transmission line(s) out of the power plant, complete upset of the geothermal fluid injection system, or if pressure in the steam line exceeds design set points, a steam release facility is used to release steam treated with sodium hydroxide (NaOH) to remove 96 percent of the H_2S through two rock mufflers (which will reduce noise levels) while the wellfield production rate is being reduced or shutoff. The rock muffler system is designed to handle the 100 percent of the maximum total plant flow. After this reduction, the power plant will emit less than 2 percent of full flow uncontrolled H_2S (90 percent flow control). After an upset condition is brought under control, a minimum steam/geo flow, as required to maintain an appropriate wellhead temperature, will be directed to injection wells until the plant can resume normal operation.

A.6 Electrical Systems

The power plant contains several electrical systems. The major electrical equipment includes the main power, auxiliary power, station service, and current and potential transformers; generator circuit breakers; high voltage switchgear; load centers; motor control centers; and station batteries.

The power from each of the ten (10) 13.8 KV generators feeds to the 13.8 KV busbars, with a switchgear for each generator. Each 13.8 KV busbar connects to a 13.8/69 KV step up transformer and power feeds into the HELCO switching and metering yard at a voltage of 69 KV. The 13.8 KV/480 V step down transformers supply 480 V power for all the power plant internal requirements and for the auxiliary systems.

A 1400 KW diesel generator unit is installed at the plant site to produce power for essential electrical services at the PGV site under emergency conditions, if needed. The power that would be generated from the diesel generator is sufficient to support one air compressor; the battery chargers; the heating, ventilating, and air conditioning (HVAC) system; control room systems; steam release facility H_2S abatement system; and emergency lighting.

Expansion Plant

Each of the two turbines is coupled to a synchronous generator. The generator is air-to-water cooled with a maximal output power of 8 MW, at 10 MVA, 60 Hz, 13.8 kV. The three-phase power output is distributed through the high voltage switch gear.

A.7 Control Systems

The control system consists of three control subsystems:

- ☒ Wellhead control subsystem
- ☒ OEC control subsystem
- ☒ ITLU control subsystem
- ☒ Power plant control subsystem

A.7.1 Wellhead Control Subsystem

The wellhead control subsystem includes the individual wellheads, the wellpads, the gathering systems, and the emergency steam release facility.

All wellheads are equipped with temperature and pressure gauges on the well casing below the master valves. Flow from each wellhead can be automatically controlled by plant's steam pressure. The steam flow leaving each wellpad is measured. Control valves at the steam release facility will have air and pneumatic piston operators that respond automatically to signals from the plant control room or upon sensing over pressure in the steam pipeline. The H_2S abatement system at the steam release facility operates automatically when steam is released through the rock mufflers.

A.7.2 OEC Control Subsystem

The OEC control, housed in an individual OEC control shelter located adjacent to each OEC module, controls both turbines and the entire OEC operation.

A programmable controller is used to record, process, and signal steam and working fluid pressures, voltage levels, speed, kilowatt output, and current of each OEC unit. The programmable controller provides diagnostic as well as control functions and allows the operator to isolate an individual unit for testing or repairs and then automatically restart it after the failure condition has been rectified.

The individual OEC control shed will also house the high power, high voltage components of the OEC units including the circuit breakers, magnetic contacts, fuses, transformers, power capacitors, metering instruments, overload, short circuit asymmetry, and reverse power protective devices.

ITLU Control Subsystem

The ITLU control, housed in an individual ITLU control shelter located adjacent to each ITLU module controls each turbine and the entire ITLU operation.

A programmable controller is used to record, process brine and working fluid pressures, voltage levels, speed, kilowatt output, and current of each ITLU unit. The programmable controller provides diagnostic as well as control functions and allows the operator to isolate an individual unit for testing or repairs and then automatically restart it after the failure condition has been rectified.

The individual ITLU control shelter will also house the high power, high voltage components of the a ITLU units including the circuit breakers, magnetic contacts, fuses, transformers, power capacitors, metering instruments, overload, short circuit asymmetry, and reverse power protective devices.
ITLU control, housed in an individual ITLU control shelter located adjacent to each ITLU module, controls each turbine and the entire ITLU operation.

A.7.3 Power Plant Control

The entire power plant is designed with a computerized automatic control system that will require a minimum number of personnel to operate the plant. The plant operators monitor the plant during operation from the central control station (CSC) with regular on site monitoring of all equipment. Individual and plant-wide control systems operate automatically to prevent injuries to plant personnel or equipment and to protect public health and safety. Standby equipment will start automatically to avoid tripping a turbine unit during normal operations. Monitoring data will be logged and stored in the programmable controller. Information and control signals from the individual OEC controllers will be recorded and controlled from the main power plant control room.

A.8 Auxiliary Systems

The primary auxiliary systems will be the compressed air system, HVAC system, service water system, fire protection system, vapor recovery system, H_2S abatement system and H_2S monitoring system.

A.8.1 Compressed Air System

Compressed air is required for instrumentation, control, and plant maintenance (service air) requirements. Compressed air at 100 psig is distributed throughout the plant from a central compression system that includes air compressors, desiccant type dryers, and dry air storage tanks.

A.8.2 HVAC Systems

Air conditioning will be provided for the electrical equipment and CSC. The system is designed to prevent heat buildup and maintain a positive pressure in the rooms. The air conditioning includes a sealed refrigeration system and coil, outside air supply duct, and an air distribution fan.

A.8.3 Fire Protection System

Facility safety considerations played a significant role in the plant design. The fire protection system is designed in accordance with applicable National Fire Protection Association (NFPA) and Hawaii State and local fire standards and major components of the plant's safety features include the following:

Fire Fighting: The plant is equipped with an underground fire main system, which completely encircles the OEC units. Strategically placed hydrant/monitors permit full coverage of the plant's components, including the OEC's, air coolers, control room, utility building, motor control center rooms, noncondensible gas, compressors, and pentane storage tanks. The fire main is maintained under continuous pressure by an electric jockey pump. Whenever the fire main is utilized, the system pressure momentarily drops, activating a diesel driven 2500 gpm centrifugal fire pump. The fire pump is supplied by a 500,000 gallon water storage tank located adjacent to the pump house.

Flame and Combustible Gas Detection: The entire installation of OEC's, air coolers, and pentane storage tanks are continuously monitored by a series of flame and gas detectors tied into a centralized control/alarm panel located in the plant's control room.

Halon: The plant's control room and all the OEC control shelters are protected by halon flooding systems.

FM 200: The ITLU expansion plant control shelters are protected by FM 200 flooding systems.

Sprinkler Systems: The pentane storage tanks in the power block (existing plant) and storage tank on Pad D extension (new plant) are protected by a deluge type water sprinkler system.

Portable Extinguisher: Portable extinguishers are located throughout the plant (see Figure 4.3 and Table 4.2)

A.8.4 Service and Supplemental Water

Service water is used for general purpose cleaning and maintenance of the power plant. A 250,000 gallon supply from the upper half of a 500,000 gallon tanks provides the service water for the facility.

Supplemental water may need to be added to the fluid injection system during periods of operation at low load or during start-up to ensure maintenance of the water column in the injection system, which is necessary for proper operation of the gas control system. Make-up is obtained from one of three sources. Two on-site wells with a capacity of 1,450 gallons per minute are available as the project's primary water source. A connection to the County water system has been made and is a back-up water source for the Project.

A.8.5 Vapor Recovery System

Operational and maintenance considerations require the purging of non-condensable gases (O_2, N_2) from the pentane condensers. These NCGs also contain pentane vapor. To reduce pentane emissions, these purges are routed through a Vapor Recovery Unit (VRU) or Vapor Recovery Maintenance Unit (VRMU)

Vapor Recovery Unit (VRU)

Uses a two stage refrigeration cycle

Vapor Recovery Maintenance Unit (VRMU)

Uses a 4-step recovery and an activated carbon filtration system.

Both units achieve a 95% or better recovery of pentane. The pentane recovered is returned to the pentane storage vessels in power block.

A.8.6 H_2S Abatement System (Sulfa Treat)

To reduce fugitive H_2S emissions from equipment handling the noncondensible gases, the H_2S abatement system collects potential gaseous emissions and passes them through two reactor beds which absorbs and chemically destroys any H_2S.

A.8.7 Plant H_2S Monitoring System

This system has 36 sensors located at potential H_2S emission sources and along internal plant boundaries. The sensors are tied into a panel located in control room to provide early warning of any upset abnormal or emergency condition within the plant boundaries. This system allows plant personnel to become more quickly aware of fugitive H_2S emissions so that they may be addressed.

A.9 Process Flow Monitoring Systems

The power plant is serviced by a fully automated control station which constantly monitors the facility process flows, rates, temperatures, and pressures. The status of these processes are displayed on two CRT displays, both graphically and in digital readout form, and on console gauges. Abnormal conditions are monitored via audible and visual alarms. Pressure switches and gauges are installed in the motive fluid and oil systems for monitoring and operation control. Thermistors and RTD's are installed in the motive fluid and in the electrical and lubrication oil systems to shut down the unit in case of excessive temperatures in the system. Level switches are installed in the motive fluid and lubrication oil systems to warn and to protect the unit against low or high liquid levels.

A.10 Power Plant Structures and Facilities

Buildings exist for the central station control (CSC), offices, warehouse, workshop, air compression system, emergency generator, storage for heavy equipment, and fire pumps. In addition, there are ten shelters for the OEC units.

A.10.1 Chemical Storage Facilities

The chemicals and hydrocarbons used or stored in quantities over 100 gallons at the site are 50% sodium hydroxide (caustic soda), pentane, diesel fuel, gasoline, and water treatment chemicals.

Pentane is a colorless liquid that vaporizes at 97°F. It is non-toxic or corrosive, but is flammable at concentrations between 1.5 percent and 7.8 percent (volume) in air (see Appendix F). Pentane is similar to propane (bottle gas), which is used for heating and cooking in many rural locations, but is much less hazardous than propane because of its higher boiling point and lower vapor pressure.

Each OEC unit in the power block will contain approximately 3,560 gallons of pentane. Additional pentane, as much as 9,000 gallons is stored on site in two tanks which also have sufficient capacity to receive the entire pentane contents of one OEC unit. The tanks have a design temperature of 250°F and design pressure of 150 psig. Working fluid pumps are used to transfer pentane to and from the tanks to recharge the systems or remove the pentane from OEC units requiring maintenance.

Each ITLU unit on Pad D will contain approximately 12,000 gallons of pentane. Additional pentane, as much as 6000 gallons, is stored on Wellpad D in one tank which also have sufficient capacity to receive the entire pentane contents of one ITLU unit. The tanks have a design temperature of 250°F and design pressure of 150 psig.

Caustic soda (NaOH) is a corrosive material that is toxic if ingested and can cause skin and eye irritation upon contact. It is soluble in water and used in households as a cleaning agent. Sodium hydroxide will be delivered to the site as a 50 percent solution and stored in two tanks;

one with a 50 percent solution as delivered and the other tank with a 15 percent solution, diluted for use in the abatement system.

Sulfuric acid is a corrosive material that is toxic if ingested and can cause skin and eye irritation upon contact. It is soluble in water and used in households as a cleaning agent. Sodium hydroxide will be delivered to the site as a 50 percent solution and stored in two tanks; one with a 50 percent solution as delivered and the other tank with a 15 percent solution, diluted for use in the abatement system.

Secondary containment structures such as dikes or berms are constructed around the sodium hydroxide storage tanks, gasoline, diesel, and bulk treatment chemical day tanks. These tanks are segregated by distance from any incompatible materials. Applicable federal regulations (e.g., OSHA and EPA) and Hawaii regulations (e.g., DOSH and HDOH) will be incorporated into procedures and standard policies of the facility. Applicable Department of Transportation (DOT) regulations (Title 49 CFR, Section 171-178) are incorporated into the procedures for delivery of any hazardous materials used on site.

A.10.2 Fencing

A six-foot high chain link fence is installed around the power plant site boundary and each of the wellpads. A gate at each entrance to the facility restricts unauthorized access.

A.11 Construction Yard

During construction a temporary yard of about 5 acres is used next to the main entrance road to the plant, off State Highway 132. The construction yard is used for the temporary storage of construction materials and fabrication of some project components. The construction yard perimeter is fenced.

A.12 Operation and Maintenance

The operational life of the PGV Project facilities is estimated to be 35 years. The power plant and wellfield are operated in a manner that protects human health and the environment. The facility staff operates equipment, oversees production, and responds to emergency conditions. An important part of the operational phase of the project is regular maintenance and monitoring of both the power plant and the wellfield.

The power plant and wellfield operate continuously 24 hours per day, seven days per week. Qualified operators are on site at all times. Routine maintenance is conducted by workers during the normal daytime work shift. If repair work is required because of malfunction of part of the power plant modules, the maintenance work may continue 24 hours per day, seven days per week, until full power output can be resumed.

Scheduled power plant maintenance is conducted for each generating module, as needed. Thorough maintenance procedures, such as turbine disassembly and inspection, may be conducted during this scheduled maintenance, and is coordinated with HELCO to ensure the maintenance of a reliable power system.

A.13 Plant Start Up and Shutdown

The modular nature of the power plant allows a gradual start up process as relatively small increments of power are synchronized to the grid, one at a time. The total process is relatively rapid due to that small moment of inertia and small volume to be heated during each step of the start up process.

The start up of the generating modules typically begins with energizing the auxiliary systems needed for starting one OEC unit. These auxiliary systems include the air compressor, OEC lube and sealing oil pumps, condenser fans for one OEC unit, and working fluid circulation pump. The power for the auxiliary systems can be supplied either from the 1400 KW diesel generator or from the utility grid.

To start an OEC unit, the steam turbine bypass is opened, and the steam gradually let into the OEC vaporizer until it reaches full flow. After the start up and synchronization of the first OEC unit, the power plant supplies its own power and also supply power to the grid. As more OEC units are started and synchronized, the wells will be opened up to allow more steam to flow from the wellfield.

The steam turbine paired with each OEC unit can be started as soon as its OEC unit is in operation. The steam is gradually introduced into the steam turbines and increased until full load steam turbine operation is achieved.

Shutdown of each OEC/steam turbine module is handled in reverse order, i.e, first the steam flow to the steam turbine is gradually reduced while the steam turbine bypass is gradually opened. After the steam turbine is shut down, the steam to the OEC unit is gradually closed. Finally, either the diesel generator or the utility grid supplies the power to the auxiliaries after the last OEC unit has been shutdown.

A.14 Hydrologic Monitoring

The hydrologic monitoring program consists of the following activities:

- ☒ Review and update, with field measurements, the data for existing non-geothermal wells in the site area;
- ☒ Permit, drill, and sample two on-site monitoring wells;
- ☒ Obtaining background samples and water levels from existing well locations; and,
- ☒ Continue the monitoring program with quarterly water level measurements and water quality sampling and analyses at selected locations.

PGV will immediately notify the County Planning Department, State Department of Health, and the Department of Land and Natural Resources in situations when a change in any geothermal well conditions indicates there is a leak or failure in the production or injection well casing. PGV will take the appropriate steps to test the production/injection system and evaluate the related well and casing downhole conditions. If leakage of geothermal waters to the shallow aquifer is demonstrated, any leaking well would be shut-in, and an assessment of the potential impact would be made by the monitoring contractor or other qualified consultants. In addition, steps would be identified to evaluate the impact as it relates to down gradient water users.

A.15 Air Quality and Meteorological Monitoring

A total of three fixed locations are operated by PGV for the continuous off-site monitoring of ambient H_2S in accordance with the Hawaii County Geothermal Resource Permit (GRP) and the Hawaii State Department of Health Permit to Operate (PTO) permit conditions (Figure A-1). Each station contains support equipment to accumulate and average the data and a real-time alarm system in the event that ambient H_2S concentrations exceed the levels specified in the permit conditions.

The first location (southwest) is in an area in the prevailing downwind direction from most of the project activities including the power plant.

The second location (southeast) is in topographically down gradient from the power plant in an area where ambient H_2S concentrations associated with night-time drainage flow of air to the southeast from the plant site area would likely occur. In addition, this location is downwind from the plant site when the winds are from the northeast as occurs frequently in the project area in the daytime.

The third location is in an area northwest of the power plant which generally would not be directly downwind but is topographically down gradient.

A meteorological station (southwest) provides data on site meteorologic conditions (Figure A-1). Continuously-recording instrumentation on a 10-meter tower will provide data for:

- ☒ wind speed,
- ☒ wind direction,
- ☒ air temperature,

- ☒ relative humidity,
- ☒ sigma theta (calculated by the data logger), and
- ☒ precipitation.

These stations communicate data and alarm conditions to a control room computer terminal. The DOH operates three stations: one in Lanipuna Gardens and two in Leilani Estates which also communicates ambient conditions to the control room computer terminal.

In addition if an upset causes off-site H_2S emissions, PGV personnel can use portable monitors to quantify the level and exact location of any off-site emissions.

A.16 Noise Monitoring

A total of two fixed locations are operated by PGV to monitor noise. The first location (southwest) is in an area in the prevailing downwind direction from most of the project activities including the power plant. The second location (south end) is in topographically down-gradient from the power plant.

PGV recognizes the need to establish close communication with the public. Nuisance and annoyance may develop from occasional noises that, although they may not exceed levels identified in the permit conditions may occur from time to time at the site. Therefore, PGV will respond by visiting the complaint site and taking sound readings with portable sound meters. PGV also makes scheduled tours of the plant perimeter to determine sound levels. In this manner reports of permit conditions being exceeded are investigated by PGV or its monitoring contractor responding to a complaint from the public. The County can then become involved only if a specific incident, continuing or complaint-type situation cannot be resolved at this level.

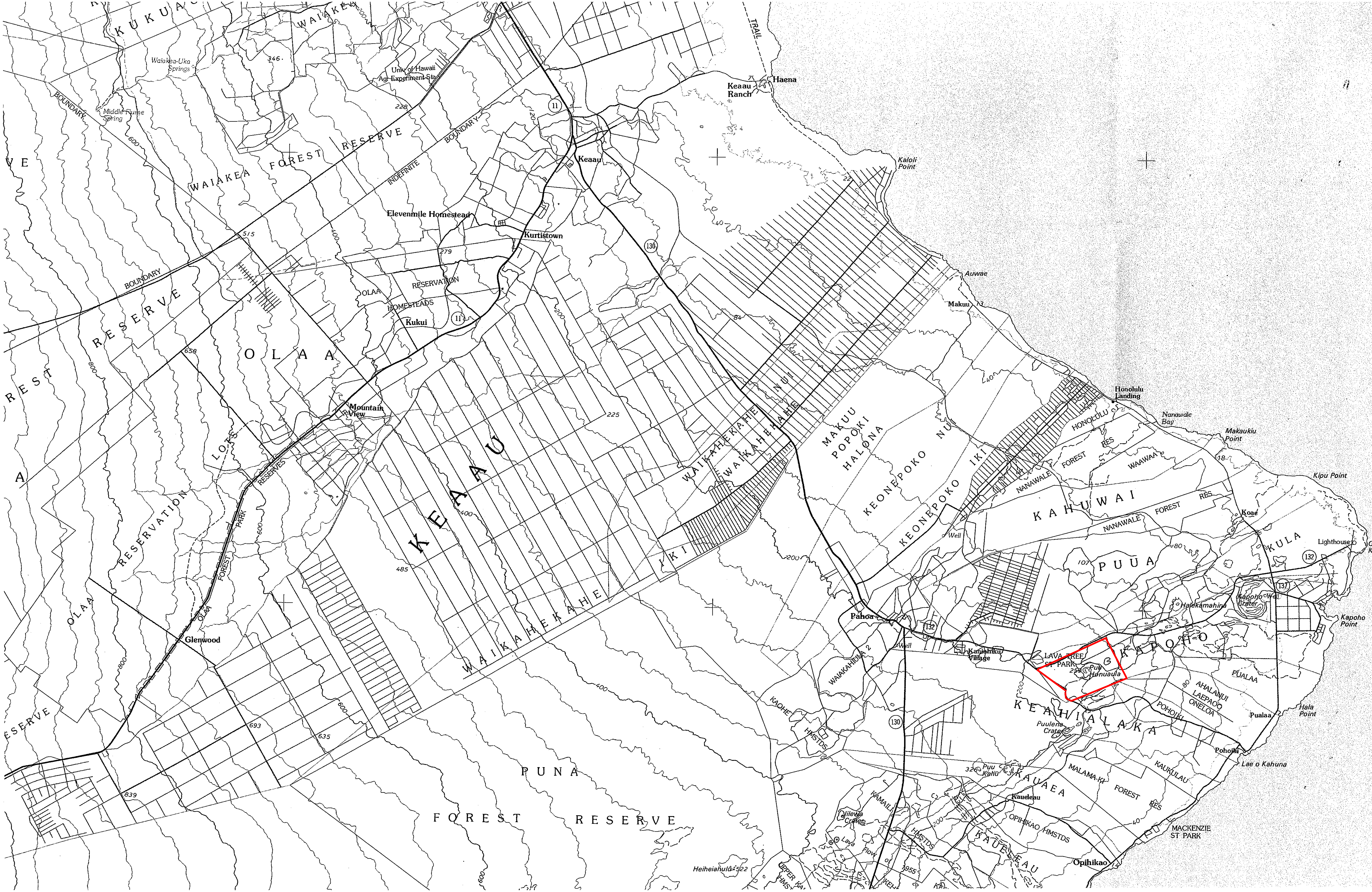
A.17 Monitoring Procedures While Drilling

A.17.1 H_2S Releases

H_2S sensors are installed in the well cellar, rig floor and mud shaker. Measurements from these sensors are logged continuously in the mud logging trailer.

A.17.2 Well Casing Problems

Mud circulating temperature in and out are logged continuously during drilling. A rapid increase in the mud out temperature could indicate a casing problem. If this occurs, mud or water is pumped continuously into the well to keep it cool. The well can then be surveyed with temperature, caliper or sonic measurement tools to investigate the casing integrity.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TRAIL
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Middle Flume Spring
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Haena
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INDEFINITE BOUNDARY
Keaau
Kaloli Point
Elevenmile Homestead
Kurtistown
OLAA RESERVATION HOMESTEADS
Kukui
Auwae
Makuu
RESERVE
OLAA
FOREST
Mountain View
KEAAU
WAIKAHEKAHE NUI
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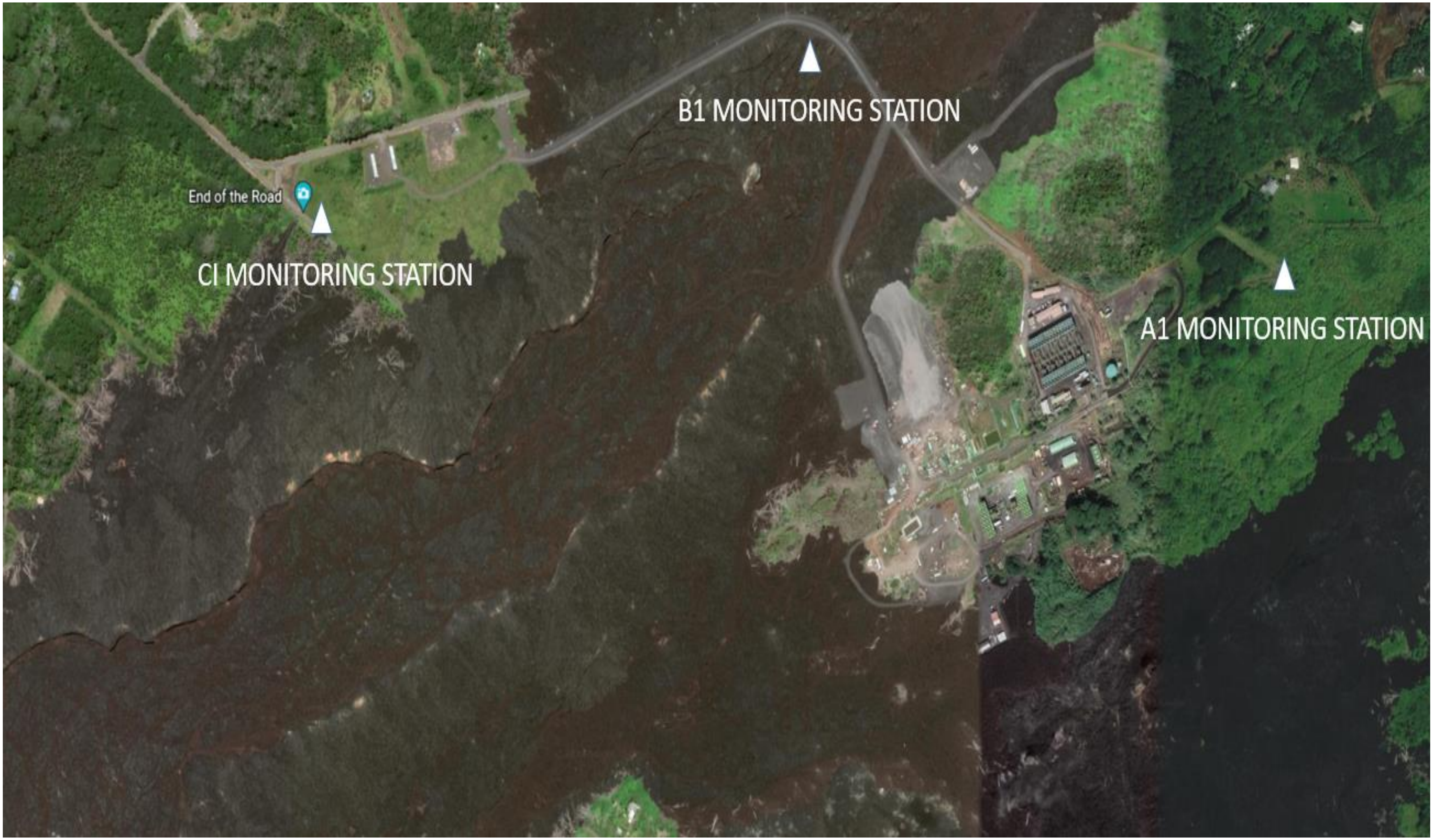
MAKUU
POPOKI
HALONA
KEONEPOKO NUI
KEONEPOKO IKI
Honolulu Landing
Nanawale Bay
Makaukiu Point
HONOLULU FOREST RES
NANAWALE FOREST RES
WAAWAA
Kipu Point
KAHUWAI
Koae
Lighthouse
KULA
PUUA
Well
LOTS RESERVES
RESERVATION
FOREST PARK
Kapoho Crater
Kapoho Point
Halekamahina
Pahoa
Kaniahiku Village
LAVA TREE ST PARK
Puu Honuaula
KAPOHO
PUALAA
AHALANUI
LAEPAOO
ONELOA
Pualaa
Hala Point
WAIAKAHIULA 2
KAOHE HMSTDS
KEAHIALAKA
POHOIKI
Pohoiki
Lae o Kahuna
Puulena Crater
Glenwood
Puu Kahu
KAUAEA
MALAMA-KI FOREST RES
KAUKULAU
Kauleleau
KAMAILI
OPIHIKAO HMSTDS
Opihikao
MACKENZIE ST PARK
KAUELEAU
Ilewia Crater
Lava Flow
Heiheiahulu
PUNA
FOREST RESERVE
ESERVE

PUNA GEOTHERMAL VENTURE ENVIRONMENTAL STATION LOCATIONS



APPENDIX B

COURSE CONTENT - HYDROGEN SULFIDE SAFETY TRAINING

B1 – H2S Summit Training Program

PGV TRAINING PROGRAM

HYDROGEN SULFIDE SAFETY

EMPLOYEE HANDBOOK

Summit Training Source

What's Inside

If you wish to purchase additional copies, please call our office at 1-800-842-0466.

Why These Guidelines Are Vital to Your Safety

In very low concentrations, hydrogen sulfide is a nuisance due to its distinctive, unpleasant odor. In very high concentrations, however, exposure can be fatal—paralyzing breathing ability and causing nearly instantaneous death.

While the effects of exposure can vary from person to person, by understanding and respecting the potential hazards, you can work safely with hydrogen sulfide.

In this handbook, "Hydrogen Sulfide Safety," you will learn:

- What hydrogen sulfide is
- Potential hazards associated with hydrogen sulfide
- Best Safety Practices you can use to reduce your risk

About Hydrogen Sulfide

Hydrogen sulfide is an extremely toxic, colorless, flammable gas with a characteristic "rotten egg" smell when present in low concentrations. Hydrogen sulfide is a liquid when stored at low temperature or high pressure. It turns rapidly into a gas at room temperature and under normal pressure conditions.

Hydrogen sulfide, or H2S, occurs naturally in crude petroleum, natural gas, volcanic gases, and hot springs. It can also result from bacterial breakdown of organic matter, as well as being produced by human and animal wastes.

Hydrogen sulfide is used in processing many different types of products. For example, in the Pulp and Paper industry, it is used as a whitening agent for paper products.

Hydrogen sulfide is also a by-product of petroleum production, and occurs naturally in crude oil. It may be present in petroleum production facilities or in petrochemical operations. It may also be present at natural gas wells or in natural gas pipelines.

Hydrogen sulfide may also be released during wastewater treatment and during landfill operations.

Key Point

Hydrogen sulfide is an extremely toxic, colorless, flammable gas with a characteristic "rotten egg" smell when present in small concentrations.

Potential Hazards

Hydrogen sulfide is released primarily as a gas. It is heavier than air, meaning concentrations of hydrogen sulfide are greatest near the ground or in low-lying areas.

Hydrogen sulfide's distinctive "rotten egg" smell can be detected at very low concentrations, as low as 5 to 10 parts per billion. As an example, one part per billion is about the same as a thimble of gas in a theatre full of air.

Agencies have established requirements and guidelines to limit exposure. An 8-hour threshold limit value of 10 parts per million has been established for exposure to hydrogen sulfide. A 15 minute short-term exposure limit of 15 parts per million has also been established with a ceiling limit of 20-parts per million.

Hydrogen sulfide is irritating to the eyes and respiratory tract. Eye irritations may persist for several days. Symptoms include scratchiness, tearing, and burning. Respiratory tract symptoms include coughing, pain in breathing, and pain in the nose and throat. Most symptoms disappear when exposure stops.

Chronic exposure has been associated with damage to the eyes, and possibly nerve tissue damage. A concentration level in the atmosphere of 100 parts per million is considered dangerous. At this level, short-term exposure causes severe eye irritation, coughing, dizziness, headache, and nausea.

Hydrogen sulfide can paralyze the sense of smell at concentrations between 50 and 100 parts per million. Just because you can't smell rotten eggs doesn't mean hydrogen sulfide is not present in harmful concentrations.

Exposure to very high concentrations—over 700 parts per million —may result in collapse, coma, and death from respiratory failure, even in very brief exposures.

The gas may be present around pumps, valves, and pipe fittings. Compressors or relief valves may also emit hydrogen sulfide gas. Since the gas is heavier than air, confined spaces, like sewers, manholes, tunnels, utility vaults, boilers, or tanks, may be collection points.

Liquids containing hydrogen sulfide may be present on or near wastewater piping systems.

Hydrogen sulfide is extremely flammable. Both the liquid and the gas pose a serious fire hazard if released. Since the gas is heavier than air, and can remain in the air for long periods of time, it can travel long distances along floors or the ground. An ignition source distant from where the gas was released can cause ignition and flashback, with a resulting fire or explosion.

Key Point

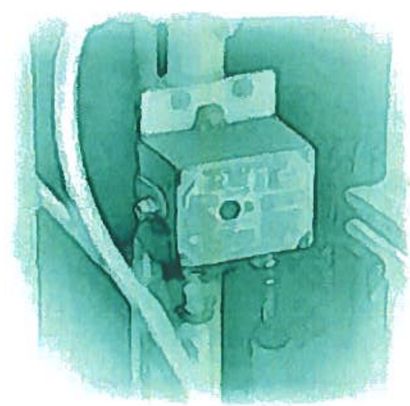
Exposure to very high concentrations of hydrogen sulfide—over 700 parts per million—may result in collapse, coma, and death from respiratory failure, even in very brief exposures.

Working Safely with Hydrogen Sulfide

The key to working safely with hydrogen sulfide is detection. Knowing when and where the gas is present is essential to your safety. While engineering controls, like ventilation, minimize your exposure, the gas may be present in the work environment.

Since hydrogen sulfide is both flammable and toxic, safety policies and standards focus on minimizing your exposure to the gas and eliminating sources of ignition.

Wear a **personal monitor** whenever there is the possibility of exposure to hydrogen sulfide. The monitor detects the presence of the gas in the air. It should be set to sound an alarm if concentrations go above established standards.



Fixed monitors should be in place in areas where a release of hydrogen sulfide may occur, such as near pumps, compressors, or relief valves. These monitors should be set to sound an alarm when concentrations rise above established standards.

Key Point

The key to working safely with hydrogen sulfide is detection—knowing when and where the gas is present.

A **portable monitor** should be used to test air quality before using any equipment that may be a source of ignition, and as part of every confined space entry procedure.

Since high concentrations can paralyze your sense of smell, do not rely on your nose to detect the presence of hydrogen sulfide. Just one breath of a very high concentration of the gas can be fatal.

If a fixed or personal monitor sounds, immediately leave the area. Your health and safety depend on your quick reaction to the alarm. Report the incident to your supervisor. Reenter the area only after testing has occurred and concentrations have returned to acceptable levels.

Key Point

If the alarm on your personal air quality monitor or if a fixed monitor sounds, immediately leave the area. Your health and safety depend on your quick reaction to the alarm.

Working Safely with Hydrogen Sulfide *(continued)*

When working with hydrogen sulfide, you must take action to protect your health and safety by selecting and wearing the correct Personal Protective Equipment, or PPE.

To work safely in an area with a high concentration of hydrogen sulfide, you must wear respiratory protection in the form of an air supplying respirator. An air supplying respirator provides you with breathable air from a source that is different from the contaminated air.

There are three types of air supplying respirators:

- Air line
- Self-contained breathing apparatus, or SCBA
- A combination of an air line with an escape pack

Air line respirators supply clean air from a cylinder of compressed air, a large diameter tube, or a compressor. When using a compressor, the clean air source is located away from the contaminated area, but not further than 300 yards.

Key Point

To work safely in an area with a high concentration of hydrogen sulfide, you must wear respiratory protection in the form of an air supplying respirator.

SCBA respirators supply clean air from a cylinder worn on the back. The air flows through a regulator to a mask, providing clean air to the user. The air supply is typically rated for 30 to 60 minutes, but actual times may vary according to body size, physical condition, and the type of work activity. An alarm sounds when the air supply is low.

A combination air line respirator with an escape pack provides a small cylinder of air for escape if the air line supply is cut off.

- Since hydrogen sulfide irritates the eyes, it is recommended that a full-face piece be used when working in environments where there is a potential for exposure.
- Before wearing any type of respirator, you must complete a medical questionnaire, be fit tested, and receive training on the proper use and limitations of the respirator to be used in your workplace.

Working Safely with Hydrogen Sulfide *(continued)*

Chemical Resistant Gloves
To protect your skin, wear chemical resistant gloves if you may be exposed to hydrogen sulfide gas or a liquid containing hydrogen sulfide. Neoprene, butyl rubber, or PVC gloves are recommended.

Eye/Face Protection
To minimize the likelihood of exposure to liquid or pressurized hydrogen sulfide gas, wear splash goggles or safety glasses, and a face shield.

Wash Stations/Safety Showers
Know where eyewash stations and safety showers are located in your work environment, in case an accidental exposure to your skin or eyes occurs.

Since hydrogen sulfide is **extremely flammable**, keep sparks, heat, or open flame out of any area where hydrogen sulfide may be present. Be sure all electrical equipment is grounded before use and is equipped with a ground fault circuit interrupter. If possible, use only spark-proof tools or explosion-proof equipment.

If you must use spark-producing equipment in areas where the gas may be present, always comply with your site's procedures and policies. Monitor air quality before using these tools or equipment, and follow all safe work permit procedures in place for identifying potential hazards in your work area.

Emergency Response

In an emergency, a person who rushes into a situation without taking the necessary precautions can often become another victim. Thorough training and precautions are vital to responding correctly to an emergency situation.

There are different levels of emergency response training. A Level One Responder is an employee who witnesses or discovers a release of hazardous material and is trained to notify proper authorities.

In a hydrogen sulfide emergency situation, such as an uncontrolled release of the gas, you and your coworkers must immediately leave the area. Call for help, using a radio or the emergency telephone number for your site to contact emergency personnel. Provide your name, the location of the emergency, and what type of help is needed.

You may have inhaled hydrogen sulfide; move to fresh air immediately and seek medical attention. The physical effects of hydrogen sulfide are reversible, if fresh air is supplied quickly.

If your skin has been exposed to liquids containing hydrogen sulfide, wash under running water for at least fifteen minutes.

Since symptoms may be delayed, anyone who has inhaled hydrogen sulfide should remain under medical observation.

Key Point

Only respond to an emergency according to the level of your training, never respond to a situation for which you are not prepared.

Only authorized personnel should attempt rescue operations. Do not attempt rescue if you have not been trained. Rescuers should always work in the buddy system. At a minimum, an air supplying respirator and gloves must be worn. Under certain conditions, fire retardant clothing may also be necessary. Only authorized personnel should administer bottled oxygen or perform CPR.

Secure the area to be sure no one else can be exposed. Use tape or barricades to block access to the area.

Report the incident to your supervisor or safety staff.

Summary

While exposure to high concentrations of hydrogen sulfide can be fatal, you can work safely with this substance if you understand and respect the potential hazards.

The key to working safely with hydrogen sulfide is detection. Wear a personal hydrogen sulfide monitor whenever there is the possibility of exposure. Use portable monitoring equipment when performing certain tasks, such as before using equipment that may be an ignition source, or before confined space entry.

If a monitor alarm sounds, you and your coworkers must leave the area immediately and report the incident to your supervisor.

Wear the correct Personal Protective Equipment for your work tasks. Respiratory protection may be necessary in certain situations.

Keep sparks, heat, or open flames out of areas where hydrogen sulfide may be present. Follow safe work procedures when using any possible ignition source in these areas.

Be prepared for emergency situations. Never respond to an emergency beyond your training. Do not become part of the problem.

Your ability to recognize the hazards, and take action to reduce the risk, will ensure your health and safety.

Safety Quiz

To review your knowledge of Hydrogen Sulfide Safety, answer the questions below.

Your Name ______________________ Date ______________

1. Characteristics of Hydrogen sulfide include all of the following except:
   a. Toxic
   b. Colorless
   c. Flammable
   d. Odorless
   e. Heavier than air

2. Since hydrogen sulfide is heavier than air, concentrations of it are often found _______.
   a. In high places and along ceilings
   b. Along the ground or low-lying areas
   c. Near doorways and windows
   d. None of the above.

3. Regulatory agencies have established limits for exposure to hydrogen sulfide. An 8-hour threshold limit value of ___ parts per million has been established.
   a. 20
   b. 10
   c. 45
   d. 40

4. Exposure to high concentrations of hydrogen sulfide—over 700 parts per million—may result in collapse, coma, and death from respiratory failure, even in very brief exposures.
   a. True
   b. False

Safety Quiz *(continued)*

5. High concentrations can paralyze your sense of smell; do not rely on your nose to detect the presence of hydrogen sulfide.

   a. True b. False

6. To work safely in an area with a high concentration of hydrogen sulfide, you must wear respiratory protection in the form of a(n)_____ respirator.

   a. Air purifying
   b. Medical
   c. Air supplying
   d. Filtered

7. SCBA stands for __________.

   a. Safety Carbon Breathing Assistance
   b. Self-Contained Breathing Apparatus
   c. Self-Contained Breath Analyzer
   d. Safety Controlled Breathing Apparatus

8. If your personal monitor or a fixed air quality monitor signals an alarm indicating the presence of hydrogen sulfide, you should immediately ___________.

   a. Call your supervisor
   b. Locate the source of the leak
   c. Leave the area and seek fresh air
   d. Call the police

9. If exposed to a liquid containing hydrogen sulfide, wash eyes or skin for at least ________.

   a. 20 minutes
   b. 15 minutes
   c. 1 hour
   d. 45 seconds

10. Before wearing any type of respirator, you must complete a medical questionnaire, be fit tested, and receive training on the respirator to be used in your workplace.

    a. True b. False

Notes

SUMMIT TRAINING SOURCE

4170 Embassy Drive SE
Grand Rapids, MI 49546
800-842-0466
www.safetyontheweb.com

APPENDIX C

COURSE CONTENT - BLOWOUT PREVENTION TRAINING FOR DRILLING OPERATIONS

AMERICAN WELL CONTROL & SAFETY LLC

WellCAP Accredited

MODULAR FULL - COMBINATION WELL CONTROL COURSE FOR DRILLING; WELL COMPLETION/WORKOVER and WELL SERVICING , WITH SUBSEA OPTION

Modular Format

Outline

DAY 1 - 8 HOURS

TOPIC I – Enrollment and Orientation (1 hour)

TOPIC II – Pressure Concepts (2 hours)

A. Pressure Gradient

B. Hydrostatic Pressure and U-tube concept

C. Formation Pressure

D. Fracture Pressure and Gradient
   1. Methods of determination

E. Friction Pressure
   1. Equivalent circulation density (ECD)
   2. Slow pump pressure, slow pump rate

TOPIC III – B O P EQUIPMENT Configuration (1 hour)

A. Components
B. Annular Preventers
C. Ram Preventers
D. Drilling Spool or integral body valves
E. Accumulators
F. Other equipment
G. Video – PETEX – "Causes and prevention of blowouts – Part III Equipment)

TOPIC IV - KICK Detection (2 hours)

A. Kick indicators

B. Elements necessary to take a kick

C. Causes while drilling

D. Causes while tripping

E. Warning signs while drilling

F. Warning signs while tripping

G. Blowouts

  1. Definition
  2. Reasons for Blowouts
     a) Video –(Petex –"Causes and Prevention of Blowouts" Part 1)

TOPIC V - SHUT-IN PROCEDURES (1 hour)

A. Shut-in procedures--Surface stack while drilling

  1. Pick up the Kelly
  2. Stop pumps and do a flow check
  3. If well flows, shut the well in

     a) **<u>The Soft Shut-in</u>**
     b) Stop the rotary, sound the alarm
     c) Open the remote choke-line (HCR) valve
     d) Close the annular preventer
     e) Close the drilling choke
     f) Adjust closing pressure on the BOP
     g) Read and record SIDPP, SICP, Pit Gain
     h) Notify supervisor

     i) **<u>The Hard Shut-in</u>**
     j) Stop the rotary, sound the alarm
     k) Pick up the string until tool joint clears the rotary table
     l) Stop the pumps
     m) Close the pipe rams
     n) Confirm all flow has stopped
     o) Open the HCR valve
     p) Read and record SIDPP, SICP, Pit Gain,

B. Shut-in procedures--Surface stack while tripping

1. Set the drillpipe on slips
2. Sound the alarm
3. Install an FOSV
4. Close the FOSV
5. Open the HCR valve to choke
6. Close the BOP
7. Close the choke
8. Confirm flow has stopped
9. Install Kelly then open FOSV
10. Record SIDPP, SCIP, Pit gain, and time
11. Notify supervisor

C. Shut-in Drill Pipe Pressure

1. Definition
2. Differential Pressures

D. Shut-in Casing Pressure

1. Definition
2. Differential Pressures

E. Trapped Pressure

1. Definition
2. Trapped pressure
   a) Bleed no more than ½ barrel at a time

   Example of drillpipe and casing pressure liquid vs. gas kick

F. Diverter

1. Minerals Management Service (MMS) on the use of diverter systems
2. Diverter equipment and purpose
   a) Annular preventer
   b) Diverter lines and hydraulic valves

   Diverter procedure

TOPIC VI - SIMULATOR EXERCISE: ORIENTATION & SHUT-IN PROCEDURES (1 hour)

Each team executes a shut-in, other teams will observe the active team.

DAY 2 - 9 HOURS

TOPIC VII – MMS Regulations Subpart D & F(1 hour)

A. 30 CFR Part 250 Subpart D---Oil and Gas Drilling Operations

B. 30 CFR Part 250 Subpart F--- Oil and Gas Well Workover Operations

C. Bridging documents. Company & contractor differences addressed.

TOPIC VIII - Volume Calculations (1 hour)

A. Workbook exercises 1 -4

B. Pulling pipe and / HP loss

TOPIC IX - FLUIDS (1 hour)

A. Drilling fluids

B. Completion and workover fluids:

C. Types of well bore fluids

TOPIC X – Constant Bottomhole Pressure Well Control Methods (1.5 hours)

Video –(PETEX –"Causes and Prevention of Blowouts" Part II)

Objectives of well control methods

Driller's Method

The Driller's method takes two circulations;

Shut-in the well
Record SIDPP, SICP, and Pit Gain
Open choke and bring pump to SPR while pumping CMW
Maintain casing pressure at or slightly above SICP using the choke
After SPR is achieved, use drill pipe gauge to maintain BHP
Shut the well in after influx is removed from the well.
<u>Back pressure on both gauges should read original SIDPP (at a minimum)</u>
Complete Kill Work sheet
Open choke and bring pump to SPR while pumping KMW
Maintain casing pressure at or slightly above SICP using the choke
After SPR is achieved, use casing gauge to maintain BHP
After drill pipe is full of KMW, use drill pipe gauge to maintain BHP
Maintain Drillpipe pressure until KMW reaches surface.
Verify mud weight
Close well in
SIDPP & SICP should read "0".
Clear floor, open BOP and resume operations

Wait and Weight Method

The wait and weight takes one circulation;

Detect kick, shut well in.
Allow pressures to stabilize.
Record the SIDPP, SICP, Pit Gain
Complete kill worksheet
Bring mud weight to KMW.
Attain SPR while holding casing gauge at or slightly above SICP
Once SPR has been reached observe the DP gauge; it should indicate ICP.
Keep pump rate constant, pressure will decrease as KMW fills the DP. DP pressure drop should follow schedule with minor adjustments to choke.
When the KMW reaches the bit, hold FCP until the KMW reaches the surface.
Stop the pumps, close the well in, check pressures, if no pressure, open choke and check for flow.
No flow – clear the floor and open the BOP
Resume operations (Make necessary calculations)

TOPIC XI - KILL SHEETS (2 hours)

A. Demonstration (Kill Sheet Problem #9000')
B. Do Kill Sheet Problem announced by instructor

TOPIC XII - SIMULATOR EXERCISE: KILL PROCEDURES (1 1/2 hour)

Students simulates kill operation, using the driller's method.

TOPIC XIII - WORKBOOK SESSION (1 hour)

Student not involved in current simulator exercises will work on practice problems in workbook.

DAY 3 - 9 HOURS

9 hours for drilling then test, 9 hours for workover then return for day 4

TOPIC XIV – MMS Regulations Subpart D, F, E, C, and O (30 min)

A. Class goes over regulation questions in part 2 of workbook

TOPIC XV - BOP TESTING PROCEDURES (video) (30 min)

PETEX – "Blowout Preventer Controls"

TOPIC XVI - WELL COMPLETION WELL CONTROL PROBLEMS (15 min)

A. Multiple Completions
B. Performing a drill-stem test
C. Underbalanced operations

TOPIC XVII – Do Kill Sheet Problem announced by instructor to be done on simulator using the wait & weight method.(1¾hours)

TOPIC XVIII - SPECIAL PROBLEMS (30 min.)

A. H_2S
B. Off Bottom Kills
C. Open hole kick (Top Kill)
D. Volumetric method
E. False Kick Indicators
F. Drill string washout
G. Stripping pipe
H. Snubbing, coil-tubing and small tubing
I. Dynamic Lubrication Methods
J. Pipe reciprocation during well kill. page 7-11

TOPIC XIX - SIMULATOR EXERCISE (1 ½ hours) with multiple situations. (The kill sheet was done on day 2). Crews will be brought in separately to ensure solutions aren't to be passed from crew to crew.

TOPIC XX - Review Workbook (1 hr.)

TOPIC XXI - SIMULATOR EXERCISES (1 1/2 hours)
strip pipe in the hole using an annular preventer. All students work together on calculations.

TOPIC XXII – Do kill sheet assigned by instructor and simulate (1 ½ hrs.)

TOPIC XXIII - TEST DRILLING & COMBINATION STUDENTS
(2 hour time limit)

A. Drilling Test (Written)

DAY 3 / 4

COMPLETION/WORKOVER day 3 for 4 hours or
COMBINATION/WellServicing day 4 for 9 hours

TOPIC XXIV – MMS Regulations Subpart F (30 min.)

A. 30 CFR Part 250 Subpart F – Workover
B. Field rules

TOPIC XXV - REASONS FOR COMPLETION WORKOVER OPERATIONS (30 min.)

A. Definitions: Completing Operations
B. Definitions: Workover Operations

TOPIC XXVI - LIVE WELL OPERATIONS (30 min.)

A. Techniques for controlling or killing a producing well
   1. Bullheading
   2. Volumetric Method
   3. Lubricate and bleed
   4. Snubbing unit
   5. Coiled Tubing operation
   6. Packer uses and operation
B. Preparing for well entry

TOPIC XXVII – Simulator Exercise (1 ½ Hours)

A. Static well operations: Underbalance a static well and return it to production.

TOPIC XXVIII – PACKERS (1 hour)

A. Purpose of a packer
   1. Types of packers
   2. Setting a packer
      a) Hydraulic
      b) Mechanical
      c) Electric wireline
      d) Sandline (slickline)
B. Calculate differential forces exerted on a packer (example on board)

TOPIC XXIX – TEST - WORKOVER / COMBINATION STUDENTS
(2 hour time limit)

A. **Completion/Workover Test (Written)**

TOPIC XXX – Coiled Tubing (2 1/2 hours)

A. Uses
   1. Sand washing
   2. Spotting acid
   3. Cementing
   4. Cleanout
   5. Drilling
   6. Milling

B. Advantages

C. Disadvantages

D. Equipment
   1. Power Pack
      a. Prime mover
      b. Hydraulic System
   2. Tubing Injector
   3. Tubing Reel
      a. Reel mechanism
      b. level wind mechanism
   4. Stripper assembly
   5. Blowout Preventers
   6. Operating Console
   7. Accessories and auxiliary equipment
      a. Tubing depth counter
      b. Hydraulic crane
      c. Freestanding injector base
      d. Fluid pumping unit
      e. Liquid pump
      f. Tanks and mixing equipment
      g. Centrifugal pumps

8. Coiled tubing calculations

   a. Tubing volumes

   b. Cased hole

   c. Inside tubing

TOPIC XXXI - SIMULATOR EXERCISE: Circulating well (1 1/2 hour)

Students participate in simulator exercise calculating volumes and spotting acid at the perforations in practice well.

TOPIC XXXII - SMALL TUBING OPERATIONS (30 min.)

A. Applications

B. BOP equipment

C. Flow string systems

D. Pump down equipment

E. Small Tubing Calculations

   1. Hole Volumes
   2. Hydrostatic Pressure
   3. Pressure losses

TOPIC XXXIII - WELL EQUIPMENT (30 min.)

B. Surface equipment

C. Down hole tools and tubulars

TOPIC XXXIV - WELL SERVICING / COMBO Students

(1 hour time limit)

Well Servicing Test -written

Day 5

SUBSEA *(4 Hours)*

TOPIC XXXV - MMS Regulations Subparts C, D, E, F (45 min.)

A. Cover Subsea specific operations in the following subparts
B. 30 CFR Subpart C – Pollution
C. 30 CFR Subpart D – Drilling
D. 30 CFR Subpart E – Completion
E. 30 CFR Subpart F -- Workover

TOPIC XXXVI - SUBSEA EQUIPMENT (45 min.)

A. Diverter system
   1. Shallow flow prior to BOP installation
   2. Shallow prevention technique, procedures and practices
   3. Shallow flow well control methods

B. BOPE
   1. Marine riser systems
   2. BOP control systems
   3. BOP stack
   4. Ball joint
   5. Flex joint
   6. Slip joint
   7. Riser dump valve
      a. Reasons
      b. Consequences
   8. Control options

TOPIC XXXVII - SUBSEA WELL CONTROL CONSIDERATIONS (30 min.)

A. Early kick detection
B. Tripping practices
C. Circulating practices
D. Connecting and rotating practices
E. Ballooning
F. Hydrates
G. Risers
H. Fluids
I. Choke line friction pressure (CLFP)

TOPIC XXXVIII - SUBSEA SHUT-IN PROCEDURES (15 min.)

A. Pre-kick preparation
B. Hard vs Soft shut-in
C. While drilling

D. While tripping

E. Shut-in with bit above BOP's

F. Shut-in with casing or liner

TOPIC XXXIX – CONSTANT BOTTOM HOLE PRESSURE METHODS (15 min.)

A. Drillers method
B. Wait and weight method

TOPIC XXXX - KILL SHEET & SIMULATION (1 1/2 hour)

Students complete a Subsea kill worksheet and use data to complete kill on simulator using the wait and weight method.

TOPIC XXXXI - TEST SUBSEA STUDENTS

(1 HOUR TIME LIMIT)

B. Subsea Test (written)

WellCAP Quality Statement & Comment Policy

Dear Training Participant:
IADC is committed to ensuring that its accredited training providers offer quality instruction and adhere to high standards of conduct. One of the ways we can continue to improve our accreditation system is by listening and responding to the views of training participants. IADC wishes to ensure that:

1. making a comment is as easy as possible
2. we treat any unfavorable comment regarding accredited training providers seriously.
3. we will respond in the right way – for example, with an investigation, an explanation, or collection of further information before taking appropriate action.
4. we learn from comments received and use them to improve the quality of our accreditation program.
5. our training providers learn from comments received and use them to improve the quality of the instruction they provide.

How do you make a comment?
You can comment in person, in writing, by fax, by e-mail, by telephone, or through a form on the IADC website through the addresses listed below.
Please provide sufficient detail concerning your course experience to permit IADC to collect further information as needed (course date, location, training provider, etc.) Your contact information is optional, but will assist IADC if follow-up communications are required.

In Person:	IADC Headquarters 10370 Richmond Ave., Suite 760 Houston, TX 77042 USA	
In Writing:	Western Hemisphere: IADC PO Box 4287 Houston, TX 77210-4287 USA	Eastern Hemisphere: PO Box 1430 6501 BC Nijmegen, The Netherlands
By Fax:	Western Hemisphere: +1-713-292-1946	Eastern Hemisphere: +31-24-360-0759
By Telephone:	Western Hemisphere: +1-713-292-1945	Eastern Hemisphere: +31-24-675-2252
By e-mail:	*training@iadc.org*	
Website:	*www.iadc.org/wellcap/comments.htm*	

WellCAP Quality Statement & Comment Policy Form WCT-25 – Revision 060226

APPENDIX D

POST EMERGENCY RESPONSE PROCEDURES

WRITTEN CONFIRMATION OF RELEASES/INCIDENTS

Following the occurrence of a release of a reportable quantity or any emergency situations described in this plan and in compliance with the GRP, PTO and other County or State requirements, a report will be prepared by the PGV environmental representative or designee of the incident and the appropriate report will be transmitted after review by PGV management to the appropriate individuals and agencies listed below:

- ☒ Federal National Response Center
- ☒ Hawaii County Civil Defense Agency
- ☒ Hawaii County Planning Commission
- ☒ Hawaii State Department of Health, Clean Air Branch
- ☒ Hawaii State Emergency Response Commission
- ☒ Hawaii State Department of Land and Natural Resources
- ☒ Local Emergency Planning Commission

The written notification will include an update of verbal notification information plus the following:

- Actions taken to respond to and contain the release.
- Any known or anticipated acute or chronic health risks associated with the release; and
- Where appropriate, advice regarding medical attention necessary for exposed individuals.

FOLLOW UP INVESTIGATION

PGV's Incident Investigation Team shall compile all documentation and perform a post-incident investigation. Using the following procedure from PGV's Incident Investigation and Reporting Program:

- An incident report shall be submitted before the end of the work shift.
- PGV shall initiate an investigation no later than 48 hours following the incident.
- To guide and document this effort, PGV has developed an incident and investigation form which includes the following:
    - ☒ Date of incident
    - ☒ Date investigation began
    - ☒ A detailed description of the incident
    - ☒ Factors that contributed to the incident
    - ☒ Recommendations resulting from the investigation
- All investigations shall be completed in an efficient and timely fashion, and the results of the investigation distributed for recommendation follow-up and review with personnel.
- The Plant Engineer shall be responsible for follow-up and issuance of monthly status reports until all recommendations are completed.

APPENDIX E
EQUIPMENT AND SERVICE CONTRACTORS

CRANES AND TRUCKS

Yamada Trucking	*Office*
	933-8400
Industrial Crane	
Keaau Services	*Office/Fax*:
	966-9373
Justin Alonzo	960-1238

PROPANE REMOVAL

Hawaii Gas	*Office*
	935-0021
Darrell Ramos	491-3098

WELDERS/CUTTERS

Curt Neil	1-903-931-1899
Denali Welding	217-2379

MACHINING SERVICES

Pacifica Services	*Office*
Trent Bateman	345-6600

APPENDIX F
PENTANE SAFETY DATA SHEET

ConocoPhillips
Specialty Solvents

MATERIAL SAFETY DATA SHEET
n-Pentane (Pure Grade)

1. PRODUCT AND COMPANY IDENTIFICATION

Product Name: n-Pentane (Pure Grade)

Synonyms: Normal Pentane
Pentane

Intended Use: Solvent

Chemical Family: Aliphatic hydrocarbon

Responsible Party: ConocoPhillips Specialty Solvents
Borger, Texas
79007

For Additional MSDSs (800) 762-0942

Technical Information: (832) 486-3339

The intended use of this product is indicated above. If any additional use is known, please contact us at the Technical Information number listed.

EMERGENCY OVERVIEW

24 Hour Emergency Telephone Numbers:

Spill, Leak, Fire or Accident
Call CHEMTREC
North America: (800)424-9300
Others: (703)527-3887 (collect)

California Poison Control System: (800) 356-3129

Health Hazards/Precautionary Measures: Aspiration hazard if swallowed. Can enter lungs and cause damage. Use with adequate ventilation. Avoid contact with eyes, skin and clothing. Do not taste or swallow. Wash thoroughly after handling.

Physical Hazards/Precautionary Measures: Extremely flammable liquid and vapor. Vapor can cause flash fire. Keep away from heat, sparks, flames, static electricity or other sources of ignition.

Appearance: Colorless

Physical form: Liquid

Odor: Mild, gasoline-like

NFPA Hazard Class:

```
Health:       1 (Slight)
Flammability:4 (Extreme)
Reactivity:   0 (Least)
```

HMIS Hazard Class

```
Health:          1 (Slight)
Flammability:    4 (Extreme)
Physical Hazard: 0 (Least)
```

2. COMPOSITION/INFORMATION ON INGREDIENTS

HAZARDOUS COMPONENTS	% WEIGHT	EXPOSURE GUIDELINE Limits	Agency	Type
n-Pentane	99.7	600 ppm	ACGIH	TWA
		1000 ppm	OSHA	TWA

CAS# 109-66-0	1500 ppm	NIOSH	IDLH

Note: State, local or other agencies or advisory groups may have established more stringent limits. Consult an industrial hygienist or similar professional, or your local agencies, for further information.

1%=10,000 PPM.

All components are listed on the TSCA inventory.

3. HAZARDS IDENTIFICATION

Potential Health Effects:

Eye: Contact may cause mild eye irritation including stinging, watering, and redness.

Skin: Contact may cause mild skin irritation including redness, and a burning sensation. Prolonged or repeated contact can worsen irritation by causing drying and cracking of the skin leading to dermatitis (inflammation). No information available on skin absorption. Studies of other exposure routes suggest a low degree of hazard by skin absorption.

Inhalation (Breathing): Low degree of toxicity by inhalation.

Ingestion (Swallowing): Low to moderate degree of toxicity by ingestion. ASPIRATION HAZARD - This material can enter lungs during swallowing or vomiting and cause lung inflammation and damage.

Signs and Symptoms: Effects of overexposure may include irritation of the nose and throat, irritation of the digestive tract, nausea, vomiting, diarrhea, transient excitation followed by signs of nervous system depression (e.g., headache, drowsiness, dizziness, loss of coordination, disorientation and fatigue) and abdominal pain.

Cancer: No data available.

Target Organs: Inadequate data available for this material.

Developmental: Inadequate data available for this material.

Other Comments: Reports have associated repeated and prolonged occupational overexposure to solvents with permanent brain and nervous system damage (sometimes referred to as Solvent or Painters' Syndrome). Intentional misuse by deliberately concentrating and inhaling this material may be harmful or fatal.

Pre-Existing Medical Conditions: Conditions aggravated by exposure may include skin disorders and respiratory (asthma-like) disorders.

Exposure to high concentrations of this material may increase the sensitivity of the heart to certain drugs. Persons with pre-existing heart disorders may be more susceptible to this effect (see Section 4 - Note to Physicians).

4. FIRST AID MEASURES

Eye: If irritation or redness develops, move victim away from exposure and into fresh air. Flush eyes with clean water. If symptoms persist, seek medical attention.

Skin: Remove contaminated shoes and clothing and cleanse affected area(s) thoroughly by washing with mild soap and water. If irritation or redness develops and persists, seek medical attention.

Inhalation (Breathing): First aid is not normally required. If breathing difficulties develop, move victim away from source of exposure and into fresh air. Seek immediate medical attention.

Ingestion (Swallowing): Aspiration hazard: Do not induce vomiting or give anything by mouth because this material can enter the lungs and cause severe lung damage. If victim is drowsy or unconscious and vomiting, place on the left side with the head down. If possible, do not leave victim unattended and observe closely for adequacy of breathing. Seek medical attention.

Note To Physicians: Epinephrine and other sympathomimetic drugs may initiate cardiac arrhythmias in persons exposed to high concentrations of hydrocarbon solvents (e.g., in enclosed spaces or with deliberate abuse). The use of other drugs with less arrhythmogenic potential should be considered. If sympathomimetic drugs are administered, observe for the development of cardiac arrhythmias.

5. FIRE FIGHTING MEASURES

Flammable Properties:

Flash Point: -56.2°F/-49°C (TCC, ASTM D56)
OSHA Flammability Class: Flammable Liquid
LEL%: 1.42 / UEL%: 7.8
Autoignition Temperature: 588°F/309°C

Unusual Fire & Explosion Hazards: This material is extremely flammable and can be ignited by heat, sparks, flames, or other sources of ignition (e.g., static electricity, pilot lights, mechanical/electrical equipment, and electronic devices such as cell phones, computers, calculators, and pagers which have not been certified as intrinsically safe). Vapors may travel considerable distances to a source of ignition where they can ignite, flash back, or explode. May create vapor/air explosion hazard indoors, in confined spaces, outdoors, or in sewers. Vapors are heavier than air and can accumulate in low areas. If container is not properly cooled, it can rupture in the heat of a fire.

Extinguishing Media: Dry chemical, carbon dioxide, or foam is recommended. Water spray is recommended to cool or protect exposed materials or structures. Carbon dioxide can displace oxygen. Use caution when applying carbon dioxide in confined spaces. Water may be ineffective for extinguishment, unless used under favorable conditions by experienced fire fighters.

Fire Fighting Instructions: For fires beyond the incipient stage, emergency responders in the immediate hazard area should wear bunker gear. When the potential chemical hazard is unknown, in enclosed or confined spaces, or when explicitly required by DOT, a self contained breathing apparatus should be worn. In addition, wear other appropriate protective equipment as conditions warrant (see Section 8).

Isolate immediate hazard area, keep unauthorized personnel out. Stop spill/release if it can be done with minimal risk. Move undamaged containers from immediate hazard area if it can be done with minimal risk.

Water spray may be useful in minimizing or dispersing vapors and to protect personnel. Cool equipment exposed to fire with water, if it can be done with minimal risk. Avoid spreading burning liquid with water used for cooling purposes.

6. ACCIDENTAL RELEASE MEASURES

Extremely flammable. Keep all sources of ignition and hot metal surfaces away from spill/release. The use of explosion-proof equipment is recommended.

Stay upwind and away from spill/release. Notify persons down wind of the spill/release, isolate immediate hazard area and keep unauthorized personnel out. Stop spill/release if it can be done with minimal risk. Wear appropriate protective equipment including respiratory protection as conditions warrant (see Section 8).

Prevent spilled material from entering sewers, storm drains, other unauthorized drainage systems, and natural waterways. Dike far ahead of spill for later recovery or disposal. Use foam on spills to minimize vapors (see Section 5). Spilled material may be absorbed into an appropriate absorbent material.

Notify fire authorities and appropriate federal, state, and local agencies. Immediate cleanup of any spill is recommended.

7. HANDLING AND STORAGE

Handling: Open container slowly to relieve any pressure. Bond and ground all equipment when transferring from one vessel to another. Can accumulate static charge by flow or agitation. Can be ignited by static discharge. The use of explosion-proof equipment is recommended and may be required (see appropriate fire codes). Refer to NFPA-704 and/or API RP 2003 for specific bonding/grounding requirements.

Do not enter confined spaces such as tanks or pits without following proper entry procedures such as ASTM D-4276 and 29CFR 1910.146. The use of appropriate respiratory protection is advised when concentrations exceed any established exposure limits (see Sections 2 and 8).

Wash thoroughly after handling. Do not wear contaminated clothing or shoes. Keep contaminated clothing away from sources of ignition such as sparks or open flames. Use good personal hygiene practices.

High pressure injection of hydrocarbon fuels, hydraulic oils or greases under the skin may have serious consequences even though no symptoms or injury may be apparent. This can happen accidentally when using high pressure equipment such as high pressure grease guns, fuel injection apparatus or from pinhole leaks in tubing of high pressure hydraulic oil equipment.

"Empty" containers retain residue and may be dangerous. Do not pressurize, cut, weld, braze, solder, drill, grind, or expose such containers to heat, flame, sparks, or other sources of ignition. They may explode and cause injury or death. "Empty" drums should be completely drained, properly bunged, and promptly shipped to the supplier or a drum reconditioner. All containers should be disposed of in an environmentally safe manner and in accordance with governmental regulations.

Before working on or in tanks which contain or have contained this material, refer to OSHA regulations, ANSI Z49.1 and other references pertaining to cleaning, repairing, welding, or other contemplated operations.

Storage: Keep container(s) tightly closed. Use and store this material in cool, dry, well-ventilated areas away from heat, direct sunlight, hot metal surfaces, and all sources of ignition. Post area "No Smoking or Open Flame." Store only in approved containers. Keep away from any incompatible material (see Section 10). Protect container(s) against physical damage. Outdoor or detached storage is preferred. Indoor storage should meet OSHA standards and appropriate fire codes.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Engineering controls: If current ventilation practices are not adequate to maintain airborne concentrations below the established exposure limits (see Section 2), additional engineering controls may be required. Where explosive mixtures may be present, electrical systems safe for such locations must be used (see appropriate electrical codes).

Personal Protective Equipment (PPE):

Respiratory: A NIOSH certified air purifying respirator with an organic vapor cartridge may be used under conditions where airborne concentrations are expected to exceed exposure limits (see Section 2).

Protection provided by air purifying respirators is limited (see manufacturer's respirator selection guide). Use a NIOSH approved self-contained breathing apparatus (SCBA) or equivalent operated in a pressure demand or other positive pressure mode if there is potential for an uncontrolled release, exposure levels are not known, or any other circumstances where air purifying respirators may not provide adequate protection.

A respiratory protection program that meets OSHA's 29 CFR 1910.134 and ANSI Z88.2 requirements must be followed whenever workplace conditions warrant a respirator's use.

Skin: The use of gloves impervious to the specific material handled is advised to prevent skin contact, possible irritation, and absorption. Examples of approved materials are nitrile, or Viton® (see glove manufacturer literature for information on permeability).

Eye/Face: Approved eye protection to safeguard against potential eye contact, irritation, or injury is recommended. Depending on conditions of use, a face shield may be necessary.

Other Protective Equipment: A source of clean water should be available in the work area for flushing eyes and skin. Impervious clothing should be worn as needed.

Suggestions for the use of specific protective materials are based on readily available published data. Users should check with specific manufacturers to confirm the performance of their products.

9. PHYSICAL AND CHEMICAL PROPERTIES

Note: Unless otherwise stated, values are determined at 20°C (68°F) and 760 mm Hg (1 atm).
Appearance: Colorless
Physical State: Liquid
Odor: Mild, gasoline-like
pH: Not applicable
Vapor Pressure (mm Hg): 15.6 psia @100°F (37.8°C)
Vapor Density (air=1): 2.49
Boiling Point/Range: 98°F / 37°C
Freezing/Melting Point: -129.7°C
Solubility in Water: Negligible
Specific Gravity: 0.63 @60/60°F (15.6/15.6°C)
Percent Volatile: 100 vol.%
Evaporation Rate (nBuAc=1): >1
Viscosity: 0.23 cp @ 68°F (20°C)
Bulk Density: 5.25 lbs/gal
Flash Point: -56.2°F / -49°C (TCC, ASTM D56)
Flammable/Explosive Limits (%): LEL: 1.42 / UEL: 7.8

10. STABILITY AND REACTIVITY

Stability: Stable under normal ambient and anticipated storage and handling conditions of temperature and pressure. Extremely flammable liquid and vapor. Vapor can cause flash fire.

Conditions To Avoid: Avoid all possible sources of ignition (see Sections 5 and 7).

Materials to Avoid (Incompatible Materials): Avoid contact with strong acids, selected amines, strong bases and oxidizing agents.

Hazardous Decomposition Products: Combustion can yield carbon dioxide and carbon monoxide.

Hazardous Polymerization: Will not occur.

11. TOXICOLOGICAL INFORMATION

Chronic Data: No definitive information available on carcinogenicity, mutagenicity, target organ, or developmental toxicity.

Acute Data:
Pentane: Dermal LD50=No data available
LC50>6,106 ppm (4-hr., Rat)
Oral LD50>2,000 mg/kg (Rat).

12. ECOLOGICAL INFORMATION

Not evaluated at this time

13. DISPOSAL CONSIDERATIONS

This material, if discarded as produced, would be a RCRA "characteristic" hazardous waste due to the characteristic(s) of ignitability (D001). If the spilled or released material impacts soil, water, or other media, characteristic testing of the contaminated materials may be required prior to their disposal. Further, this material, once it becomes a waste, is subject to the land disposal restrictions in 40 CFR 268.40 and may require treatment prior to disposal to meet specific standards. Consult state and local regulations to determine whether they are more stringent than the federal requirements.

Container contents should be completely used and containers should be emptied prior to discard. Container rinsate could be considered a RCRA hazardous waste and must be disposed of with care and in full compliance with federal, state and local regulations. Larger empty containers, such as drums, should be returned to the distributor or to a drum reconditioner. To assure proper disposal of smaller empty containers, consult with state and local regulations and disposal authorities.

14. TRANSPORT INFORMATION

DOT Shipping Description:	Pentanes,3,UN1265,I
Bulk Package Placard/Marking:	Flammable/1265
Hazardous Substance/RQ	None
Packaging References	49 CFR 173.150, 173.202,173.242
Emergency Response Guide:	128

15. REGULATORY INFORMATION

EPA SARA 311/312 (Title III Hazard Categories):

Acute Health:	Yes
Chronic Health:	No
Fire Hazard:	Yes
Pressure Hazard:	No
Reactive Hazard:	No

SARA 313 and 40 CFR 372:

This material contains the following chemicals subject to the reporting requirements of SARA 313 and 40 CFR 372:

--None--

California Proposition 65:

Warning: This material contains the following chemicals which are known to the State of California to cause cancer, birth defects or other reproductive harm, and are subject to the requirements of California Proposition 65 (CA Health & Safety Code Section 25249.5):

--None Known--

Carcinogen Identification:

This material has not been identified as a carcinogen by NTP, IARC, or OSHA.

EPA (CERCLA) Reportable Quantity:

--None--

Canada - Domestic Substances List: Listed

WHMIS Class:

B2-Flammable Liquid
D2B-Materials causing other toxic effects - Toxic Material

This product has been classified in accordance with the hazard criteria of the Controlled Products Regulations (CPR) and the MSDS contains all the information required by the CPR.

16. OTHER INFORMATION

Issue Date: 01/08/03
Previous Issue Date: 03/21/02
Revised Sections: 1, 2, 8, 11, 13, 16
Previous Product Code: Multiple
MSDS Number: 003459
Status: Final

Disclaimer of Expressed and Implied Warranties:

APPENDIX G
50% S MATERIAL SAFETY DATA SHEET

15185 Main Street
Lemont, IL 60439
630-257-3900

Material Safety Data Sheet

50 % Caustic Soda

Section 1: Product Identification

PRODUCT NAME
50% Caustic Soda - Liquid

EVISION DATE
April 1, 2002

SYNONYM
Sodium Hydroxide Solution

ID NUMBER
UN 1824

CHEMICAL FORMULA
NaOH

CAS NUMBER
1310-73-2

EMERGENCY NUMBERS
24 Hour Emergency : CHEMTREC 1-800-424-9300
Product Information: Lemont, IL 1-630-257-3900

Section 2: Physical Data & Ingredients

APPEARANCE
Colorless to slightly grey solution

ODOR
Virtually Odorless

VAPOR PRESSURE
1 mm Hg. @ 68º F (20º C)

BOILING POINT
288º F (142 C)

SPECIFIC GRAVITY
1.53 @ 60º F

SOLUBILITY
Complete in water

DENSITY
12.76 lbs/gal @ 60º F.

pH OF SOLUTIONS
Strongly Basic (14)

HEAT OF SOLUTION
Exothermic

INGREDIENTS	%
Materials : Sodium Hydroxide	Approx. 50%
Water	Balance

Section 3: Fire & Explosion Information

FIRE EXTINGUISHING MEDIA
Not Applicable

FIRE
Not Flammable

EXPLOSION - Contact with some metals, particularly magnesium, aluminum and zinc (galvanized), can generate hydrogen rapidly, which is explosive.

Section 4: Reactivity Data

STABILITY - Stable under ordinary conditions of use and storage.

HAZARDOUS DECOMPOSITION PRODUCTS - Reaction with various food sugars may form carbon monoxide.

HAZARDOUS POLYMERIZATION - This substance does not polymerize.

INCOMPATIBILITY: (MATERIALS TO AVOID) - May react violently with water, acids and a number of organic compounds. Reacts rapidly with aluminum, tin and zinc. Also reacts with bronze and brass.

Section 5: Leak, Spill, Disposal Information

STEPS TO BE TAKEN IF MATERIAL IS SPILLED OR RELEASED
Dike area to contain spill. Only trained personnel equipped with NIOSH/MSHA approved, full face combination dust/mist respirators should be permitted in this area. Reclaim spilled material if possible or dilute material with a large quantity of water, then neutralize with dilute acid. Properly neutralize liquid residues (pH 6-9) may be disposed of in waste water treatment facilities which allow the discharge of neutral salt solutions. Neutralized material can be recovered by vacuum truck for disposal. After all visible traces have been removed, flush area with large amounts of water.

WASTE DISPOSAL METHOD
Dispose of neutralized material in an approved hazardous waste management facility. Care must be taken when using or disposing of chemical materials and/or their containers to prevent environmental contamination. It is your duty to dispose of chemical materials and/or their containers in accordance with all federal, state and local regulations.

Section 6: Health & Hazard Data

IS CHEMICAL LISTED AS A CARCINOGEN OR POTENTIAL CARCINOGEN?

NTP - NO IARC - NO OSHA - NO

MEDICAL CONDITION GENERALLY AGGRAVATED BY EXPOSURE: None Known

PERMISSIBLE EXPOSURE LIMIT -OSHA 2mg./m^3 ceiling

ACUTE TOXICITY

PRIMARY ROUTES OF EXPOSURE - Skin and eyes contact, inhalation

INHALATION - Respiratory tract irritant. Severe injury is usually avoided by the self-limiting coughing and sneezing symptoms.

INGESTION - CORROSIVE ! Ingestion of caustic soda liquid can cause perforation of the esophagus and stomach. Abdominal pain, nausea, vomiting and general gastro-intestinal upset can be expected.

SKIN CONTACT - CORROSIVE ! Will cause severe chemical burns and tissue destruction. Immediately flush with water. Seek medical attention.

EYE CONTACT - Will cause severe and possible permanent eye damage. Continuously flush eyes with large amounts of water for at least 15 minutes. Seek medical attention.

CHRONIC TOXICITY- No Data Found

Section 7: Emergency & First Aid Procedures

INHALATION - Move person to fresh air. If not breathing, give artificial respiration, preferably mouth-to-mouth. If breathing is difficult, give oxygen. Call a physician.

EYE OR SKIN CONTACT - In case of contact, immediately flush eyes and skin with plenty of water (soap and water for skin) for at least 15 minutes, while removing contaminated clothing and shoes. Hold eyelids open during this flushing with water. Call a physician. If skin feels slippery, caustic may still be present in sufficient quantities to cause rash or burn. Continue washing until slick skin feeling is gone. Thoroughly clean contaminated clothing and shoes before reuse or discard.

INGESTION - If swallowed, give at least 3-4 glasses of water or acidic beverages (tomato or orange juice, carbonated soft drinks). Do not induce vomiting. Do not give anything by mouth to an unconscious or convulsing person. Get medical attention.

NOTES TO PHYSICIAN - Treat symptomatically.

Section 8: Occupational Control Measures

VENTILATION REQUIREMENTS - Local exhaust - to meet the exposure requirements and avoid mist.

PERSONAL RESPIRATORS: (NIOSH APPROVED) - Dust/mist respirators recommended for all personnel working in or about an area of potential mist exposure.

SKIN PROTECTION REQUIREMENTS - Wear impervious protective clothing; including boots; gloves; lab coat; apron or coveralls to prevent skin contact. Preferred Materials: Nitrile, Neoprene, PVC

EYE PROTECTION REQUIREMENTS - Use chemical safety goggles impervious to product. Contact lenses should not be worn when working with this material. Maintain eye wash fountain and quick-drench facilities in immediate work area.
NOTE: ALL PROTECTIVE EQUIPMENT MUST CONFORM WITH 29 CFR 1910.132.

Section 9: Handling & Storage

Store and handle only in containers suitably lined with or constructed of materials specified for this product. Keep separate from incompatibles.

Section 10: Regulatory Information

DOT HAZARD CLASS
8

DOT PLACARD REQUIRED
Corrosive - UN 1824

DOT LABEL
Corrosive - 8

REPORTABLE QUANTITY
1,000 lbs -/ 454 Kgs.

NFPA / HMIS RATINGS
Health - 3 Flammability - 0 Reactivity - 1

TSCA - Sodium Hydroxide is on the TSCA inventory under CAS. NO.1310-73-2.

OSHA - Listed as a “Hazardous Chemical” as defined in 29 CFR 1910.1200 (Hazcom).

CERCLA
Listed in table 302.4 of 40 CFR part 302 as a hazardous substance with a reportable quantity of 1,000 pounds. Release to air, land or water which exceed the RQ must be reported to the National Response Center,
1-800-424-8802.

EUROPE EINECS
This product is listed on EINECS. (204-825-9)

CANADA DSL
This product is listed on the Canadian DSL.

AUSTRALIA AIC
This product is listed on AICS

KOREA ECL
This product is listed on MITI.

JAPAN MITI (ENCS)
This product is listed on MITI.

SARA TITLE III
SARA (311,312) HAZARD CLASS: Acute Health Hazard. Reactive Hazard.
SARA (313) CHEMICALS: Not Listed
SARA Section 302: Not listed as an Extremely Hazardous Substance/

CANADIAN REGULATIONS (WHMIS)
a.) Class E - Corrosive Material.
b.) Sensitization to product - None known.
c.) Reproductivity Toxicity - None known.
d.) Odor Threshold - No Odor.
e.) Product Use - Neutralization, chemical processing.

The information contained herein is provided in good faith and is believed to be correct as of the date hereof. However, K.A. Steel Chemicals makes no representation as to the comprehensiveness or accuracy of the information. It is expected that individuals receiving information will exercise their independent judgement in determining its appropriateness for a particular purpose. Accordingly, K.A. Steel Chemicals will not be responsible for damages of any kind resulting from the use of or reliance upon such information. No representation, or warranties, either express or implied, of merchantability fitness for a particular purpose or of any nature are made hereunder with respect to the information set forth herein or to the product to which the information refers.

APPENDIX H

HAZARD ANALYSIS OF THE POSSIBLE WELL-RELATED UNCONTROLLED FLOW EVENT AND POWER PLANT UPSET EMISSION SCENARIOS PUNA GEOTHERMAL VENTURE PROJECT

HAZARD ANALYSIS OF THE POSSIBLE WELL-RELATED UNCONTROLLED FLOW EVENT AND POWER PLANT UPSET EMISSION SCENARIOS PUNA GEOTHERMAL VENTURE PROJECT

To determine the "worst case" conditions under which geothermal fluid emissions could occur during an uncontrolled flow event at any wellpad, or during specified power plant upset conditions, Puna Geothermal Venture (PGV) conducted a simplified hazard analysis of the possible well-related uncontrolled flow event and power plant upset scenarios to determine the range of credible situations under which hydrogen sulfide and other contaminants could be released from any well or the power plant. Table 1 provides a summary of the twelve (12) scenarios determined by PGV, in consultation with the Hawaii Department of Health and its consultants, to be credible events.

Table 2 lists the parameters of the geothermal resource (geochemistry [hydrogen sulfide and other chemical constituents], likely maximum credible productivity [flow rate], temperature [enthalpy], etc.) which were determined by PGV, in consultation with the Hawaii Department of Health and its consultants, to be the emitted (released) constituents for the hazard analysis.

In order to determine the maximum ("worst case") impacts which could result from each of these 12 different emission scenarios, PGV conducted an impact analysis utilizing the Industrial Source Complex Short Term (ISCST) model. The ISCST model is a steady-state Gaussian model used to assess pollutant concentrations from a wide variety of sources associated with an industrial source complex which can be used for a wide variety of applications, from initial screening to refined determinations of maximum concentrations. Its use is appropriate here because it is the most popular EPA guideline model, making it readily accessible to most modelers. The emissions to be modeled are assumed to be steady state, or the emissions are scaled to the one-hour modelling period, and one-hour concentrations are calculated. The emitted steam and gas plume is not heavier than air, eliminating the need for dense gas models. ISCST can be used in the screen mode to evaluate impacts over a wide range of atmospheric stability and wind speeds.

Because the ultimate product of the air modeling was to evaluate the "worst-case" results of many different release scenarios, each scenario was modeled as a single source with the ISCST model in the flat terrain mode. In order to ensure that the analysis would be very conservative, in consultation with the Hawaii Department of Health and its consultants, PGV modeled receptors placed both at the same height as the source and at "flagpole" heights of 10 meters. A narrow (100 meter wide) two-dimensional generated Cartesian receptor grid (1,000 meter spacing from 1,000 to 25,000 meters) with discrete receptors located at 50 and 100 through 900 meters (at 100 meter intervals) was used, which provided sufficient detail without overburdening the analysis. To err again on the conservative side, building downwash calculations were modeled for those source(s) which could be located within the zone of influence of the power plant turbine and air cooler pads.

Because the air modeling is conducted to select the "worst-case" results of each of the different release scenarios under a wide variety of meteorological conditions, the ISCST model was used in the "screen" mode. This mode calculates "worst-case" ambient air concentrations for each of the 33 different wind-speed/stability classes used by the SCREEN model (see Table 3 for a listing of each of the SCREEN combinations) for each of the designated receptor points. The mixing height was changed from the default value to 300 meters (stability classes A, B, C, and D) or 100 meters (stability classes E and F), and ambient temperatures scaled, to conform to the requests of the Hawaii Department of Health and its consultants, to ensure "worst-case" values.

Appropriate emission rates and other necessary air modeling parameters (temperature, flow rate, stack diameter, etc.) for the hydrogen sulfide emissions for each of the potentially credible release scenarios were established by PGV in consultation with the Hawaii Department of Health and it consultants, and are presented in Table 4. Emission parameters for the non-hydrogen sulfide noncondensible gas constituents of the geothermal fluid are identical to those for the hydrogen sulfide. Emission characteristics for the brine portion of the geothermal fluid are also identical to those for hydrogen sulfide, except that many of the emission mechanisms substantially reduce the emission of geothermal brine into the atmosphere over the hydrogen sulfide (and other noncondensible gases), and only a portion of the brine emitted into the atmosphere is converted into atmospheric aerosols. As a result, an additional reduction in the emission rate of the brine components over the hydrogen sulfide is appropriate. These reduction values are presented in Table 5.

Once the emission parameters, receptor locations and meteorological conditions were selected, the ISCST model was then run for each of the credible release scenarios to determine the highest modeled atmospheric concentration of hydrogen sulfide at each receptor point under any of the modeled meteorological conditions and receptor elevations. The output of this air dispersion modeling is presented in Attachment 2, and the maximum modeled concentrations for each scenario are graphically displayed in Attachment 3, Maps H-1 through H-12. Table 6 summarizes the results of the modeling for each of the 12 release scenarios, organized on the basis of the maximum distance at which each of the HDOH-specified threshold levels are predicted to be exceeded under the "worst case" meteorological conditions/receptor elevations and the point and concentration of maximum impact. Table 6 has further categorized each release scenario by which, if any, of the HDOH-specified threshold levels is predicted to be exceeded by the maximum predicted concentration, thus ensuring that each release scenario is categorized by the highest impact it can create.

Based on the ratio of the "emission rates" for hydrogen sulfide and each of the other noncondensible gas species which was determined in Attachment 1 as likely to result from the emission (release) of the geothermal fluid into the atmosphere, and the modeled ambient hydrogen sulfide concentrations at each receptor point for each of the scenarios as presented in Attachment 2, the "worst case" ambient concentrations of each of these noncondensible gas species can be estimated. These values are presented in Table 7. By ratioing these values further as appropriate by the reduced brine emission rates presented in Table 5, the maximum predicted concentrations of each of the brine aerosol species can be calculated. These maximum predicted concentrations for each of the brine aerosol species are listed in Table 8.

TABLE 1 WELL-RELATED UNCONTROLLED FLOW EVENT AND POWER PLANT UPSET EMISSION SCENARIOS	
1.	Abated **vertical** flow through the well 13-3/8" flow line and muffler (assumes that the new well control and abatement system works as designed to divert and abate any uncontrolled flow).
2.	Unabated **vertical** flow through the well 13-3/8" flow line and muffler (assumes that the abatement system does not operate).
3.	Unabated **horizontal** flow through the well 13-3/8" flow line (assumes that the flow through the flow line knocks the muffler off the end of the flow line and the abatement equipment is not operated. This scenario can be quickly controlled through closing valves to shut in the well).
4.	Unabated **vertical** flow through the well 13-3/8" casing (assumes that the rupture disk on the flow line does not rupture and the flow continues up the 13-3/8" casing through the BOPE stack).
5.	Unabated **vertical** flow through the well 9-5/8" casing (assumes that the well is unable to be shut-in at the surface after the 9-5/8" casing is set, or the vertical line is ruptured after the rig is removed from the well).
6.	Unabated **vertical** well flow channeled by the rig subbase (assumes that the rupture disk on the flow line does not rupture and the flow blows off the annular preventer and the vertical flow is channeled by the drill rig structure [this is essentially what happened during the first few hours of the KS-8 uncontrolled flow event]).
7.	Unabated **vertical** well flow through an area of fractured rock surrounding the well (assumes that the uncontrolled flow is not coming through the casing of the well but through an area of fractured rock surrounding the well casing).
8.	Abated **vertical** flow from the well drilling rig mud tanks (assumes that the choke line is used to divert the geothermal fluid to the mud tanks. Abatement is through NaOH injected into the choke line and lime in the mud tanks).
9.	Abated **vertical** flow from the well drilling rig mud sump (assumes that the choke line is used to divert the geothermal fluid to the mud sump. Abatement is through NaOH injected into the choke line and lime in the mud sump).
10.	Unabated **horizontal** flow through the well drilling rig 4" choke line (assumes that the choke line is used to divert the geothermal fluid, but the fluid flow knocks the "tee" off of the end of the choke line, at which point the hydrogen sulfide is unabated. This scenario can be controlled through closing valves to divert the geothermal fluid to the flow diverter or shut in the well).
11.	Unabated **horizontal** "puff" flow through 3" noncondensible gas flow line from noncondensible gas compressor to fluid injection line (assumes that the line is ruptured and the contents of the pipeline (4.9 pounds of hydrogen sulfide) is emitted to the air).
12.	Unabated **vertical** flow through the power plant steam release facility (assumes that the emergency steam release facility abatement system does not operate when needed).

TABLE 2 EMITTED GEOTHERMAL RESOURCE CHARACTERISTICS ASSUMED FOR THE PGV PROJECT EMERGENCY RESPONSE PLAN		
PARAMETERS	VALUE	COMMENT
MAXIMUM SINGLE WELL MASS FLOW	500,000 lbs/hr	Estimated maximum credible flow of geothermal fluid from a single well.
STEAM FLASH	80 percent	Based on enthalpy of KS-8 and flashing steam at atmospheric pressures.
HYDROGEN SULFIDE IN GEOTHERMAL FLUID	896 ppm	Based on assumed hydrogen sulfide concentration in steam (from below) calculated back to reservoir conditions by adding back in the 20% brine not flashed to steam.
HYDROGEN SULFIDE IN FLASHED STEAM	1,120 ppm	Calculated based upon average hydrogen sulfide measurements from KS-1A, KS-3, and HGP-A (834 ppmv) plus one standard deviation (286 ppmv) of all measurements.
BRINE AEROSOL SPECIES CONCENTRATIONS	See Attachment 1	
VAPOR PHASE INITIAL SPECIES CONCENTRATIONS	See Attachment 1	

TABLE 3 33 WIND SPEED/STABILITY COMBINATIONS ANALYZED BY SCREEN AND USED FOR THE PGV PROJECT EMERGENCY RESPONSE PLAN						
10 Meter Wind Speed (m/s)	Stability Class					
	A	B	C	D	E	F
1.0	1	4	9	16	25	30
2.0	2	5	10	17	26	31
3.0	3	6	11	18	27	32
4.0		7	12	19	28	33
5.0		8	13	20	29	
8.0			14	21		
10.0			15	22		
15.0				23		
20.0				24		

TABLE 4 EMISSION CHARACTERISTICS FOR WELL-RELATED UNCONTROLLED FLOW EVENT AND POWER PLANT UPSET SCENARIOS FOR THE PGV EMERGENCY RESPONSE PLAN								
SCENARIO	Source Type	Stack or Effective Height	Inside Diameter or Sigma y (feet)	Emission Velocity (ft/min) **OR**	**OR** Volumetric Flow Rate (ACFM)	Temperature of Effluent (F) or Sigma z (feet)	Abatement Efficiency (%)	Abated Emission Rate (lb/hr)
1. Abated **vertical** flow through the well 13-3/8" flow line and muffler	Stack	20[1]	15[2]		182,000[3]	211[4]	90[5]	44.8[6]
2. Unabated **vertical** flow through the well 13-3/8" flow line and muffler	Stack	20	15		182,000	211	0	448
3. Unabated **horizontal** flow through the well 13-3/8" flow line only	Volume x5[7]	65[8]	58.1[9]			30.2[10]	0	448[11]

[1] Based upon current design of muffler.

[2] Based upon current design of muffler.

[3] 500,000 lb/hr x 80% steam flash = 400,000 lb/hr x 27.3 cu.ft/lb / 60 min/hr = 182,000 ACFM.

[4] Temperature of geothermal fluid at point of release after flashing.

[5] Abatement efficiency conservatively estimated from the literature.

[6] Assumes 400,000 lb/hr geothermal steam x 1,120 ppm hydrogen sulfide x 90% abatement.

[7] Assumes that the source is a line source, which is modeled as five volume sources, each with initial height of 65 ft and initial width of 125 ft. The center of each volume source along the line is assumed to be 62.5 ft, 312.5 ft, 562.5 ft, 812.5 ft, and 1,062.5 ft. Initial strength of each volume source is proportional to its distance from the origin; the first source is 29.9 lb/hr; the second 59.7 lb/hr; the third 89.6 lb/hr; the fourth 119.5 lb/hr; and the fifth 149.3 lb/hr, for a total emission rate of 448 lb/hr.

[8] The effective emission height of each volume source is set to the height of the volume.

[9] Initial Sigma y for each volume source is calculated as the initial width (125 ft) divided by 2.15.

TABLE 4 EMISSION CHARACTERISTICS FOR WELL-RELATED UNCONTROLLED FLOW EVENT AND POWER PLANT UPSET SCENARIOS FOR THE PGV EMERGENCY RESPONSE PLAN								
SCENARIO	Source Type	Stack or Effective Height	Inside Diameter or Sigma y (feet)	Emission Velocity (ft/min) **OR**	**OR** Volumetric Flow Rate (ACFM)	Temperature of Effluent (F) or Sigma z (feet)	Abatement Efficiency (%)	Abated Emission Rate (lb/hr)
4. Unabated **vertical** flow through the well 13-3/8" casing	Stack	71[12]	75[13]	41	182,000	211[14]	0	448
5. Unabated **vertical** flow through the well 9-5/8" casing	Stack	71	75	41	182,000	211	0	448
6. Unabated **vertical** flow channeled by	Stack	40[15]	80[16]		182,000[17]	211	0	448

[10]Initial Sigma z for each volume source is calculated by dividing the initial vertical dimension of the source (65 feet) by 2.15.

[11]The initial strength of each volume source is proportional to its distance from the origin; the first source is 29.9 lb/hr; the second 59.7 lb/hr; the third 89.6 lb/hr; the fourth 119.5 lb/hr; and the fifth 149.3 lb/hr, for a total emission rate of 448 lb/hr. Note, however, that this scenario can be quickly controlled through closing valves to shut in the well, resulting in a significantly reduced emission rate over any one-hour period.

[12]The effective stack height (71 ft) is calculated by adding the assumed actual height of the stack (6 ft) to the calculated height (65 ft) at which the sonic cone has reached its maximum spread.

[13]Calculated effective stack diameter of release based upon sonic flow at release point (6 ft), resulting in expansion of the sonic cone at a 60° angle up to a additional height of 65 ft, which results in an effective diameter of 75 ft.

[14]Temperature of geothermal fluid at effective point of release after flashing.

[15]Assumes that the soundproofing around rig floor railing, which tops out at about 40' above ground level, channels most of the steam flow.

[16]Because the rig floor was blown out during the KS-8 uncontrolled flow event, this scenario assumes that the effective diameter is equal to the observed diameter of the plume during the KS-8 uncontrolled flow event (80 ft diameter).

TABLE 4 EMISSION CHARACTERISTICS FOR WELL-RELATED UNCONTROLLED FLOW EVENT AND POWER PLANT UPSET SCENARIOS FOR THE PGV EMERGENCY RESPONSE PLAN								
SCENARIO	Source Type	Stack or Effective Height	Inside Diameter or Sigma y (feet)	Emission Velocity (ft/min) **OR**	**OR** Volumetric Flow Rate (ACFM)	Temperature of Effluent (F) or Sigma z (feet)	Abatement Efficiency (%)	Abated Emission Rate (lb/hr)
the rig subbase								
7. Unabated **vertical** flow through an area of fractured rock surrounding the well	Stack	0	50[18]		182,000	211	0	448
8. Abated **vertical** flow from the well drilling rig mud tanks	Stack	6[19]	25.5[20]	3.28[21]	-[22]	160[23]	99[24]	4.5
9. Abated **vertical** flow from the well	Stack	0	70.7[25]	3.28[26]	-[27]	160	99	4.5

[17]Assumes total steam flow of 400,000 lb/hr is exiting through area of effective diameter.

[18]Reasonable but arbitrary assumption for a steam release through fractured rock. Assumes total area of rock fractures releasing steam and hydrogen sulfide equals approximately 2,000 square feet.

[19]Height of mud tanks above ground surface.

[20]Assumes mud tank surface area is approximately 650 sq. ft.

[21]Assumes a very low (1 meter per minute) vertical velocity.

[22]Assumes that a 4-inch diameter choke line limits steam and brine flow to only 50% of the unlimited flow rate.

[23]Assumes that the temperature of the mud is limiting the temperature of the discharge.

[24]High abatement percentage assumes discharge is abated through limitations in flow through the small-diameter choke line (50%); abatement by chemical injection in the choke-line (96%), and discharge into the mud tanks under the level of the mud in the tanks (50%).

[25]Assumes a 50' x 100' mud sump.

TABLE 4 EMISSION CHARACTERISTICS FOR WELL-RELATED UNCONTROLLED FLOW EVENT AND POWER PLANT UPSET SCENARIOS FOR THE PGV EMERGENCY RESPONSE PLAN								
SCENARIO	Source Type	Stack or Effective Height	Inside Diameter or Sigma y (feet)	Emission Velocity (ft/min) **OR**	**OR** Volumetric Flow Rate (ACFM)	Temperature of Effluent (F) or Sigma z (feet)	Abatement Efficiency (%)	Abated Emission Rate (lb/hr)
drilling rig mud sump								
10. Unabated **horizontal** flow through the well drilling rig 4" choke line	Volume x5[28]	65[29]	58.1[30]			30.2[31]	50[32]	224[33]
11. Unabated **horizontal** "puff" of noncondensible gases through 3"	Stack	0[35]	3.28[36]	0.00[37]		150[38]	0	4.9[39]

[26]Assumes a very low (1 meter per minute) vertical velocity.

[27]Assumes that a 4-inch diameter choke line limits steam and brine flow to only 50% of the unlimited flow rate.

[28]Assumes that the source is a line source, which is modeled as five volume sources, each with initial height of 65 ft and initial width of 125 ft. The center of each volume source along the line is assumed to be 62.5 ft, 312.5 ft, 562.5 ft, 812.5 ft, and 1,062.5 ft. Initial strength of each volume source is proportional to its distance from the origin.

[29]The effective emission height of each volume source is set to the height of the volume.

[30]Initial Sigma y for each volume source is calculated as the initial width (125 ft) divided by 2.15.

[31]Initial Sigma z for each volume source is calculated by dividing the initial vertical dimension of the source (65 feet) by 2.15.

[32]Abatement is assumed to be 50% as total flow of geothermal fluid is restricted through choke line to only 50% (250,000 lb/hr).

[33]The initial strength of each volume source is proportional to its distance from the origin; the first source is 14.9 lb/hr; the second 29.9 lb/hr; the third 44.8 lb/hr; the fourth 59.7 lb/hr; and the fifth 74.7 lb/hr, for a total emission rate of 224 lb/hr. Note, however, that this scenario can be quickly controlled through closing valves to divert the flow to the flow diverter or to shut in the well, resulting in a significantly reduced emission rate over any one hour period.

TABLE 4 EMISSION CHARACTERISTICS FOR WELL-RELATED UNCONTROLLED FLOW EVENT AND POWER PLANT UPSET SCENARIOS FOR THE PGV EMERGENCY RESPONSE PLAN								
SCENARIO	Source Type	Stack or Effective Height	Inside Diamete r or Sigma y (feet)	Emissio n Velocity (ft/min) **OR**	**OR** Volumetric Flow Rate (ACFM)	Temperature of Effluent (F) or Sigma z (feet)	Abatement Efficiency (%)	Abated Emission Rate (lb/hr)
line[34]								
12. <u>Unabated</u> **vertical** flow through power	Stack	20[40]	15[41]		500,000[42]	211[43]	0	560[44]

[35]Assumes a ground-level release.

[36]Assumes a small diameter stack release.

[37]Uses the extremely conservative assumption that the emission occurs with no vertical velocity.

[38]Operating temperature for the line.

[39]The quantity of hydrogen sulfide contained in the pipeline at any given time.

[34]This scenario results in the emission of only that noncondensible gas contained in the line (4.9 pounds) at the time of the pipe rupture (which is an extremely remote possibility. If the pipeline ruptured, the system would bypass the compressor and attempt to inject the noncondensible gases into the fluid injection line through an independent line. If the noncondensible gas injection system became completely inoperable for whatever reason, the power plant would go off-line and the geothermal steam and noncondensible gases would be released (and abated) through the power plant steam release facility, or through the well pad rock mufflers, or the wells would be shut in.

[40]Stack height as built is 20 feet.

[41]Diameter of the steam release facility as designed and constructed is 15 feet.

[42]Total flow of steam through the power plant.

[43]Temperature of the steam at release.

TABLE 4 EMISSION CHARACTERISTICS FOR WELL-RELATED UNCONTROLLED FLOW EVENT AND POWER PLANT UPSET SCENARIOS FOR THE PGV EMERGENCY RESPONSE PLAN								
SCENARIO	Source Type	Stack or Effective Height	Inside Diamete r or Sigma y (feet)	Emissio n Velocity (ft/min) **OR**	**OR** Volumetric Flow Rate (ACFM)	Temperature of Effluent (F) or Sigma z (feet)	Abatement Efficiency (%)	Abated Emission Rate (lb/hr)
plant steam release facility								

[44] Assumes 500,000 lb/hr geothermal steam x 1,120 ppm hydrogen sulfide.

TABLE 5 ABATEMENT ESTIMATES FOR EMITTED NON-HYDROGEN SULFIDE PRODUCTS FOR WELL UNCONTROLLED FLOW EVENT AND POWER PLANT UPSET EMISSION SCENARIOS FOR THE PGV EMERGENCY RESPONSE PLAN				
SCENARIO	Total Mass Flow (lb/hr)	Brine Droplet Abatement Percentage	Aerosol Production Percentage	Noncondensible Gas Abatement Percentage
1. Abated **vertical** flow through the well 13-3/8" flow line and muffler	500,000[45]	80[46]	50[47]	0[48]
2. Unabated **vertical** flow through the well 13-3/8" flow line and muffler	500,000	80	50	0
3. Unabated **horizontal** flow through the well 13-3/8" flow line	500,000	0	50	0
4. Unabated **vertical** flow through the well 13-3/8" casing	500,000	0	50	0
5. Unabated **vertical** flow through the well 9-5/8" casing	500,000	0	50	0
6. Unabated **vertical** flow channeled by the rig subbase	500,000	20[49]	50	0
7. Unabated **vertical** flow through an area of fractured rock surrounding the well	500,000	50[50]	50	0
8. Abated **vertical** flow from the well drilling rig mud tanks	250,000[51]	90[52]	50	0
9. Abated **vertical** flow from the well drilling	250,000	90[53]	50	0

[45]Total flow of geothermal fluid; brine, steam, steam condensate and noncondensible gases.

[46]Estimated abatement percentage for brine droplets due to mechanics of the emission process. Assumption that cyclonic muffler abates 80 percent of the brine droplets.

[47]General assumption is that only 50 percent of the emitted brine droplets produce aerosols.

[48]Percentage of noncondensible gases in the geothermal fluid which are abated before emission to the atmosphere.

[49]Assumes the rig substructure and floor abates 20 percent of the brine droplets.

[50]Assumption that 50 percent of the brine is abated for small-diameter release.

[51]Total flow is limited by the small diameter (4") of the choke line.

[52]Assumes that flow through the mud tank abates 90 percent of the brine droplets.

[53]Assumes that flow through the mud sump abates 90 percent of the brine droplets.

TABLE 5 ABATEMENT ESTIMATES FOR EMITTED NON-HYDROGEN SULFIDE PRODUCTS FOR WELL UNCONTROLLED FLOW EVENT AND POWER PLANT UPSET EMISSION SCENARIOS FOR THE PGV EMERGENCY RESPONSE PLAN				
SCENARIO	Total Mass Flow (lb/hr)	Brine Droplet Abatement Percentage	Aerosol Production Percentage	Noncondensible Gas Abatement Percentage
rig mud sump				
10. Unabated **horizontal** flow through the well drilling rig 4" choke line	250,000	0	50	0
11. Unabated **horizontal** "puff" of noncondensible gases through 3" line	8.77[54]	100[55]	N/A	0
12. Unabated **vertical** flow through power plant steam release facility	500,000	100[56]	N/A	0

[54] Noncondensible gas line from compressor to injection line contains approximately 8.77 pounds of noncondensible gasses, including approximately 4.9 pounds of hydrogen sulfide.

[55] Contents of pipeline is noncondensible gases only.

[56] Discharge will be of steam and noncondensible gases only.

TABLE 6: SUMMARY OF MODELLED HYDROGEN SULFIDE IMPACTS				
RELEASE SCENARIO	MAXIMUM OFF-SITE (>0.3 km) DISTANCE FROM SOURCE (km) TO IDENTIFIED ACTION LEVEL		POINT OF MAXIMUM PREDICTED OFF-SITE IMPACT (>0.3 km)	
	"WATCH" LEVEL (25 ppb)	"WARNING" LEVEL (1,000 ppb)	CONCENTRATION (ppb)	DISTANCE FROM SOURCE (km)
TYPE "1" EVENTS [EXCEED ONLY THE "WATCH" ACTION LEVEL]				
1. Abated vertical flow through diverter/muffler	0.9 km	N/A	40.3	0.4
9. Abated vertical flow from the mud sump	2.8 km	N/A	57.1	0.4
8. Abated vertical flow from the mud tanks	4.5 km	N/A	253.1	0.4
11. Unabated noncondensible gas flow	5.5 km	N/A	935.7	0.4
4. Unabated vertical flow through 13-3/8" casing	25.+ km	N/A	146.0	0.6
5. Unabated vertical flow through 9-5/8" casing	25.+ km	N/A	146.0	0.6
12. Unabated vertical flow through power plant steam release facility	25.+ km	N/A	150.6	0.8
6. Unabated vertical flow through drill rig subbase	25.+ km	N/A	246.8	0.5
2. Unabated vertical flow through diverter/muffler	25.+ km	N/A	403.4	0.4
7. Unabated vertical flow through area of fractured rock	25.+ km	N/A	789.4	0.4
TYPE "2" EVENTS [EXCEED THE "WATCH" AND "WARNING" ACTION LEVELS]				
10. Unabated horizontal flow through a 4" choke line	25.+ km	3.7 km	6,395[57]	0.4
3. Unabated horizontal flow through diverter	25.+ km	6.7 km	12,786[58]	0.4

[57]Note that this scenario can and will be quickly controlled through closing valves to shut in the well, resulting in a significantly reduced emission rate over any one hour period.

[58]Note that this scenario can and will be quickly controlled through closing valves to shut in the well, resulting in a significantly reduced emission rate over any one hour period.

TABLE 7: SUMMARY OF MODELED GEOTHERMAL VAPOR PHASE EMISSION IMPACTS														
	POINT OF MAXIMUM PREDICTED OFF-SITE IMPACT (>0.3 km)													
	CONCENTRATION (µg/m3) (Rn-222=aCi/m3 [pCi/m3/1,000,000)													DISTANCE FROM SOURCE (km)
RELEASE SCENARIO	HAsO2	NH3	CH4	C2H4	C2H6	C3H6	C3H8	C4H10	C4H10	C5H12	C5H12	HCl	Rn-222	
1. Abated vertical flow through diverter/muffler	0.0045	0.690	8.49	0.0023	0.045	0.041	0.036	0.0131	0.0198	0.0063	0.0068	8.07	0.0635	0.4
9. Abated vertical flow from the mud sump	0.0635	9.732	119.75	0.0318	0.635	0.583	0.507	0.1847	0.2794	0.0888	0.0953	113.89	0.8954	0.4
8. Abated vertical flow from the mud tanks	0.2814	43.127	530.68	0.1407	2.814	2.585	2.248	0.8183	1.2382	0.3937	0.4221	504.69	3.9677	0.4
11. Unabated noncondensible gas flow	0.9576	146.762	1,805.91	0.4788	9.576	8.796	7.650	2.7847	4.2134	1.3397	1.4364	1,717.44	13.5022	0.4
4. Unabated vertical flow through 13-3/8" casing	0.0016	0.245	3.02	0.0008	0.016	0.015	0.013	0.0047	0.0070	0.0022	0.0024	2.87	0.0226	0.6
5. Unabated vertical flow through 9-5/8" casing	0.0016	0.245	3.02	0.0008	0.016	0.015	0.013	0.0047	0.0070	0.0022	0.0024	2.87	0.0226	0.6
12. Unabated vertical flow through power plant steam release facility	0.0017	0.261	3.21	0.0009	0.017	0.016	0.014	0.0049	0.0075	0.0024	0.0026	3.05	0.0240	0.8
6. Unabated vertical flow through drill rig subbase	0.0028	0.429	5.28	0.0014	0.028	0.026	0.022	0.0081	0.0123	0.0039	0.0042	5.02	0.0395	0.5
2. Unabated vertical flow through diverter/muffler	0.0045	0.690	8.49	0.0023	0.045	0.041	0.036	0.0131	0.0198	0.0063	0.0068	8.07	0.0635	0.4
7. Unabated vertical flow through small area of fractured rock	0.0088	1.349	16.60	0.0044	0.088	0.081	0.070	0.0256	0.0387	0.0123	0.0132	15.78	0.1241	0.4
10. Unabated horizontal flow through a 4" choke line	0.0714	10.943	134.65	0.0357	0.714	0.656	0.570	0.2076	0.3142	0.0999	0.1071	128.05	1.0067	0.4
3. Unabated horizontal flow through diverter	0.1428	21.886	269.30	0.0714	1.428	1.312	1.141	0.4153	0.6283	0.1998	0.2142	256.11	2.0135	0.4

TABLE 8: SUMMARY OF MODELED GEOTHERMAL BRINE AEROSOL IMPACTS

RELEASE SCENARIO	POINT OF MAXIMUM PREDICTED OFF-SITE IMPACT (>0.3 km)																				
	CONCENTRATION (µg/m3) (Hg=nanograms/m3)																				DISTANCE FROM SOURCE (km)
	Na	K	Ca	Mg	Fe	Li	Sr	Zn	Ba	Mn	Pb	Cl	F	Br	SO4	H4SiO4	H3BO3	HAsO2	Hg (1/1000)	SiO2	
1. Abated vertical flow through diverter/muffler	383	89	67	1.00	40	0.27	0.96	0.88	1.76	3.29	0.038	846	0.0000	3.41	0.077	0.23	0.38	0.0000	0.0766	24	0.4
9. Abated vertical flow from the mud sump	2,699	629	472	7.02	281	1.89	6.75	6.21	12.42	23.21	0.270	5,962	0.0000	24.02	0.540	1.62	2.70	0.0000	0.5398	166	0.4
8. Abated vertical flow from the mud tanks	11,962	2,787	2,093	31.10	1,244	8.37	29.91	27.51	55.03	102.87	1.196	26,424	0.0000	106.46	2.392	7.18	11.96	0.0000	2.3924	736	0.4
11. Unabated noncondensible gas flow	0	0	0	0.00	0	0.00	0.00	0.00	0.00	0.00	0.000	0	0.0000	0.00	0.000	0.00	0.00	0.0000	0.0000	0	0.4
4. Unabated vertical flow through 13-3/8" casing	693	161	121	1.80	72	0.49	1.73	1.59	3.19	5.96	0.069	1,531	0.0000	6.17	0.139	0.42	0.69	0.0000	0.1386	43	0.6
5. Unabated vertical flow through 9-5/8" casing	693	161	121	1.80	72	0.49	1.73	1.59	3.19	5.96	0.069	1,531	0.0000	6.17	0.139	0.42	0.69	0.0000	0.1386	43	0.6
12. Unabated vertical flow through power plant steam release facility	0	0	0	0.00	0	0.00	0.00	0.00	0.00	0.00	0.000	0	0.0000	0.00	0.000	0.00	0.00	0.0000	0.0000	0	0.8
6. Unabated vertical flow through drill rig subbase	938	219	164	2.44	98	0.66	2.35	2.16	4.31	8.07	0.094	2,072	0.0000	8.35	0.188	0.56	0.94	0.0000	0.1876	58	0.5
2. Unabated vertical flow through diverter/muffler	383	89	67	1.00	40	0.27	0.96	0.88	1.76	3.29	0.038	846	0.0000	3.41	0.077	0.23	0.38	0.0000	0.0766	24	0.4
7. Unabated vertical flow through small area of fractured rock	1,874	437	328	4.87	195	1.31	4.69	4.31	8.62	16.12	0.187	4,140	0.0000	16.68	0.375	1.12	1.87	0.0000	0.3748	115	0.4
10. Unabated horizontal flow through a 4" choke line	30,355	7,073	5,312	78.92	3,157	21.25	75.89	69.82	139.63	261.05	3.036	67,054	0.0000	270.16	6.071	18.21	30.36	0.0000	6.0710	1,867	0.4
3. Unabated horizontal flow through diverter	60,697	14,142	10,622	157.81	6,312	42.49	151.74	139.60	279.21	521.99	6.070	134,080	0.0000	540.20	12.139	36.42	60.70	0.0000	12.1394	3,733	0.4

APPENDIX H

HAZARD ANALYSIS OF THE POSSIBLE WELL-RELATED UNCONTROLLED FLOW EVENT AND POWER PLANT UPSET EMISSION SCENARIOS PUNA GEOTHERMAL VENTURE PROJECT

HAZARD ANALYSIS OF THE POSSIBLE WELL-RELATED UNCONTROLLED FLOW EVENT AND POWER PLANT UPSET EMISSION SCENARIOS PUNA GEOTHERMAL VENTURE PROJECT

To determine the "worst case" conditions under which geothermal fluid emissions could occur during an uncontrolled flow event at any wellpad, or during specified power plant upset conditions, Puna Geothermal Venture (PGV) conducted a simplified hazard analysis of the possible well-related uncontrolled flow event and power plant upset scenarios to determine the range of credible situations under which hydrogen sulfide and other contaminants could be released from any well or the power plant. Table 1 provides a summary of the twelve (12) scenarios determined by PGV, in consultation with the Hawaii Department of Health and its consultants, to be credible events.

Table 2 lists the parameters of the geothermal resource (geochemistry [hydrogen sulfide and other chemical constituents], likely maximum credible productivity [flow rate], temperature [enthalpy], etc.) which were determined by PGV, in consultation with the Hawaii Department of Health and its consultants, to be the emitted (released) constituents for the hazard analysis.

In order to determine the maximum ("worst case") impacts which could result from each of these 12 different emission scenarios, PGV conducted an impact analysis utilizing the Industrial Source Complex Short Term (ISCST) model. The ISCST model is a steady-state Gaussian model used to assess pollutant concentrations from a wide variety of sources associated with an industrial source complex which can be used for a wide variety of applications, from initial screening to refined determinations of maximum concentrations. Its use is appropriate here because it is the most popular EPA guideline model, making it readily accessible to most modelers. The emissions to be modeled are assumed to be steady state, or the emissions are scaled to the one-hour modelling period, and one-hour concentrations are calculated. The emitted steam and gas plume is not heavier than air, eliminating the need for dense gas models. ISCST can be used in the screen mode to evaluate impacts over a wide range of atmospheric stability and wind speeds.

Because the ultimate product of the air modeling was to evaluate the "worst-case" results of many different release scenarios, each scenario was modeled as a single source with the ISCST model in the flat terrain mode. In order to ensure that the analysis would be very conservative, in consultation with the Hawaii Department of Health and its consultants, PGV modeled receptors placed both at the same height as the source and at "flagpole" heights of 10 meters. A narrow (100 meter wide) two-dimensional generated Cartesian receptor grid (1,000 meter spacing from 1,000 to 25,000 meters) with discrete receptors located at 50 and 100 through 900 meters (at 100 meter intervals) was used, which provided sufficient detail without overburdening the analysis. To err again on the conservative side, building downwash calculations were modeled for those source(s) which could be located within the zone of influence of the power plant turbine and air cooler pads.

Because the air modeling is conducted to select the "worst-case" results of each of the different release scenarios under a wide variety of meteorological conditions, the ISCST model was used in the "screen" mode. This mode calculates "worst-case" ambient air concentrations for each of the 33 different wind-speed/stability classes used by the SCREEN model (see Table 3 for a listing of each of the SCREEN combinations) for each of the designated receptor points. The mixing height was changed from the default value to 300 meters (stability classes A, B, C, and D) or 100 meters (stability classes E and F), and ambient temperatures scaled, to conform to the requests of the Hawaii Department of Health and its consultants, to ensure "worst-case" values.

Appropriate emission rates and other necessary air modeling parameters (temperature, flow rate, stack diameter, etc.) for the hydrogen sulfide emissions for each of the potentially credible release scenarios were established by PGV in consultation with the Hawaii Department of Health and it consultants, and are presented in Table 4. Emission parameters for the non-hydrogen sulfide noncondensible gas constituents of the geothermal fluid are identical to those for the hydrogen sulfide. Emission characteristics for the brine portion of the geothermal fluid are also identical to those for hydrogen sulfide, except that many of the emission mechanisms substantially reduce the emission of geothermal brine into the atmosphere over the hydrogen sulfide (and other noncondensible gases), and only a portion of the brine emitted into the atmosphere is converted into atmospheric aerosols. As a result, an additional reduction in the emission rate of the brine components over the hydrogen sulfide is appropriate. These reduction values are presented in Table 5.

Once the emission parameters, receptor locations and meteorological conditions were selected, the ISCST model was then run for each of the credible release scenarios to determine the highest modeled atmospheric concentration of hydrogen sulfide at <u>each</u> receptor point under <u>any</u> of the modeled meteorological conditions and receptor elevations. The output of this air dispersion modeling is presented in Attachment 2, and the maximum modeled concentrations for each scenario are graphically displayed in Attachment 3, Maps H-1 through H-12. Table 6 summarizes the results of the modeling for each of the 12 release scenarios, organized on the basis of the maximum distance at which each of the HDOH-specified threshold levels are predicted to be exceeded under the "worst case" meteorological conditions/receptor elevations and the point and concentration of maximum impact. Table 6 has further categorized each release scenario by which, if any, of the HDOH-specified threshold levels is predicted to be exceeded by the maximum predicted concentration, thus ensuring that each release scenario is categorized by the <u>highest</u> impact it can create.

Based on the ratio of the "emission rates" for hydrogen sulfide and each of the other noncondensible gas species which was determined in Attachment 1 as likely to result from the emission (release) of the geothermal fluid into the atmosphere, and the modeled ambient hydrogen sulfide concentrations at each receptor point for each of the scenarios as presented in Attachment 2, the "worst case" ambient concentrations of each of these noncondensible gas species can be estimated. These values are presented in Table 7. By ratioing these values further as appropriate by the reduced brine emission rates presented in Table 5, the maximum predicted concentrations of each of the brine aerosol species can be calculated. These maximum predicted concentrations for each of the brine aerosol species are listed in Table 8.

TABLE 1 WELL-RELATED UNCONTROLLED FLOW EVENT AND POWER PLANT UPSET EMISSION SCENARIOS	
1.	Abated **vertical** flow through the well 13-3/8" flow line and muffler (assumes that the new well control and abatement system works as designed to divert and abate any uncontrolled flow).
2.	Unabated **vertical** flow through the well 13-3/8" flow line and muffler (assumes that the abatement system does not operate).
3.	Unabated **horizontal** flow through the well 13-3/8" flow line (assumes that the flow through the flow line knocks the muffler off the end of the flow line and the abatement equipment is not operated. This scenario can be quickly controlled through closing valves to shut in the well).
4.	Unabated **vertical** flow through the well 13-3/8" casing (assumes that the rupture disk on the flow line does not rupture and the flow continues up the 13-3/8" casing through the BOPE stack).
5.	Unabated **vertical** flow through the well 9-5/8" casing (assumes that the well is unable to be shut-in at the surface after the 9-5/8" casing is set, or the vertical line is ruptured after the rig is removed from the well).
6.	Unabated **vertical** well flow channeled by the rig subbase (assumes that the rupture disk on the flow line does not rupture and the flow blows off the annular preventer and the vertical flow is channeled by the drill rig structure [this is essentially what happened during the first few hours of the KS-8 uncontrolled flow event]).
7.	Unabated **vertical** well flow through an area of fractured rock surrounding the well (assumes that the uncontrolled flow is not coming through the casing of the well but through an area of fractured rock surrounding the well casing).
8.	Abated **vertical** flow from the well drilling rig mud tanks (assumes that the choke line is used to divert the geothermal fluid to the mud tanks. Abatement is through NaOH injected into the choke line and lime in the mud tanks).
9.	Abated **vertical** flow from the well drilling rig mud sump (assumes that the choke line is used to divert the geothermal fluid to the mud sump. Abatement is through NaOH injected into the choke line and lime in the mud sump).
10.	Unabated **horizontal** flow through the well drilling rig 4" choke line (assumes that the choke line is used to divert the geothermal fluid, but the fluid flow knocks the "tee" off of the end of the choke line, at which point the hydrogen sulfide is unabated. This scenario can be controlled through closing valves to divert the geothermal fluid to the flow diverter or shut in the well).
11.	Unabated **horizontal** "puff" flow through 3" noncondensible gas flow line from noncondensible gas compressor to fluid injection line (assumes that the line is ruptured and the contents of the pipeline (4.9 pounds of hydrogen sulfide) is emitted to the air).
12.	Unabated **vertical** flow through the power plant steam release facility (assumes that the emergency steam release facility abatement system does not operate when needed).

TABLE 2 EMITTED GEOTHERMAL RESOURCE CHARACTERISTICS ASSUMED FOR THE PGV PROJECT EMERGENCY RESPONSE PLAN		
PARAMETERS	**VALUE**	**COMMENT**
MAXIMUM SINGLE WELL MASS FLOW	500,000 lbs/hr	Estimated maximum credible flow of geothermal fluid from a single well.
STEAM FLASH	80 percent	Based on enthalpy of KS-8 and flashing steam at atmospheric pressures.
HYDROGEN SULFIDE IN GEOTHERMAL FLUID	896 ppm	Based on assumed hydrogen sulfide concentration in steam (from below) calculated back to reservoir conditions by adding back in the 20% brine not flashed to steam.
HYDROGEN SULFIDE IN FLASHED STEAM	1,120 ppm	Calculated based upon average hydrogen sulfide measurements from KS-1A, KS-3, and HGP-A (834 ppmv) plus one standard deviation (286 ppmv) of all measurements.
BRINE AEROSOL SPECIES CONCENTRATIONS	See Attachment 1	
VAPOR PHASE INITIAL SPECIES CONCENTRATIONS	See Attachment 1	

TABLE 3 33 WIND SPEED/STABILITY COMBINATIONS ANALYZED BY SCREEN AND USED FOR THE PGV PROJECT EMERGENCY RESPONSE PLAN						
10 Meter Wind Speed (m/s)	Stability Class					
	A	B	C	D	E	F
1.0	1	4	9	16	25	30
2.0	2	5	10	17	26	31
3.0	3	6	11	18	27	32
4.0		7	12	19	28	33
5.0		8	13	20	29	
8.0			14	21		
10.0			15	22		
15.0				23		
20.0				24		

TABLE 4
EMISSION CHARACTERISTICS FOR WELL-RELATED UNCONTROLLED FLOW EVENT AND POWER PLANT UPSET SCENARIOS FOR THE PGV EMERGENCY RESPONSE PLAN

SCENARIO	Source Type	Stack or Effective Height	Inside Diameter or Sigma y (feet)	Emission Velocity (ft/min) OR	OR Volumetric Flow Rate (ACFM)	Temperature of Effluent (F) or Sigma z (feet)	Abatement Efficiency (%)	Abated Emission Rate (lb/hr)
1. Abated **vertical** flow through the well 13-3/8" flow line and muffler	Stack	20[1]	15[2]		182,000[3]	211[4]	90[5]	44.8[6]
2. Unabated **vertical** flow through the well 13-3/8" flow line and muffler	Stack	20	15		182,000	211	0	448
3. Unabated **horizontal** flow through the well 13-3/8" flow line only	Volume x5[7]	65[8]	58.1[9]			30.2[10]	0	448[11]

[1]Based upon current design of muffler.

[2]Based upon current design of muffler.

[3]500,000 lb/hr x 80% steam flash = 400,000 lb/hr x 27.3 cu.ft/lb / 60 min/hr = 182,000 ACFM.

[4]Temperature of geothermal fluid at point of release after flashing.

[5]Abatement efficiency conservatively estimated from the literature.

[6]Assumes 400,000 lb/hr geothermal steam x 1,120 ppm hydrogen sulfide x 90% abatement.

[7]Assumes that the source is a line source, which is modeled as five volume sources, each with initial height of 65 ft and initial width of 125 ft. The center of each volume source along the line is assumed to be 62.5 ft, 312.5 ft, 562.5 ft, 812.5 ft, and 1,062.5 ft. Initial strength of each volume source is proportional to its distance from the origin; the first source is 29.9 lb/hr; the second 59.7 lb/hr; the third 89.6 lb/hr; the fourth 119.5 lb/hr; and the fifth 149.3 lb/hr, for a total emission rate of 448 lb/hr.

[8]The effective emission height of each volume source is set to the height of the volume.

[9]Initial Sigma y for each volume source is calculated as the initial width (125 ft) divided by 2.15.

TABLE 4
EMISSION CHARACTERISTICS FOR WELL-RELATED UNCONTROLLED FLOW EVENT AND POWER PLANT UPSET SCENARIOS FOR THE PGV EMERGENCY RESPONSE PLAN

SCENARIO	Source Type	Stack or Effective Height	Inside Diameter or Sigma y (feet)	Emission Velocity (ft/min) OR	OR Volumetric Flow Rate (ACFM)	Temperature of Effluent (F) or Sigma z (feet)	Abatement Efficiency (%)	Abated Emission Rate (lb/hr)
4. Unabated **vertical** flow through the well 13-3/8" casing	Stack	71[12]	75[13]	41	182,000	211[14]	0	448
5. Unabated **vertical** flow through the well 9-5/8" casing	Stack	71	75	41	182,000	211	0	448
6. Unabated **vertical** flow channeled by	Stack	40[15]	80[16]		182,000[17]	211	0	448

[10]Initial Sigma z for each volume source is calculated by dividing the initial vertical dimension of the source (65 feet) by 2.15.

[11]The initial strength of each volume source is proportional to its distance from the origin; the first source is 29.9 lb/hr; the second 59.7 lb/hr; the third 89.6 lb/hr; the fourth 119.5 lb/hr; and the fifth 149.3 lb/hr, for a total emission rate of 448 lb/hr. Note, however, that this scenario can be quickly controlled through closing valves to shut in the well, resulting in a significantly reduced emission rate over any one-hour period.

[12]The effective stack height (71 ft) is calculated by adding the assumed actual height of the stack (6 ft) to the calculated height (65 ft) at which the sonic cone has reached its maximum spread.

[13]Calculated effective stack diameter of release based upon sonic flow at release point (6 ft), resulting in expansion of the sonic cone at a 60° angle up to a additional height of 65 ft, which results in an effective diameter of 75 ft.

[14]Temperature of geothermal fluid at effective point of release after flashing.

[15]Assumes that the soundproofing around rig floor railing, which tops out at about 40' above ground level, channels most of the steam flow.

[16]Because the rig floor was blown out during the KS-8 uncontrolled flow event, this scenario assumes that the effective diameter is equal to the observed diameter of the plume during the KS-8 uncontrolled flow event (80 ft diameter).

TABLE 4
EMISSION CHARACTERISTICS FOR WELL-RELATED UNCONTROLLED FLOW EVENT AND POWER PLANT UPSET SCENARIOS FOR THE PGV EMERGENCY RESPONSE PLAN

SCENARIO	Source Type	Stack or Effective Height	Inside Diameter or Sigma y (feet)	Emission Velocity (ft/min) **OR**	**OR** Volumetric Flow Rate (ACFM)	Temperature of Effluent (F) or Sigma z (feet)	Abatement Efficiency (%)	Abated Emission Rate (lb/hr)
the rig subbase								
7. Unabated **vertical** flow through an area of fractured rock surrounding the well	Stack	0	50[18]		182,000	211	0	448
8. Abated **vertical** flow from the well drilling rig mud tanks	Stack	6[19]	25.5[20]	3.28[21]	-[22]	160[23]	99[24]	4.5
9. Abated **vertical** flow from the well	Stack	0	70.7[25]	3.28[26]	-[27]	160	99	4.5

[17]Assumes total steam flow of 400,000 lb/hr is exiting through area of effective diameter.

[18]Reasonable but arbitrary assumption for a steam release through fractured rock. Assumes total area of rock fractures releasing steam and hydrogen sulfide equals approximately 2,000 square feet.

[19]Height of mud tanks above ground surface.

[20]Assumes mud tank surface area is approximately 650 sq. ft.

[21]Assumes a very low (1 meter per minute) vertical velocity.

[22]Assumes that a 4-inch diameter choke line limits steam and brine flow to only 50% of the unlimited flow rate.

[23]Assumes that the temperature of the mud is limiting the temperature of the discharge.

[24]High abatement percentage assumes discharge is abated through limitations in flow through the small-diameter choke line (50%); abatement by chemical injection in the choke-line (96%), and discharge into the mud tanks under the level of the mud in the tanks (50%).

[25]Assumes a 50' x 100' mud sump.

TABLE 4
EMISSION CHARACTERISTICS FOR WELL-RELATED UNCONTROLLED FLOW EVENT AND POWER PLANT UPSET SCENARIOS FOR THE PGV EMERGENCY RESPONSE PLAN

SCENARIO	Source Type	Stack or Effective Height	Inside Diameter or Sigma y (feet)	Emission Velocity (ft/min) OR	OR Volumetric Flow Rate (ACFM)	Temperature of Effluent (F) or Sigma z (feet)	Abatement Efficiency (%)	Abated Emission Rate (lb/hr)
drilling rig mud sump								
10. Unabated **horizontal** flow through the well drilling rig 4" choke line	Volume x5[28]	65[29]	58.1[30]			30.2[31]	50[32]	224[33]
11. Unabated **horizontal** "puff" of noncondensible gases through 3"	Stack	0[35]	3.28[36]	0.00[37]		150[38]	0	4.9[39]

[26]Assumes a very low (1 meter per minute) vertical velocity.

[27]Assumes that a 4-inch diameter choke line limits steam and brine flow to only 50% of the unlimited flow rate.

[28]Assumes that the source is a line source, which is modeled as five volume sources, each with initial height of 65 ft and initial width of 125 ft. The center of each volume source along the line is assumed to be 62.5 ft, 312.5 ft, 562.5 ft, 812.5 ft, and 1,062.5 ft. Initial strength of each volume source is proportional to its distance from the origin.

[29]The effective emission height of each volume source is set to the height of the volume.

[30]Initial Sigma y for each volume source is calculated as the initial width (125 ft) divided by 2.15.

[31]Initial Sigma z for each volume source is calculated by dividing the initial vertical dimension of the source (65 feet) by 2.15.

[32]Abatement is assumed to be 50% as total flow of geothermal fluid is restricted through choke line to only 50% (250,000 lb/hr).

[33]The initial strength of each volume source is proportional to its distance from the origin; the first source is 14.9 lb/hr; the second 29.9 lb/hr; the third 44.8 lb/hr; the fourth 59.7 lb/hr; and the fifth 74.7 lb/hr, for a total emission rate of 224 lb/hr. Note, however, that this scenario can be quickly controlled through closing valves to divert the flow to the flow diverter or to shut in the well, resulting in a significantly reduced emission rate over any one hour period.

TABLE 4
EMISSION CHARACTERISTICS FOR WELL-RELATED UNCONTROLLED FLOW EVENT AND POWER PLANT UPSET SCENARIOS FOR THE PGV EMERGENCY RESPONSE PLAN

SCENARIO	Source Type	Stack or Effective Height	Inside Diameter or Sigma y (feet)	Emission Velocity (ft/min) OR	OR Volumetric Flow Rate (ACFM)	Temperature of Effluent (F) or Sigma z (feet)	Abatement Efficiency (%)	Abated Emission Rate (lb/hr)
line[34]								
12. Unabated **vertical** flow through power	Stack	20[40]	15[41]		500,000[42]	211[43]	0	560[44]

[35]Assumes a ground-level release.

[36]Assumes a small diameter stack release.

[37]Uses the extremely conservative assumption that the emission occurs with no vertical velocity.

[38]Operating temperature for the line.

[39]The quantity of hydrogen sulfide contained in the pipeline at any given time.

[34]This scenario results in the emission of only that noncondensible gas contained in the line (4.9 pounds) at the time of the pipe rupture (which is an extremely remote possibility. If the pipeline ruptured, the system would bypass the compressor and attempt to inject the noncondensible gases into the fluid injection line through an independent line. If the noncondensible gas injection system became completely inoperable for whatever reason, the power plant would go off-line and the geothermal steam and noncondensible gases would be released (and abated) through the power plant steam release facility, or through the well pad rock mufflers, or the wells would be shut in.

[40]Stack height as built is 20 feet.

[41]Diameter of the steam release facility as designed and constructed is 15 feet.

[42]Total flow of steam through the power plant.

[43]Temperature of the steam at release.

TABLE 4
EMISSION CHARACTERISTICS FOR WELL-RELATED UNCONTROLLED FLOW EVENT AND POWER PLANT UPSET SCENARIOS FOR THE PGV EMERGENCY RESPONSE PLAN

SCENARIO	Source Type	Stack or Effective Height	Inside Diamete r or Sigma y (feet)	Emissio n Velocity (ft/min) **OR**	**OR** Volumetric Flow Rate (ACFM)	Temperature of Effluent (F) or Sigma z (feet)	Abatement Efficiency (%)	Abated Emission Rate (lb/hr)
plant steam release facility								

[44] Assumes 500,000 lb/hr geothermal steam x 1,120 ppm hydrogen sulfide.

TABLE 5
ABATEMENT ESTIMATES FOR EMITTED NON-HYDROGEN SULFIDE PRODUCTS FOR WELL UNCONTROLLED FLOW EVENT AND POWER PLANT UPSET EMISSION SCENARIOS FOR THE PGV EMERGENCY RESPONSE PLAN

SCENARIO	Total Mass Flow (lb/hr)	Brine Droplet Abatement Percentage	Aerosol Production Percentage	Noncondensible Gas Abatement Percentage
1. Abated **vertical** flow through the well 13-3/8" flow line and muffler	500,000[45]	80[46]	50[47]	0[48]
2. Unabated **vertical** flow through the well 13-3/8" flow line and muffler	500,000	80	50	0
3. Unabated **horizontal** flow through the well 13-3/8" flow line	500,000	0	50	0
4. Unabated **vertical** flow through the well 13-3/8" casing	500,000	0	50	0
5. Unabated **vertical** flow through the well 9-5/8" casing	500,000	0	50	0
6. Unabated **vertical** flow channeled by the rig subbase	500,000	20[49]	50	0
7. Unabated **vertical** flow through an area of fractured rock surrounding the well	500,000	50[50]	50	0
8. Abated **vertical** flow from the well drilling rig mud tanks	250,000[51]	90[52]	50	0
9. Abated **vertical** flow from the well drilling	250,000	90[53]	50	0

[45]Total flow of geothermal fluid; brine, steam, steam condensate and noncondensible gases.

[46]Estimated abatement percentage for brine droplets due to mechanics of the emission process. Assumption that cyclonic muffler abates 80 percent of the brine droplets.

[47]General assumption is that only 50 percent of the emitted brine droplets produce aerosols.

[48]Percentage of noncondensible gases in the geothermal fluid which are abated before emission to the atmosphere.

[49]Assumes the rig substructure and floor abates 20 percent of the brine droplets.

[50]Assumption that 50 percent of the brine is abated for small-diameter release.

[51]Total flow is limited by the small diameter (4") of the choke line.

[52]Assumes that flow through the mud tank abates 90 percent of the brine droplets.

[53]Assumes that flow through the mud sump abates 90 percent of the brine droplets.

TABLE 5 ABATEMENT ESTIMATES FOR EMITTED NON-HYDROGEN SULFIDE PRODUCTS FOR WELL UNCONTROLLED FLOW EVENT AND POWER PLANT UPSET EMISSION SCENARIOS FOR THE PGV EMERGENCY RESPONSE PLAN				
SCENARIO	Total Mass Flow (lb/hr)	Brine Droplet Abatement Percentage	Aerosol Production Percentage	Noncondensible Gas Abatement Percentage
rig mud sump				
10. Unabated **horizontal** flow through the well drilling rig 4" choke line	250,000	0	50	0
11. Unabated **horizontal** "puff" of noncondensible gases through 3" line	8.77[54]	100[55]	N/A	0
12. Unabated **vertical** flow through power plant steam release facility	500,000	100[56]	N/A	0

[54]Noncondensible gas line from compressor to injection line contains approximately 8.77 pounds of noncondensible gasses, including approximately 4.9 pounds of hydrogen sulfide.

[55]Contents of pipeline is noncondensible gases only.

[56]Discharge will be of steam and noncondensible gases only.

TABLE 6: SUMMARY OF MODELLED HYDROGEN SULFIDE IMPACTS				
RELEASE SCENARIO	MAXIMUM OFF-SITE (>0.3 km) DISTANCE FROM SOURCE (km) TO IDENTIFIED ACTION LEVEL		POINT OF MAXIMUM PREDICTED OFF-SITE IMPACT (>0.3 km)	
	"WATCH" LEVEL (25 ppb)	"WARNING" LEVEL (1,000 ppb)	CONCENTRATION (ppb)	DISTANCE FROM SOURCE (km)
TYPE "1" EVENTS [EXCEED ONLY THE "WATCH" ACTION LEVEL]				
1. Abated vertical flow through diverter/muffler	0.9 km	N/A	40.3	0.4
9. Abated vertical flow from the mud sump	2.8 km	N/A	57.1	0.4
8. Abated vertical flow from the mud tanks	4.5 km	N/A	253.1	0.4
11. Unabated noncondensible gas flow	5.5 km	N/A	935.7	0.4
4. Unabated vertical flow through 13-3/8" casing	25.+ km	N/A	146.0	0.6
5. Unabated vertical flow through 9-5/8" casing	25.+ km	N/A	146.0	0.6
12. Unabated vertical flow through power plant steam release facility	25.+ km	N/A	150.6	0.8
6. Unabated vertical flow through drill rig subbase	25.+ km	N/A	246.8	0.5
2. Unabated vertical flow through diverter/muffler	25.+ km	N/A	403.4	0.4
7. Unabated vertical flow through area of fractured rock	25.+ km	N/A	789.4	0.4
TYPE "2" EVENTS [EXCEED THE "WATCH" AND "WARNING" ACTION LEVELS]				
10. Unabated horizontal flow through a 4" choke line	25.+ km	3.7 km	6,395[57]	0.4
3. Unabated horizontal flow through diverter	25.+ km	6.7 km	12,786[58]	0.4

[57]Note that this scenario can and will be quickly controlled through closing valves to shut in the well, resulting in a significantly reduced emission rate over any one hour period.

[58]Note that this scenario can and will be quickly controlled through closing valves to shut in the well, resulting in a significantly reduced emission rate over any one hour period.

TABLE 7: SUMMARY OF MODELED GEOTHERMAL VAPOR PHASE EMISSION IMPACTS

RELEASE SCENARIO	POINT OF MAXIMUM PREDICTED OFF-SITE IMPACT (>0.3 km)													
	CONCENTRATION (µg/m3) (Rn-222=aCi/m3 [pCi/m3/1,000,000)													DISTANCE FROM SOURCE (km)
	HAsO2	NH3	CH4	C2H4	C2H6	C3H6	C3H8	C4H10	C4H10	C5H12	C5H12	HCl	Rn-222	
1. Abated vertical flow through diverter/muffler	0.0045	0.690	8.49	0.0023	0.045	0.041	0.036	0.0131	0.0198	0.0063	0.0068	8.07	0.0635	0.4
9. Abated vertical flow from the mud sump	0.0635	9.732	119.75	0.0318	0.635	0.583	0.507	0.1847	0.2794	0.0888	0.0953	113.89	0.8954	0.4
8. Abated vertical flow from the mud tanks	0.2814	43.127	530.68	0.1407	2.814	2.585	2.248	0.8183	1.2382	0.3937	0.4221	504.69	3.9677	0.4
11. Unabated noncondensible gas flow	0.9576	146.762	1,805.91	0.4788	9.576	8.796	7.650	2.7847	4.2134	1.3397	1.4364	1,717.44	13.502 2	0.4
4. Unabated vertical flow through 13-3/8" casing	0.0016	0.245	3.02	0.0008	0.016	0.015	0.013	0.0047	0.0070	0.0022	0.0024	2.87	0.0226	0.6
5. Unabated vertical flow through 9-5/8" casing	0.0016	0.245	3.02	0.0008	0.016	0.015	0.013	0.0047	0.0070	0.0022	0.0024	2.87	0.0226	0.6
12. Unabated vertical flow through power plant steam release facility	0.0017	0.261	3.21	0.0009	0.017	0.016	0.014	0.0049	0.0075	0.0024	0.0026	3.05	0.0240	0.8
6. Unabated vertical flow through drill rig subbase	0.0028	0.429	5.28	0.0014	0.028	0.026	0.022	0.0081	0.0123	0.0039	0.0042	5.02	0.0395	0.5
2. Unabated vertical flow through diverter/muffler	0.0045	0.690	8.49	0.0023	0.045	0.041	0.036	0.0131	0.0198	0.0063	0.0068	8.07	0.0635	0.4
7. Unabated vertical flow through small area of fractured rock	0.0088	1.349	16.60	0.0044	0.088	0.081	0.070	0.0256	0.0387	0.0123	0.0132	15.78	0.1241	0.4
10. Unabated horizontal flow through a 4" choke line	0.0714	10.943	134.65	0.0357	0.714	0.656	0.570	0.2076	0.3142	0.0999	0.1071	128.05	1.0067	0.4
3. Unabated horizontal flow through diverter	0.1428	21.886	269.30	0.0714	1.428	1.312	1.141	0.4153	0.6283	0.1998	0.2142	256.11	2.0135	0.4

ATTACHMENT 1
AIR TOXICS PROFILE FOR THE WORST CASE WELL-RELATED
UNCONTROLLED FLOW EVENT SCENARIO
PUNA GEOTHERMAL VENTURE PROJECT

THERMOCHEM

PGV Emergency Response Plan
Worst Case Air Toxics Profile

Brine Aerosol Characterization

An estimation of the potential brine aerosol chemical speciation and mass emission rate was performed for the Puna Geothermal Venture (PGV) Uncontrolled Flow Event Scenario Hazards Analysis by Thermochem, Inc. (TCI). The worst case scenario assumes a 500 KPH vertical discharge comprised of 80% steam and 20% brine by mass at atmospheric pressure (14.4 psia).

For this initial evaluation it has been assumed that 50% of the total brine discharge is converted to droplets smaller than 100 um in the atmosphere. The actual fraction of brine converted to aerosol at a given total flow rate (steam + brine) would be strongly dependent on the discharge enthalpy (steam/brine ratio). At high enthalpies a greater proportion of brine would be converted to an aerosol, but the brine discharge rate would be lower, compensating this effect. Therefore, a 50% aerosol production rate appears to be a reasonable worst case assumption given the 500 KPH total flow and 20% brine specification that is several times above any observed discharge rate for Puna and only speculated for the KS-8 well.

The brine chemistry data used in this evaluation, summarized in Table 1, was derived primarily from the KS-3 flow test results and only supplemented with KS-1A data for certain analytes not measured or reported undetected for the KS-3 samples. The KS-3 brine chemistry clearly represents the worst case for the Puna resource known to date given the high salinity and low pH of this fluid. The KS-3 brine contains the highest concentrations of heavy metals, in addition to the other salts, due to the brine acidity that assists in mobilizing these metals in the reservoir. Data used from KS-1A brine analyses were factored up in concentration based on the KS-3/KS-1A chloride ratios. Unfortunately, numerous toxic metals were not measured or reported undetected, with relatively high detection limits, in both sets of data and could not be included in this evaluation.

The worst case discharge scenario considered here assumes that H_2S abatement chemicals (such as NaOH) are not injected into the flow. This would be the case when the well vents directly to atmosphere, bypassing any muffler or vapor/liquid separator. The injection of H_2S abatement chemicals under these conditions would have a minimal effect on H_2S emission rates and would only render the brine aerosol considerably more hazardous.

The concentrations of brine aerosol constituents (Table 2) were calculated by assuming droplet evaporation until equilibrium with atmospheric conditions was achieved. Equilibrium is realized when the water vapor pressure exerted by the aerosol, which is depressed due to the high salt concentration, equals the atmospheric water vapor pressure, defined by the ambient temperature and relative humidity. Annual average temperature and humidity data for Puna was used in the worst case exercise since actual near plume humidities would be much higher.

The primary computer model used in these computations was a heterogeneous chemical equilibrium code using Pitzer-derived specific interaction parameters to predict high ionic strength solution behavior (Weare, 1991). Under the conditions modeled, only amorphous silica precipitates to a solid phase in the aerosol. At 79% relative humidity NaCl is near saturation, which is consistent with a similar study performed by Clegg (1990) where NaCl was found to be supersaturated in seawater aerosols below 75% relative humidity. Certain iron, calcium and magnesium silicates may also precipitate in the Puna aerosol, although there is insufficient thermodynamic data available to predict their formation.

The brine aerosol speciation is based on the known form of certain elements as normally found in hydrothermal reservoirs, the initial speciation expected at the brine pH and redox condition, and consideration of oxidation reaction kinetics upon exposure to atmospheric oxygen. Only iron was assumed to oxidize substantially, although even this reaction would be relatively slow given the low aerosol pH and high chloride content. Many of the cations listed in Table 2 would be present as chloride complexes in addition to the free ion form.

All the weak acid compounds, silicic, boric and arsenious acids, would be unionized at the aerosol pH. For kinetic reasons, arsenic is assumed to remain in the trivalent oxidation state, which is also the most toxic form (Solomon, 1991). Concentrations of each constituent in the aerosol are given by weight as the actual species or compound considered present.

The mass emission rates for each constituent are based on the KS-3 or normalized KS-1A brine chemistry after flashing to 14.4 psia. A total of 50 KPH of the atmospheric flashed brine is assumed to form aerosols. After evaporation of this brine to 47% of its initial weight, 23.5 KPH of concentrated aerosol would be produced. The mass rates of individual constituents were calculated by weight as the respective element or most common compound, as shown in Table 2. These mass emission rates can be used for preliminary modeling of maximum ambient air impacts.

Vapor Phase Characterization

A vapor phase composition of the initial steam plume and mass emission rate of each species was also estimated for the worst case hazards analysis, assuming a 500 KPH discharge comprised of 80% steam and 20% brine by mass at atmospheric pressure (Table 3). Hydrogen sulfide was not evaluated in this exercise, at the request of PGV, since H_2S

emission rate estimates and dispersion modeling was previously performed by PGV and Environmental Management Associates (EMA).

For purposes in modeling vapor phase concentrations of hydrogen chloride (HCl), the wellhead pressure was assumed to be 575 psia and the temperature 250°C. No re-equilibration between phases was considered after discharge to atmosphere, which results in maximum vapor phase concentrations of HCl and arsenic. All other gas species, including H_2S, would partition essentially 100% to the vapor phase after discharge.

The steam chemistry data used in this evaluation was derived from KS-1A and KS-3 flow test sample analysis results. The highest concentration found in the available data was used for each constituent, provided there was no reason to question the data quality. The data sources are also summarized in Table 3.

Arsenic measured in KS-1A steam samples was most likely present in the same form as arsenic in the brine phase ($HAsO_2$), and occurred through direct vapor phase partitioning at the separator temperature. This arsenic would actually condense to an aerosol or particulate phase after cooling in the atmosphere.

The concentration of HCl in the steam phase was calculated based on KS-3 brine chemistry at the wellhead conditions specified above, using the chemical model proposed by Anderson (1989). This model was designed to predict the partial pressure of HCl exerted by high temperature saline brines, such as those found in the Puna resource.

The radon data used in this evaluation was obtained from analysis results of a KS-1A steam sample collected near the end of the flow test (October 27, 1985). Radon data reported for samples collected earlier in the KS-1A flow test is invalid due to the excessive time span (2 months) between sample collection and analysis. This delay resulted in virtually complete decay of the radon. The data reported was essentially the instrument noise multiplied by a decay correction factor of over 50,000. This problem was noted in the original Anatec laboratory report to Thermal Power, dated January 29, 1986. A subsequent data quality study performed by Thermochem, Inc., for Thermal Power also discussed the radon data inaccuracy (1986).

The initial steam plume concentration of each species (other than HCl) in Table 3 is based on the original analysis results (KS-1A or KS-3) after correction to atmospheric flash for the given fluid. All constituent emission rates are based on the steam plume concentrations and a 400 KPH steam flow rate at atmospheric pressure. These emission rates can also be used for preliminary maximum ambient air impact modeling.

References

1. Moller, Nancy; John H. Weare, Zhenhao Duan, Jerry Greenberg, *Models for Optimizing Geothermal Power Plant Performance,* DOE Geothermal Modeling Workshop, 1991.

2. Clegg, Simon L., Peter Brimblecombe, *Solubility of Volatile Electrolytes in Multicomponent Solutions with Atmospheric Applications,* American Chemical Society, 1990.

3. Solomon, Paul A., Samuel L. Altshuler, Marilyn L. Keller, *Arsenic Speciation in Atmospheric Aerosols at The Geysers,* Geothermal Resources Council TRANSACTIONS, Vol. 15, 1991.

4. Andersen, Greg, *A Thermodynamic Model for Predicting HCl Partial Pressure above a High Temperature Hypersaline Geothermal Fluid,* Geothermal Resources Council, TRANSACTIONS, Vol. 13, October 1989.

TABLE 1

PGV EMERGENCY RESPONSE PLAN
WORST CASE UNCONTROLLED FLOW EVENT

INITIAL BRINE COMPOSITION : ATMOSPHERIC FLASH

DISSOLVED CONSTITUENTS, CATIONS	INITIAL FORM	ug/g	DATA SOURCE
SODIUM	Na^+	3.06E+04	(1)
POTASSIUM	K^+	7.14E+03	(1)
CALCIUM	Ca^{++}	5.33E+03	(1)
MAGNESIUM	Mg^{++}	7.87E+01	(1)
IRON	Fe^{++}	3.17E+03	(1)
LITHIUM	Li^+	2.20E+01	(1)
STRONTIUM	Sr^{++}	7.80E+01	(1)
ZINC	Zn^{++}	6.95E+01	(1)
BARIUM	Ba^{++}	1.42E+02	(1)
MANGANESE	Mn^{++}	2.63E+02	(1)
LEAD	Pb^{++}	3.73E+00	(1)
DISSOLVED CONSTITUENTS, ANIONS			
CHLORIDE	Cl^-	6.76E+04	(1)
FLUORIDE	F^-	2.70E+00	(1)
BROMIDE	Br^-	2.71E+02	(2)
SULFATE	$SO_4^=$	8.10E+00	(1)
DISSOLVED CONSTITUENTS, NEUTRAL SPECIES			
SILICIC ACID	H_4SiO_4	3.02E+03	(1)
BORIC ACID	H_3BO_3	1.81E+02	(1)
ARSENIOUS ACID	$HAsO_2$	2.32E+00	(2)
MERCURY	Hg	6.21E-03	(2)
BRINE pH		3.58 units	(1)

DATA SOURCES: (1) KS-3 BRINE ANALYSIS ,SAMPLE DATE 03/31/91,FIELD I.D. BC-013
(2) KS-1A BRINE ANALYSIS , SAMPLE DATE 10/24/85,FIELD I.D. 1006 CC

TABLE 2

PGV EMERGENCY RESPONSE PLAN
WORST CASE AIR TOXICS PROFILE

BRINE AEROSOL : SPECIES CONCENTRATIONS			MASS EMISSION RATES			
	PRIMARY FORM	ug/g	Calculated by WT. as	Lbs/Hr	g/sec	DATA SOURCE
DISSOLVED CONSTITUENTS , CATIONS						
SODIUM	Na^{+}	6.51E+04	Na	1.53E+03	1.93E+02	(1)
POTASSIUM	K^{+}	1.52E+04	K	3.57E+02	4.50E+01	(1)
CALCIUM	Ca^{++}	1.13E+04	Ca	2.67E+02	3.36E+01	(1)
MAGNESIUM	Mg^{++}	1.67E+02	Mg	3.94E+00	4.96E-01	(1)
IRON	Fe^{+++}	6.74E+03	Fe	1.59E+02	2.00E+01	(1)
LITHIUM	Li^{+}	4.68E+01	Li	1.10E+00	1.39E-01	(1)
STRONTIUM	Sr^{++}	1.66E+02	Sr	3.90E+00	4.92E-01	(1)
ZINC	Zn^{++}	1.48E+02	Zn	3.48E+00	4.38E-01	(1)
BARIUM	Ba^{++}	3.01E+02	Ba	7.09E+00	8.93E-01	(1)
MANGANESE	Mn^{++}	5.60E+02	Mn	1.32E+01	1.66E+00	(1)
LEAD	Pb^{++}	7.92E+00	Pb	1.86E-01	2.35E-02	(1)
DISSOLVED CONSTITUENTS , ANIONS						
CHLORIDE	Cl^{-}	1.44E+05	Cl	3.38E+03	4.26E+02	(1)
FLUORIDE	F^{-}	5.74E+00	F	1.35E-01	1.70E-02	(1)
BROMIDE	Br^{-}	5.77E+02	Br	1.36E+01	1.71E+00	(2)
SULFATE	$SO_4^{=}$	1.72E+01	SO_4	4.05E-01	5.10E-02	(1)
DISSOLVED CONSTITUENTS , NEUTRAL SPECIES						
SILICIC ACID	H_4SiO_4	7.04E+01	SiO_2	1.03E+00	1.30E-01	(1)
BORIC ACID	H_3BO_3	3.85E+02	B	1.58E+00	1.99E-01	(1)
ARSENIOUS ACID	$HAsO_2$	4.94E+00	As	8.06E-02	1.02E-02	(2)
MERCURY	Hg	1.32E-02	Hg	3.11E-04	3.91E-05	(2)
SOLID PHASE , PRECIPITATES						
AMORPHOUS SILICA	SiO_2	4.01E+03	SiO_2	9.41E+01	1.19E+01	(1)
AEROSOL pH		3.0 units	TOTAL AEROSOL	2.35E+04	2.96E+03	

NOTES:
A. BRINE AEROSOL CONCENTRATIONS BASED ON DROPLET EVAPORATION TO EQUILIBRIUM WITH ATMOSPHERIC CONDITIONS , 71 DEG. F 79% R.H.

B. EMISSION RATES BASED ON 500 KPH VERTICAL VENT ,20 % BRINE FRACTION AT 14.4 PSIA , AND 50 % CONVERSION OF BRINE TO AEROSOL FORM .

C. DATA SOURCES: (1) KS-3 BRINE ANALYSIS ,SAMPLE DATE 03/31/91,FIELD I.D. BC-013
(2) KS-1A BRINE ANALYSIS , SAMPLE DATE 10/24/85,FIELD I.D. 1006 CC

TABLE 3

PGV EMERGENCY RESPONSE PLAN
WORST CASE AIR TOXICS PROFILE

	VAPOR PHASE : INITIAL SPECIES CONCENTRATIONS			MASS EMISSION RATES			
	PRIMARY FORM	ug/g	ug/m3	Calculated By wt. as	Lbs/Hr	g/sec	DATA SOURCE
ARSENIC	HAsO2	1.32E-02	7.76E+00	As	3.68E-03	4.63E-04	(1)
AMMONIA	NH3	1.41E+00	8.26E+02	NH3	5.64E-01	7.10E-02	(2)
METHANE	CH4	1.73E+01	1.02E+04	CH4	6.94E+00	8.74E-01	(2)
ETHENE	C2H4	4.60E-03	2.69E+00	C2H4	1.84E-03	2.32E-04	(3)
ETHANE	C2H6	9.20E-02	5.39E+01	C2H6	3.68E-02	4.63E-03	(3)
PROPENE	C3H6	8.46E-02	4.96E+01	C3H6	3.38E-02	4.26E-03	(3)
PROPANE	C3H8	7.36E-02	4.31E+01	C3H8	2.94E-02	3.71E-03	(3)
2-METHYLPROPANE	C4H10	2.67E-02	1.56E+01	C4H10	1.07E-02	1.34E-03	(3)
n-BUTANE	C4H10	4.05E-02	2.37E+01	C4H10	1.62E-02	2.04E-03	(3)
2-METHYLBUTANE	C5H12	1.29E-02	7.54E+00	C5H12	5.15E-03	6.49E-04	(3)
n-PENTANE	C5H12	1.38E-02	8.08E+00	C5H12	5.52E-03	6.95E-04	(3)
HYDROGEN CHLORIDE	HCl	1.65E+01	9.67E+03	HCl	6.60E+00	8.32E-01	(4)
		pCi/kg	pCi/m3		uCi/Hr	uCi/sec	
RADON-222	Rn-222	2.87E+03	1.68E+03	Rn-222	5.19E+02	1.44E-01	(5)

NOTES :

A. INITIAL CONCENTRATIONS OF VAPOR PHASE SPECIES EXPRESSED RELATIVE TO STEAM AT ATMOSPHERIC PRESSURE (PLUME CONDITIONS BEFORE DISPERSION)

B. MASS EMISSION RATES BASED ON 500 KPH VENT AND 80 % STEAM FRACTION AT 14.4 PSIA

C. DATA SOURCES :

(1) KS-1A STEAM ANALYSIS , SAMPLE DATE 10/24/85 , FIELD I.D. 1006 GC-A
(2) KS-3 STEAM ANALYSIS , SAMPLE DATE 03/25/91 , LAB I.D. TCI 3495-01,02
(3) KS-1A STEAM ANALYSIS , SAMPLE DATE 10/17/85 , LAB I.D. ANA 7439-69
(4) KS-3 BRINE ANALYSIS , SAMPLE DATE 03/31/91 , FIELD I.D. BC-013 (CALC.)
(5) KS-1A STEAM ANALYSIS , SAMPLE DATE 10/27/85 , LAB I.D. ANA 7328-01

TABLE 3

PGV EMERGENCY RESPONSE PLAN
WORST CASE AIR TOXICS PROFILE

VAPOR PHASE : INITIAL SPECIES CONCENTRATIONS				MASS EMISSION RATES			
	PRIMARY FORM	ug/g	ug/m3	Calculated By wt. as	Lbs/Hr	g/sec	DATA SOURCE
ARSENIC	HAsO2	1.32E-02	7.76E+00	As	3.68E-03	4.63E-04	(1)
AMMONIA	NH3	1.41E+00	8.26E+02	NH3	5.64E-01	7.10E-02	(2)
METHANE	CH4	1.73E+01	1.02E+04	CH4	6.94E+00	8.74E-01	(2)
ETHENE	C2H4	4.60E-03	2.69E+00	C2H4	1.84E-03	2.32E-04	(3)
ETHANE	C2H6	9.20E-02	5.39E+01	C2H6	3.68E-02	4.63E-03	(3)
PROPENE	C3H6	8.46E-02	4.96E+01	C3H6	3.38E-02	4.26E-03	(3)
PROPANE	C3H8	7.36E-02	4.31E+01	C3H8	2.94E-02	3.71E-03	(3)
2-METHYLPROPANE	C4H10	2.67E-02	1.56E+01	C4H10	1.07E-02	1.34E-03	(3)
n-BUTANE	C4H10	4.05E-02	2.37E+01	C4H10	1.62E-02	2.04E-03	(3)
2-METHYLBUTANE	C5H12	1.29E-02	7.54E+00	C5H12	5.15E-03	6.49E-04	(3)
n-PENTANE	C5H12	1.38E-02	8.08E+00	C5H12	5.52E-03	6.95E-04	(3)
HYDROGEN CHLORIDE	HCl	1.65E+01	9.67E+03	HCl	6.60E+00	8.32E-01	(4)
		pCi/kg	pCi/m3		pCi/Hr	pCi/sec	
RADON-222	Rn-222	2.87E+03	1.68E+03	Rn-222	5.19E+08	1.44E+05	(5)

NOTES : A. INITIAL CONCENTRATIONS OF VAPOR PHASE SPECIES EXPRESSED RELATIVE TO STEAM AT ATMOSPHERIC PRESSURE (PLUME CONDITIONS BEFORE DISPERSION)

B. MASS EMISSION RATES BASED ON 500 KPH VENT AND 80 % STEAM FRACTION AT 14.4 PSIA

C. DATA SOURCES :

(1) KS-1A STEAM ANALYSIS , SAMPLE DATE 10/24/85 , FIELD I.D. 1006 GC-A
(2) KS-3 STEAM ANALYSIS , SAMPLE DATE 03/25/91 , LAB I.D. TCI 3495-01,02
(3) KS-1A STEAM ANALYSIS , SAMPLE DATE 10/17/85 , LAB I.D. ANA 7439-69
(4) KS-3 BRINE ANALYSIS , SAMPLE DATE 03/31/91 , FIELD I.D. BC-013 (CALC.)
(5) KS-1A STEAM ANALYSIS , SAMPLE DATE 10/27/85 , LAB I.D. ANA 7328-01

TABLE 1

PGV EMERGENCY RESPONSE PLAN
WORST CASE UNCONTROLLED FLOW EVENT

INITIAL BRINE COMPOSITION : ATMOSPHERIC FLASH

	INITIAL FORM	ug/g	DATA SOURCE
DISSOLVED CONSTITUENTS , CATIONS			
SODIUM	Na^+	3.06E+04	(1)
POTASSIUM	K^+	7.14E+03	(1)
CALCIUM	Ca^{++}	5.33E+03	(1)
MAGNESIUM	Mg^{++}	7.87E+01	(1)
IRON	Fe^{++}	3.17E+03	(1)
LITHIUM	Li^+	2.20E+01	(1)
STRONTIUM	Sr^{++}	7.80E+01	(1)
ZINC	Zn^{++}	6.95E+01	(1)
BARIUM	Ba^{++}	1.42E+02	(1)
MANGANESE	Mn^{++}	2.63E+02	(1)
LEAD	Pb^{++}	3.73E+00	(1)
DISSOLVED CONSTITUENTS , ANIONS			
CHLORIDE	Cl^-	6.76E+04	(1)
FLUORIDE	F^-	2.70E+00	(1)
BROMIDE	Br^-	2.71E+02	(2)
SULFATE	$SO_4^=$	8.10E+00	(1)
DISSOLVED CONSTITUENTS , NEUTRAL SPECIES			
SILICIC ACID	H_4SiO_4	3.02E+03	(1)
BORIC ACID	H_3BO_3	1.81E+02	(1)
ARSENIOUS ACID	$HAsO_2$	2.32E+00	(2)
MERCURY	Hg	6.21E-03	(2)
BRINE pH		3.58 units	(1)

DATA SOURCES: (1) KS-3 BRINE ANALYSIS ,SAMPLE DATE 03/31/91,FIELD I.D. BC-013
(2) KS-1A BRINE ANALYSIS , SAMPLE DATE 10/24/85,FIELD I.D. 1006 CC

TABLE 2

PGV EMERGENCY RESPONSE PLAN
WORST CASE AIR TOXICS PROFILE

BRINE AEROSOL : SPECIES CONCENTRATIONS			MASS EMISSION RATES			
DISSOLVED CONSTITUENTS , CATIONS	PRIMARY FORM	ug/g	Calculated by WT. as	Lbs/Hr	g/sec	DATA SOURCE
SODIUM	Na+	6.51E+04	Na	1.53E+03	1.93E+02	(1)
POTASSIUM	K+	1.52E+04	K	3.57E+02	4.50E+01	(1)
CALCIUM	Ca ++	1.13E+04	Ca	2.67E+02	3.36E+01	(1)
MAGNESIUM	Mg++	1.67E+02	Mg	3.94E+00	4.96E-01	(1)
IRON	Fe+++	6.74E+03	Fe	1.59E+02	2.00E+01	(1)
LITHIUM	Li+	4.68E+01	Li	1.10E+00	1.39E-01	(1)
STRONTIUM	Sr++	1.66E+02	Sr	3.90E+00	4.92E-01	(1)
ZINC	Zn ++	1.48E+02	Zn	3.48E+00	4.38E-01	(1)
BARIUM	Ba++	3.01E+02	Ba	7.09E+00	8.93E-01	(1)
MANGANESE	Mn++	5.60E+02	Mn	1.32E+01	1.66E+00	(1)
LEAD	Pb++	7.92E+00	Pb	1.86E-01	2.35E-02	(1)
DISSOLVED CONSTITUENTS , ANIONS						
CHLORIDE	Cl-	1.44E+05	Cl	3.38E+03	4.26E+02	(1)
FLUORIDE	F-	5.74E+00	F	1.35E-01	1.70E-02	(1)
BROMIDE	Br-	5.77E+02	Br	1.36E+01	1.71E+00	(2)
SULFATE	SO4=	1.72E+01	SO4	4.05E-01	5.10E-02	(1)
DISSOLVED CONSTITUENTS , NEUTRAL SPECIES						
SILICIC ACID	H4SiO4	7.04E+01	SiO2	1.03E+00	1.30E-01	(1)
BORIC ACID	H3BO3	3.85E+02	B	1.58E+00	1.99E-01	(1)
ARSENIOUS ACID	HAsO2	4.94E+00	As	8.06E-02	1.02E-02	(2)
MERCURY	Hg	1.32E-02	Hg	3.11E-04	3.91E-05	(2)
SOLID PHASE , PRECIPITATES						
AMORPHOUS SILICA	SIO2	4.01E+03	SiO2	9.41E+01	1.19E+01	(1)
AEROSOL pH		3.0 units	TOTAL AEROSOL	2.35E+04	2.96E+03	

NOTES: A. BRINE AEROSOL CONCENTRATIONS BASED ON DROPLET EVAPORATION TO EQUILIBRIUM WITH ATMOSPHERIC CONDITIONS , 71 DEG. F 79% R.H.

B. EMISSION RATES BASED ON 500 KPH VERTICAL VENT ,20 % BRINE FRACTION AT 14.4 PSIA , AND 50 % CONVERSION OF BRINE TO AEROSOL FORM .

C. DATA SOURCES: (1) KS-3 BRINE ANALYSIS ,SAMPLE DATE 03/31/91,FIELD I.D. BC-013
(2) KS-1A BRINE ANALYSIS , SAMPLE DATE 10/24/85,FIELD I.D. 1006 CC

Intended for
Puna Geothermal Venture

Date
April 2021

AIR DISPERSION MODELING REPORT –

PUNA GEOTHERMAL VENTURE

RAMBOLL

CONTENTS

ATTACHMENTS

1. INTRODUCTION

Ormat requested Ramboll to update the previous air dispersion modeling, which was performed in 1991 for the 1992 PGV Facility Emergency Response Plan[1] prior to the facility's construction, which completed construction in 1993. Hydrogen sulfide (H_2S) was analyzed as the emission of greatest potential health concern.[2] Updates to the prior modeling approach include the use of the most recent version of the U.S. Environmental Protection Agency (EPA) AERMOD dispersion model and updates to the associated terrain and meteorological files used in the model to reflect current conditions, including the changes to the terrain caused by the 2018 lava flows. The same 12 upset condition scenarios used in the original air dispersion modeling were used in the updated modeling. The results were compiled and compared to several national and state warning levels and health standards for H_2S.

2. AIR QUALITY ANALYSIS APPROACH

An air dispersion modeling analysis was completed with the latest modeling tools, meteorological data, and topographic data to evaluate H_2S concentrations during uncontrolled flow events and other power plant upset conditions. The analyses were conducted to update modeling results for the 12 "worst-case" upset scenarios evaluated in the prior 1992 PGV Facility Emergency Response Plan.

This analysis evaluated H_2S concentrations for the following averaging periods: 10-minute, 30-minute, 1-hour, 4-hour, 8-hour, and 24-hour. Limits for each averaging period are described in the remainder of Section 2. A more detailed discussion of modeling is provided in Section 3, and results are provided in Section 4.

2.1 Hydrogen Sulfide (H_2S) Hazard Analysis

The EPA, Agency for Toxic Substances and Disease Registry (ATSDR), Hawaii County Civil Defense Agency (CDA), Hawaii State Department of Health (HDOH), and Ormat's operating permit for the PGV facility establish warning and health-based thresholds for H_2S concentrations in the air to protect nearby residents. These limits are summarized in Table 1 and discussed below.

AEGL: The National Academy of Science's Acute Exposure Guideline Levels (AEGLs), adopted by EPA, represent threshold exposure limits for the general public and are applicable to emergency exposure periods ranging from five averaging periods, from 10 minutes to eight hours. Three levels - AEGL-1, AEGL-2, and AEGL-3 – have been developed for each of five exposure periods (10 and 30 minutes and 1, 4, and 8 hours), representing varying degrees of severity of toxic effects:[3]

- AELG-1: The airborne concentration below which could result in mild and progressively increasing but transient and non-disabling odor, taste, and sensory irritation or certain asymptomatic, non-sensory effects in the general population, including susceptible individuals.[4] In contrast, concentrations above the AEGL-1 (but below the AEGL-2) could cause noticeable discomfort or irritation in the general population and susceptible individuals, but the effects are not disabling and are transient and reversible once exposure stops.

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[1] Puna Geothermal Venture, 1992. *Facility Emergency Response Plan*. Available at https://evols.library.manoa.hawaii.edu/bitstream/handle/10524/33575/1992%20-%20Puna%20Geothermal%20Venture%20Facility%20Emergency%20Response%20Plan.pdf

[2] *Ibid.*, page 8-14. "Because of its toxicity and concentration, of all the components of the geothermal resource, the H_2S gas is the component of most significant concern."

[3] National Research Council, Acute Exposure Guideline Levels for Selected Airborne Chemicals, Volume 9, (2010). https://www.epa.gov/sites/production/files/2014-11/documents/hydrogen_sulfide_final_volume9_2010.pdf

[4] "Susceptible individuals" include infants, children, the elderly, persons with asthma, and those with other illnesses.

- AEGL-2: The concentration above which it is predicted the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects or impaired ability to escape.
- AEGL-3: Concentrations greater than AEGL-3 could cause life-threatening health effects or death in the general population, including susceptible individuals.

MRL: The Centers for Disease Control and Prevention's (CDC) ATSDR has defined Minimal Risk Levels (MRLs) for hazardous substances, intended to serve as a screening tool (not action levels) for public health officials in assessing acute, subacute, and chronic exposure.[5] The MRLs are set below levels that may cause adverse health effects in the most sensitive populations. This study of emergency scenarios evaluates concentrations only for acute exposure, defined as 1-14 days.

Hawaii Evacuation Codes: The Hawaii County CDA, in coordination with the HDOH and EPA, developed a three-tier, color evacuation guidance system for H_2S in response to the Kīlauea volcanic eruptions in 2018. Similar to the AEGLs, the CDA color codes distinguish between varying degrees of severity and establish responses to secure and protect the public.

- The "Blue" code presents little or no risk to healthy individuals, but individuals with pre-existing medical conditions may be affected at this level (i.e., up to 600 ppb averaged over 30 minutes). People with breathing conditions should take action to avoid exposure.
- Within the range of the "Orange" code (600 up to 7,000 ppb), individuals with pre-existing medical or respiratory conditions may experience health effects, like wheezing or chest tightness, and should leave the area, but the general public is not expected to be affected in this range.
- As concentrations increase above the "Red" code limit of 7,000 ppb, sensitive populations and the general public may experience more serious health effects, such as choking or difficulty breathing.[6]

PGV Watch/Warning Levels: The prior 1992 PGV Emergency Response Plan, in consultation with the HDOH, established concentration ranges that, when exceeded, require notification to the CDA and potential evacuation. The "Watch" (1,000 ppb) and "Warning" (10,000 ppb) levels for H_2S have been set to protect human health.[7]

PGV Permit for Normal Operations: Ormat's operating permit for the PGV facility establishes maximum allowable 1-hour and 24-hour rolling average H_2S concentrations of 25 and 10 ppb, respectively. However, these limits apply to normal operations and are included for reference only. They are not used for emergency response, but rather are reporting thresholds.

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[5] ATSDR Minimum Risk Levels, https://www.atsdr.cdc.gov/mrls/index.html

[6] Evacuation Guidance on Toxic Gas Exposure, https://www.hawaiicounty.gov/departments/civil-defense/lava-flow-related-information/evacuation-guidance-on-toxic-gas-exposure

[7] Puna Geothermal Venture, 1992. *Facility Emergency Response Plan*. Available at https://evols.library.manoa.hawaii.edu/bitstream/handle/10524/33575/1992%20-%20Puna%20Geothermal%20Venture%20Facility%20Emergency%20Response%20Plan.pdf

Table 1. Relevant H_2S Exposure Limits and Guidelines

Criterion	Averaging Period	Standard (ppb)	Standard (µg/m³) [a]
AEGL-1 (Nondisabling)	10-minute	750	1,050
	30-minute	600	840
	1-hour	510	714
	4-hour	360	504
	8-hour	330	462
AEGL-2 (Potentially disabling)	10-minute	41,000	57,400
	30-minute	32,000	44,800
	1-hour	27,000	37,800
	4-hour	20,000	28,000
	8-hour	17,000	23,800
AEGL-3 (Life-threatening)	10-minute	76,000	106,400
	30-minute	59,000	82,600
	1-hour	50,000	70,000
	4-hour	37,000	51,800
	8-hour	31,000	43,400
CDA "Blue" Code	30-minute	<600	<840
CDA "Orange" Code	30-minute	600-7,000	840-9,800
CDA "Red" Code	30-minute	>7,000	>9,800
ATSDR Acute MRL	1-14 days	70	98
Ormat PGV Permit Requirement [b]	1-hour	25	35
	24-hour	10	14
PGV Watch Level	N/A	1,000	1,400
PGV Warning Level	N/A	10,000	14,000

Notes:

a) Concentration in µg/m³ assumes H_2S conversion of 1 ppb to 1.4 µg/m³.

b) The PGV permit requirements apply to typical operations and are included for reference only.

Table 2. Relevant H_2S Exposure Limits and Guidelines Sorted by Value

Averaging Period	Standard (ppb)	Standard (µg/m^3)
AEGL-3 10-minute	76,000	106,400
AEGL-3 30-minute	59,000	82,600
AEGL-3 1-hour	50,000	70,000
AEGL-2 10-minute	41,000	57,400
AEGL-3 4-hour	37,000	51,800
AEGL-2 30-minute	32,000	44,800
AEGL-3 8-hour	31,000	43,400
AEGL-2 1-hour	27,000	37,800
AEGL-2 4-hour	20,000	28,000
AEGL-2 8-hour	17,000	23,800
PGV Warning Level*	10,000	14,000
CDA Red 30-min	>7,000	>9,800
CDA Orange 30-min	600-7,000	840-9,800
PGV Watch Level*	1,000	1,400
AEGL-1 10-minute	750	1,050
AEGL-1 30-minute	600	840
CDA Blue 30-min	<600	<840
AEGL-1 1-hour	510	714
AEGL-1 4-hour	360	504
AEGL-1 8-hour	330	462
ATSDR MRL 1-14 days	70	98
PGV Permit 1-hour*	25	35
PGV Permit 24-hour*	10	14

Notes:

* The PGV permit requirements apply to typical operations and are included for reference only.

* For this study, the PGV Watch and Warning levels are evaluated for all modeled averaging periods.

3. MODELING METHODOLOGY, SETTINGS, AND INPUTS

This section outlines the technical approach used in the modeling evaluations. Figures and tables supporting this modeling evaluation and outlining the model inputs are provided in Attachment A and Attachment B, respectively.

3.1 Model Selection and Settings

The most recent version (19191) of the AERMOD modeling system was used to estimate the ambient concentrations of H_2S outside the property fenceline. AERMOD is U.S. EPA's recommended air dispersion model for near-field (within 50 kilometers) modeling analyses. AERMOD is appropriate for estimating ground-level, short-term ambient air concentrations resulting from non-reactive buoyant emissions from sources located in simple and complex terrain, such as PGV.

Ambient concentrations were estimated using AERMOD in conjunction with information about the site, the emission sources, representative meteorological data, and nearby receptors. The North American Datum of 1983 (NAD83) of the Universal Transverse Mercator (UTM) Coordinate System (Zone 5) was used, which provides a constant distance relationship anywhere on the map or domain. The units of the coordinates are in meters.

AERMOD does not typically calculate concentrations for sub-hourly (e.g., 10-minute or 30-minute) averaging periods. To be able to compare model results to the 10-minute and 30-minute AEGL limits, Ramboll prepared sub-hourly meteorological data and calculated rolling totals for each period. Sections 3.6 and 3.7 provide additional details regarding the sub-hourly modeling approach.

3.2 Modeled Sources and Release Parameters

The following sections describe the release parameters that were used in the model.

3.2.1 Emission Sources and Rates

To model the worst-case results, all emissions were assumed to be released through a single source for each upset scenario. Consistent with the prior 1992 report, well emissions were modeled as a point source using emission rates and release parameters that were prepared in consultation with the Hawaii Department of Health.

There was one variation using the updated features of AERMOD. For scenarios 3 and 10, the prior 1992 study modeled flow line and choke line emissions as a series of volume sources with progressively lower emissions. For this assessment, scenarios 3 and 10 were modeled using a line source representing the same area and total emissions evaluated in the prior study.

According to PGV, three decades of operational data indicate the estimated concentration of H_2S in steam are lower than was estimated in 1992. In the interest of consistency, the H_2S value was not lowered in this updated modeling. Modeled offsite concentrations would be lower if the model included the lower actual H_2S values rather than keeping the original estimated value.

Source locations for all scenarios are identified in Attachment A – Figure A-2. Source parameters for point sources and line sources are provided in Attachment B – Table B-1 and Table B-2, respectively. Total emission rates are provided in Attachment B – Table B-3.

3.2.2 Operating Scenarios

The prior 1992 PGV Facility Emergency Response Plan identified 12 emergency scenarios under which geothermal fluid emissions could occur during uncontrolled flow events at a well pad or during power plant upset conditions. These scenarios, summarized in Table 3, provide a conservative representation of emergency H_2S emissions from the facility. The same 12 scenarios were used again in this report.

Table 3. Uncontrolled Flow Events and Power Plant Upset Emission Scenarios

Scenario	Description
1	Abated vertical flow through the well 13-3/8" flow line and muffler (assumes that the new well control and abatement system works as designed to divert and abate any uncontrolled flow).
2	Unabated vertical flow through the well 13-3/8" flow line and muffler (assumes that the abatement system does not operate).
3	Unabated horizontal flow through the well 13-3/8" flow line (assumes that the flow through the flow line knocks the muffler off the end of the flow line and the abatement equipment is not operated. This scenario can be quickly controlled through closing valves to shut in the well).
4	Unabated vertical flow through the well 13-3/8" casing (assumes that the rupture disk on the flow line does not rupture and the flow continues up the 13-3/8" casing through the BOPE stack).
5	Unabated vertical flow through the well 9-5/8" casing (assumes that the well is unable to be shut-in at the surface after the 9-5/8" casing is set, or the vertical line is ruptured after the rig is removed from the well).
6	Unabated vertical well flow channeled by the rig subbase (assumes that the rupture disk on the flow line does not rupture and the flow blows off the annular preventer and the vertical flow is channeled by the drill rig structure.
7	Unabated vertical well flow through an area of fractured rock surrounding the well (assumes that the uncontrolled flow is not coming through the casing of the well but through an area of fractured rock surrounding the well casing).
8	Abated vertical flow from the well drilling rig mud tanks (assumes that the choke line is used to divert the geothermal fluid to the mud tanks. Abatement is through NaOH injected into the choke line and lime in the mud tanks).
9	Abated vertical flow from the well drilling rig mud sump (assumes that the choke line is used to divert the geothermal fluid to the mud sump. Abatement is through NaOH injected into the choke line and lime in the mud sump).
10	Unabated horizontal flow through the well drilling rig 4" choke line (assumes that the choke line is used to divert the geothermal fluid, but the fluid flow knocks the "tee" off of the end of the choke line, at which point the hydrogen sulfide is unabated. This scenario can be controlled through closing valves to divert the geothermal fluid to the flow diverter or shut in the well).
11	Unabated horizontal "puff" flow through 3" noncondensible gas flow line from noncondensible gas compressor to fluid injection line (assumes that the line is ruptured and the contents of the pipeline (4.9 pounds of hydrogen sulfide) is emitted to the air).
12	Unabated vertical flow through the power plant steam release facility (assumes that the emergency steam release facility abatement system does not operate when needed).
Source: PGV Facility Emergency Response Plan, 1992	

3.3 Building Downwash

The AERMOD model incorporates Plume Rise Modeling Enhancements (PRIME) to account for downwash effects on point source emissions. Individual wells do not have significant structures and no structures were identified near the modeled well location. Therefore, effects from building downwash were not included in this study.

3.4 Good Engineering Practice Stack Height Analysis

U.S. EPA has promulgated regulations that limit the maximum stack height that may be used in a modeling analysis to no more than the Good Engineering Practice (GEP) stack height. The purpose of this requirement is to prevent the use of excessively tall stacks to reduce the modeled concentrations of a pollutant. GEP stack height is impacted by the heights of nearby structures. In general, the minimum value for GEP stack height is 65 meters. The stack heights for the facility's sources do not exceed the GEP stack height.

3.5 Terrain Data and Land Use

The prior 1992 Emergency Response Plan did not include terrain or land use data. For this assessment, terrain elevations were incorporated into the model using the most recent version (18081) of AERMAP, AERMOD's terrain preprocessor.

Recent lava flows (2018) altered the terrain southwest of the facility. Therefore, terrain elevation data for the entire modeling domain were extracted from both 1/3 arc-second National Elevation Data (NED) files and July 2019 LIDAR scans of the Kīlauea Volcano and new lava flow.[8,9] AERMAP was configured to assign elevations for the property line receptors and discrete gridded receptors in the modeling domain.

Land use classification determines the type of area to be modeled. The different classifications -- urban or rural -- incorporate distinct pollutant dispersion characteristics and affect the estimation of downwind concentrations. Based on the land use around the facility, the rural boundary layer option in the model was selected.

3.6 Meteorological Data

AERMOD requires a meteorological input file to characterize the transport and dispersion of emissions in the atmosphere. Surface and upper air meteorological data inputs, as well as surface parameter data describing the land use and surface characteristics near the site, are processed using AERMET, the meteorological preprocessor to AERMOD. The output file generated by AERMET is the meteorological input file required by AERMOD.

A representative meteorological data set was developed using a combination of surface data from the National Weather Service (NWS) station PHTO and the NWS upper air data (KITO), both from Hilo International Airport located approximately 30 km north of the facility.

Per Appendix W,[10] five years of representative meteorological data are considered adequate for dispersion modeling applications. Hourly and two-minute wind speed and wind direction data from January 2015 through December 2019 were processed using the latest version of AERMINUTE (15272) and AERMET (19191). The meteorological data was processed using the ADJ_U* option that reduces overprediction of modeled concentrations that occur in stable conditions with low wind speeds due to underprediction of the surface friction velocity (u*). Underprediction of u* results in an underestimation of the mechanical mixing height and thus overprediction of ambient concentrations. The ADJ_U* option is now considered a regulatory option with the recent update to Appendix W.

Additional meteorological variables and geophysical parameters are required for use in the AERMOD dispersion modeling analysis to estimate the surface energy fluxes and construct boundary layer profiles. Surface characteristics including albedo, Bowen ratio, and surface roughness length were determined for the area surrounding the Hilo Airport meteorological station using the AERMET surface characteristic preprocessor, AERSURFACE (20060), the National Land Cover Dataset (NLCD 2001), the Urban Imperviousness Dataset (MPRV 2001), and the Tree Canopy Dataset (CNPY 2011).

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[8] NED files were obtained from the United States Geological Survey Multi-Resolution Land Characteristics Consortium at http://www.mrlc.gov

[9] 2019 airborne LIDAR survey of Kīlauea Volcano, performed by United States Geological Survey, obtained from https://www.sciencebase.gov/catalog/item/5eb19f3882cefae35a29c363

[10] EPA, 2017. *Guideline on Air Quality Models*. 40 CFR Part 51 Appendix W.

The NLCD 2001 data set used in the analysis has a 30-meter resolution and 16-class classification system. Annual surface parameters were determined using AERSURFACE according to U.S. EPA's guidance.

Annual albedo and Bowen ratio values were based on averaging over a 10-km by 10-km region centered on the Hilo Airport meteorological site. Monthly surface roughness values were calculated for twelve 30-degree sectors within 1 km of the Hilo Airport meteorological station.

The AERSURFACE input file requires the user to provide additional location and climatological information regarding the primary meteorological site (PHTO). The following information was used to process monthly surface parameters for the meteorological station:

- The site was assumed to not have continuous snow cover most of the winter.
- The site is located at an airport.
- The site was not assumed to be located in an arid region.
- The monthly surface moisture conditions at the site were assumed to be wet based on annual rainfall.

3.7 Sub-Hourly Meteorological Data

In addition to the standard hourly data set created by AERMET, a sub-hourly data set consisting of two-minute averages was also created. These data were derived from two-minute averages for windspeed and direction from the raw AERMINUTE data with other parameters based on the hourly data.

AERMOD simulations for all two-minute averages were run and post-processed to produce sub-hourly running averages that could be compared to 10- and 30-minute exposure criteria.

3.8 Receptor Grid

Concentrations were calculated at receptors placed along the facility fence line and surrounding Cartesian grid. Receptors were placed at an assumed breathing height of 1.8-meters. Elevations were based on the revised post-eruption LIDAR terrain data discussed in Section 3.5. For the analysis, receptors extending up to 25 km from the fenceline were modeled using the following resolutions:

- 10-meter resolution for fenceline receptors;
- 25-meter resolution from the fenceline to 250 meters;
- 50-meter resolution from 250 meters to 1 km;
- 100-meter resolution from 1 km to 2 km;
- 200-meter resolution from 2 km to 5 km;
- 500-meter resolution from 5 km to 10 km; and
- 1,000-meter resolution from 10 km to 25 km.

3.9 H_2S Modeling Approach

Based on the existing warning and health-based standards, Ramboll calculated maximum concentrations for 1-hour, 4-hour, 8-hour, and 24-hour averaging periods, as well as sub-hourly averaging periods of 10-minutes and 30-minutes.

The AERMOD model directly calculates concentrations for the above-mentioned averaging periods of 1-hour and greater. The maximum concentrations are calculated on a receptor-by-receptor basis allowing convenient contour (isopleth) plots of maximum concentrations at each receptor for each averaging period over the entire five-years of meteorological data (see Figure A-6 to A-9 in Appendix A).

For the sub-hourly averaging periods, the procedure was more complicated. AERMOD simulations were performed for all two-minute averaging periods of available meteorological data. The resulting output files consisted of two-minute averages of H_2S concentrations. These data were then post-processed to calculate "rolling sums", representing the desired sub-hourly averaging periods of 10- and 30-minutes. From these summations, the maximum concentrations at each receptor were determined and collected into a single file of maximum concentrations. These files, equivalent to those produced directly by AERMOD, were processed to create contours used in figures (see Figures A-4 and A-5 in Appendix A).

4. SUMMARY OF H_2S RESULTS

A hazard analysis was conducted to compare H_2S concentrations against the criteria discussed in Section 2. Maximum results for all scenarios and averaging periods are provided in Appendix B – Table B-4. Significant findings were as follows:

- The PGV Warning (evacuation) level and the AEGL-2 and AEGL-3 thresholds were not exceeded in any upset scenario.
- The PGV Watch level of 1,000 ppb was the highest threshold to be exceeded, for scenarios 3 and 10, with a maximum exposure concentration of 6,118 ppb for Scenario 3's 1-hour exposure. At this level, health-related impacts for healthy individuals are unlikely to occur, including for susceptible individuals.

Table 4 summarizes the concentrations exceeding the AEGLs, acute MRL, upper limit of the CDA evacuation color codes, or upper limit of the general PGV "Watch" concentration. These results indicate AEGL-1 and/or MRL levels – i.e., possible non-disabling and transient effects, including susceptible populations -- were exceeded for all upset conditions, except for scenarios 1, 8, and 9. Graphic depictions of the worst-case results are presented in Attachment A – Figures A-4 through A-9.

As all other compounds would be expected to result in lower effects than H_2S – i.e., no evacuation warning level would be exceeded for any emission under any scenario – no compounds other than H_2S were evaluated in this analysis.

This conclusion is consistent with and comparable to the original modeling results completed in 1992. That report estimated a maximum offsite concentration of 12,786 ppb, which the HDOH determined was "less than the levels considered to cause life-threatening effects."[11]

Table 4. H_2S Thresholds Exceeded

Scenario	Averaging Period	Modeled Concentration		Minimum Criteria Threshold		Criteria Exceeded
		ppb	µg/m³	ppb	µg/m³	
Scenario 2	1-hour	614	859	510	714	AEGL-1
	4-hour	508	712	510	714	AEGL-1
	8-hour	433	606	330	462	AEGL-1
	24-hour	309	432	70	98	MRL Acute
Scenario 3	10-minute	1102	1543	750	1050	PGV Watch, AEGL-1
	30-minute	1727	2418	600	840	PGV Watch, AEGL-1/CDA Blue
	1-hour	6118	8566	510	714	PGV Watch, AEGL-1
	4-hour	2403	3364	510	714	PGV Watch, AEGL-1
	8-hour	1524	2134	330	462	PGV Watch, AEGL-1
	24-hour	838	1173	70	98	PGV Watch, MRL Acute
Scenario 4	1-hour	672	940	510	714	AEGL-1
	4-hour	529	740	510	714	AEGL-1
	8-hour	457	639	330	462	AEGL-1
	24-hour	341	478	70	98	MRL Acute
Scenario 5	1-hour	672	940	510	714	AEGL-1
	4-hour	529	740	510	714	AEGL-1
	8-hour	457	639	330	462	AEGL-1

[11] *Health Risk Assessment: Evaluation of Potential Adverse Health Effects from Short-Term Exposure to Hydrogen Sulfide Resulting from an Unplanned Release from Geothermal Wells in Puna, Hawaii* (HDOH, 1993).

Scenario	Averaging Period	Modeled Concentration		Minimum Criteria Threshold		Criteria Exceeded
		ppb	µg/m^3	ppb	µg/m^3	
	24-hour	341	478	70	98	MRL Acute
Scenario 6	1-hour	651	912	510	714	AEGL-1
	4-hour	521	729	510	714	AEGL-1
	8-hour	447	626	330	462	AEGL-1
	24-hour	331	463	70	98	MRL Acute
Scenario 7	1-hour	434	607	510	714	AEGL-1
	4-hour	399	558	510	714	AEGL-1
	8-hour	319	446	330	462	AEGL-1
	24-hour	190	266	70	98	MRL Acute
Scenario 10	10-minute	551	771	750	1050	AEGL-1
	30-minute	863	1209	600	840	PGV Watch, AEGL-1/CDA Blue
	1-hour	3059	4283	510	714	PGV Watch, AEGL-1
	4-hour	1201	1682	510	714	PGV Watch, AEGL-1
	8-hour	762	1067	330	462	PGV Watch, AEGL-1
	24-hour	419	587	70	98	MRL Acute
Scenario 11	1-hour	493	690	510	714	AEGL-1
Scenario 12	1-hour	373	522	510	714	AEGL-1
	24-hour	123	172	70	98	MRL Acute

ATTACHMENT A
FIGURES

The figures in Appendix A depict the PGV facility location, modeled source locations, and results. Figure A-1 identifies the location of PGV facility location on the eastern tip of Hawaii. Figure A-2 shows the model source locations for each scenario and the PGV facility boundary. Dispersion modeling predicts ambient air concentrations at discrete locations outside the PGV facility boundary. The dispersion model uses meteorological data observed between January 2015 and December 2019 at the Hilo International Airport station. The wind speeds and directions are depicted in Figure A-3.

Figure A-4 through Figure A-9 represent the spatial distribution of the worst-case H_2S concentrations. For all averaging periods, the Scenario 3 simulation resulted in the worst-case model results. This scenario assumes 1) the unabated horizontal flow through the well flow line knocks the muffler off the end of the flow line and 2) the abatement equipment is not operated.

The concentrations represented in the figures represent the worst-case highest concentrations from Scenario 3 for all modeled wind directions and meteorological conditions that were observed between 2015-2019. The orange and blue contours represent the model concentrations at the thresholds defined in the legends. Locations within each contour are equal or greater than the threshold.

The single highest predicted offsite concentration is shown in Figure A-6. A maximum predicted concentration of 6,118 ppb occurs at the facility fenceline during the 1-hour averaging period. All residents – including sensitive individuals -- located within the orange “Watch” line may experience non-disabling irritation and discomfort assuming the upset condition continues unabated for an hour. However, this scenario can be quickly controlled through closing valves to shut in the well, so it is unlikely that exposures to this scenario would last as long as an hour.

PROJECT: 1690018074 | DATED: 9/24/2020 | DESIGNER: DCW

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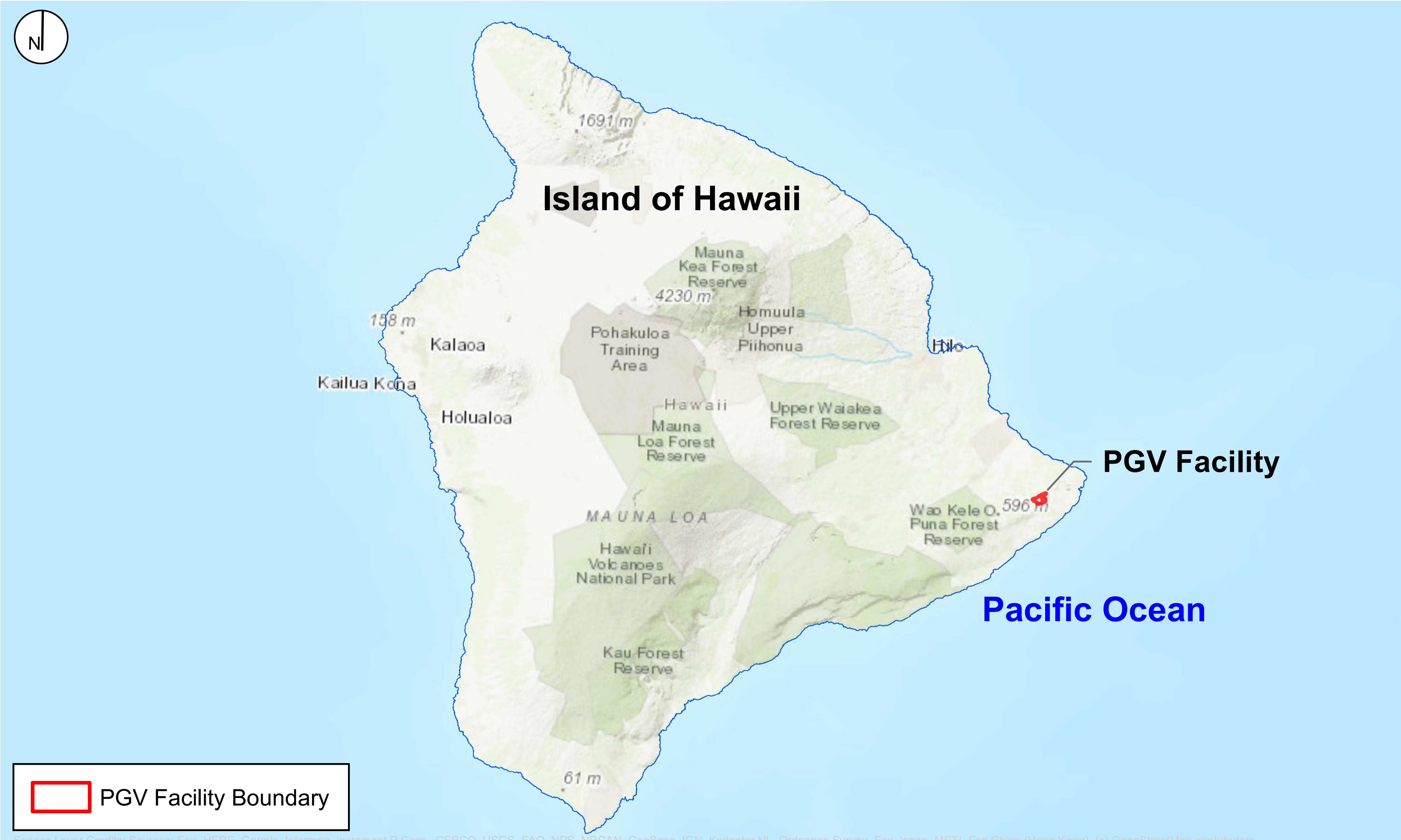


PUNA GEOTHERMAL VENTURE
FACILITY LOCATION

FIGURE A-1

RAMBOLL US CORPORATION
A RAMBOLL COMPANY

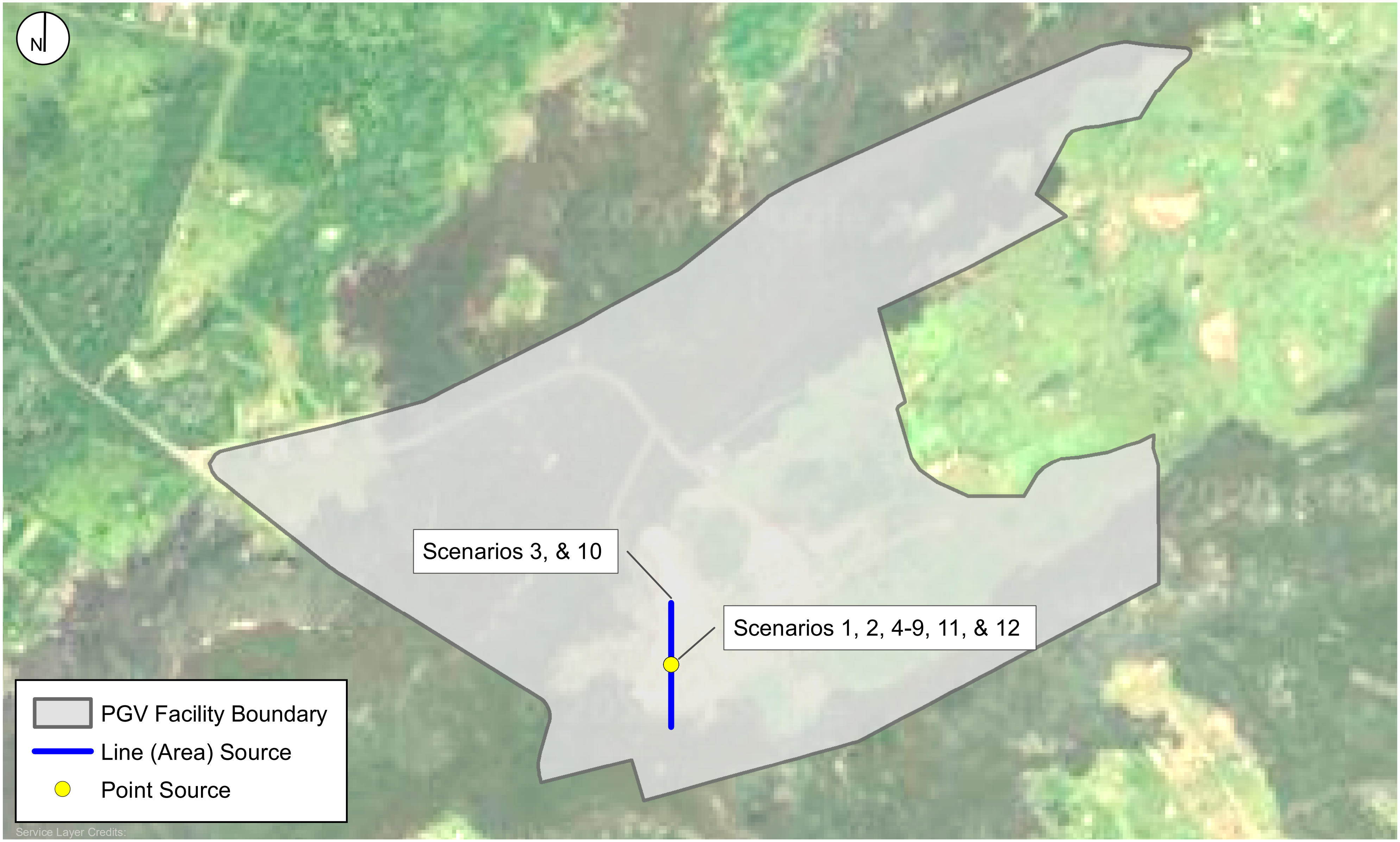
0 20 40 Miles

14-3860 Kapoho-Pahoa Road
Pahoa, Hawaii

RAMBOLL

PROJECT: 1690018074 | DATED: 9/25/2020 | DESIGNER: DCW

C:\ArcGIS\puna.geothermal\SourceLocations.mxd



PUNA GEOTHERMAL VENTURE
SOURCE LOCATIONS FOR UPSET SCENARIOS

FIGURE A-2

RAMBOLL US CORPORATION
A RAMBOLL COMPANY

0 0.3 0.6 Miles

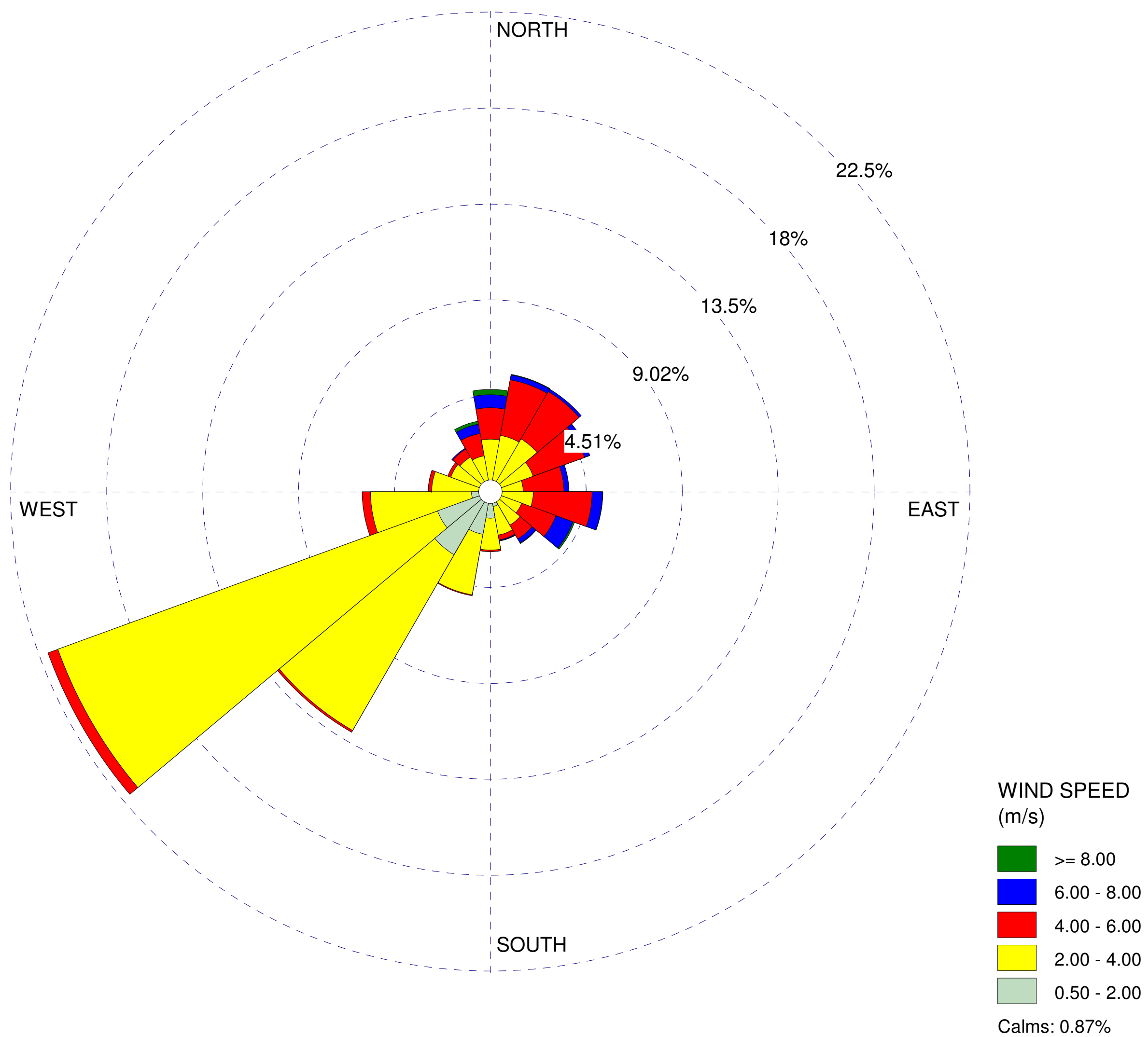
14-3860 Kapoho-Pahoa Road
Pahoa, Hawaii

WIND ROSE PLOT:

Hilo International Airport (PHTO)
January 2015 - December 2019

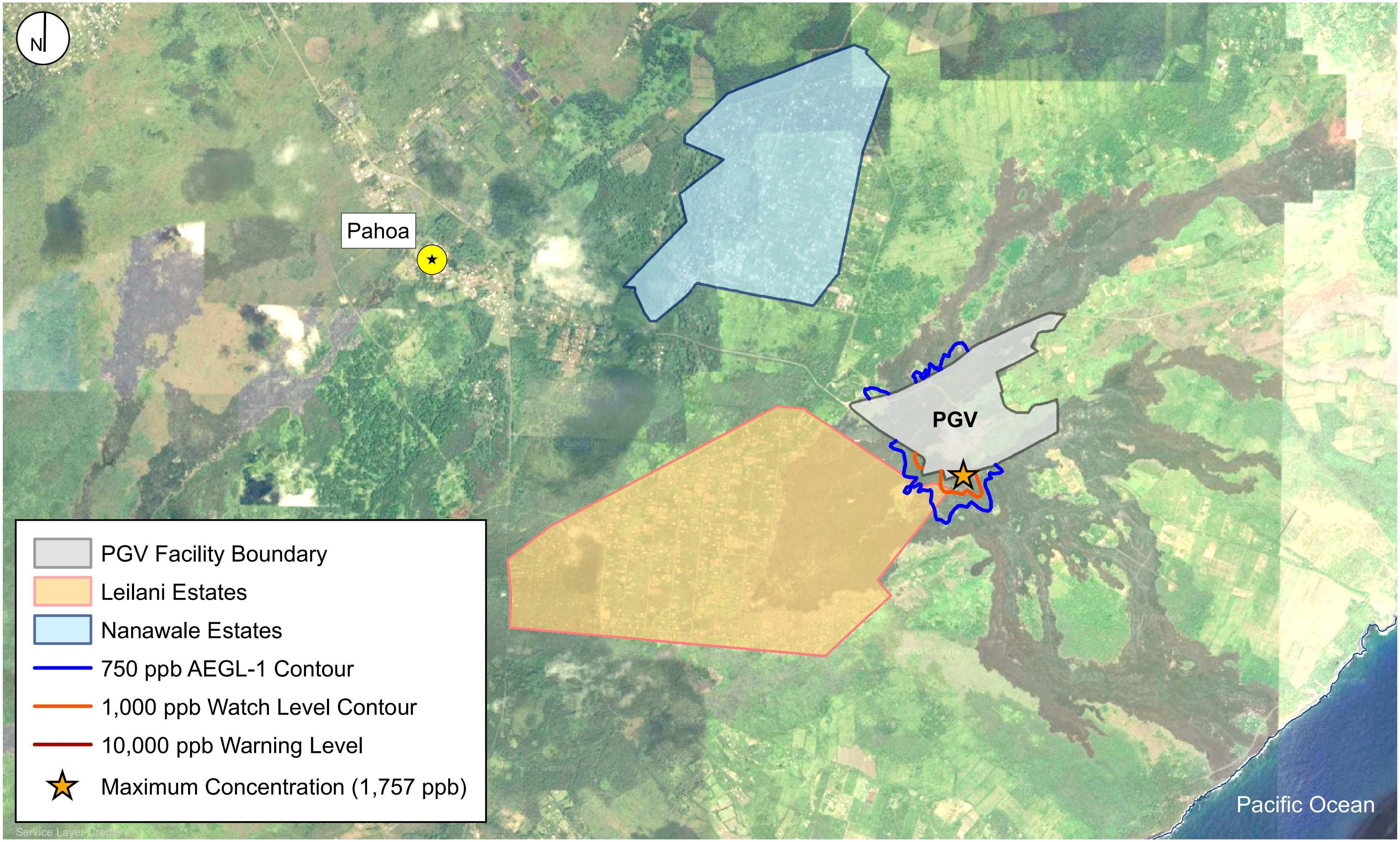
DI SPLAY:

Wi nd Speed
Di recti on (bl owi ng from)



DATA PERIOD: **Start Date: 1/1/2015 - 00:00** **End Date: 12/31/2019 - 23:59**	COMPANY NAME: **RAMBOLL**	
	MODELER: **DCW**	
CALM WINDS: **0.87%**	TOTAL COUNT: **43759 hrs.**	
AVG. WIND SPEED: **3.22 m/s**	DATE: **9/24/2020**	

WRPLOT View - Lakes Environmental Software



PUNA GEOTHERMAL VENTURE
SCENARIO 03 (448 LBS/HR)
10-MINUTE H_2S MODEL SIMULATION

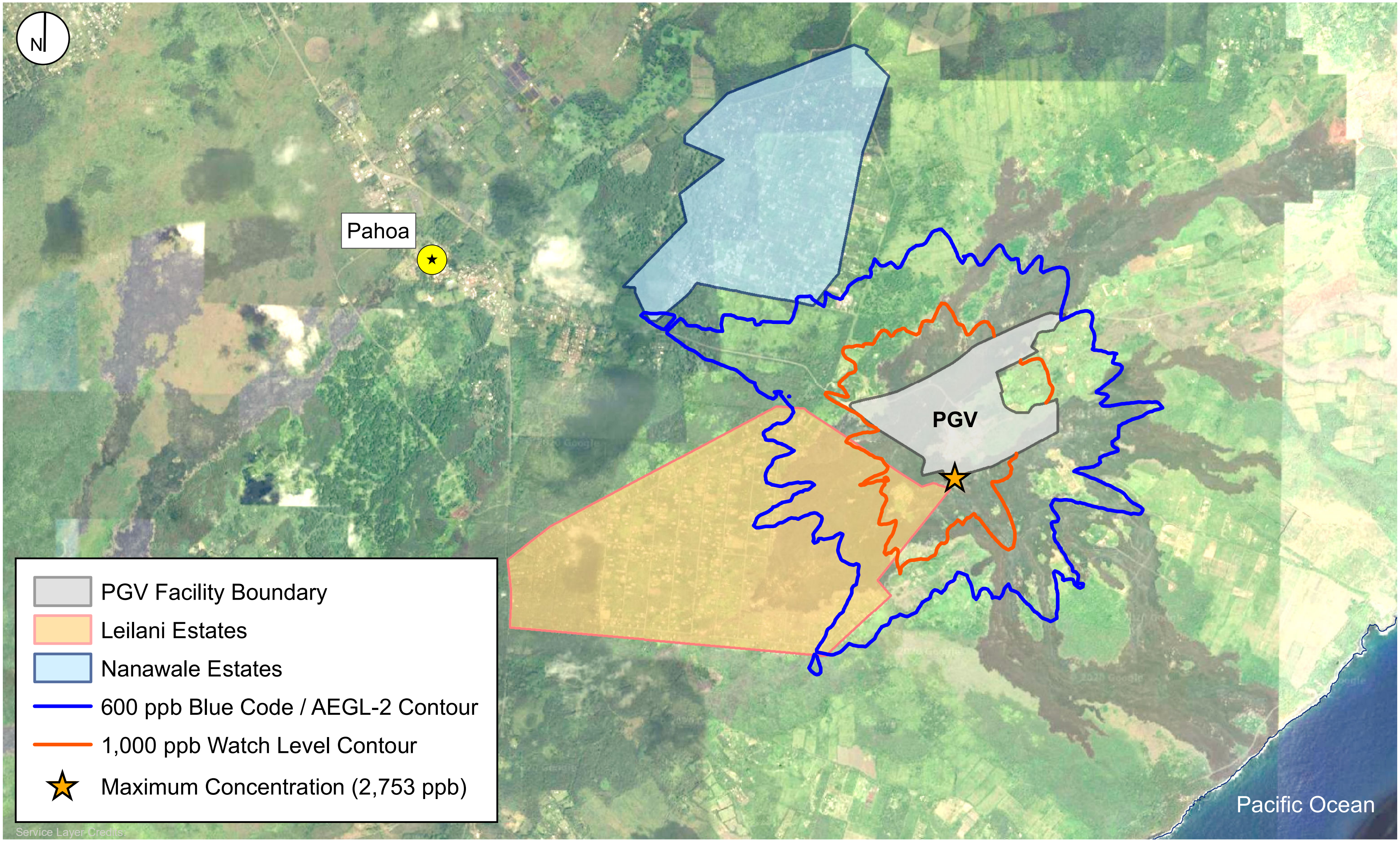
14-3860 Kapoho-Pahoa Road
Pahoa, Hawaii

FIGURE A-4

RAMBOLL US CORPORATION
A RAMBOLL COMPANY

PROJECT: 1690018074 | DATED: 12/17/2020 | DESIGNER: DCW

C:\ArcGIS\puna.geothermal\30minute.20200909.mxd



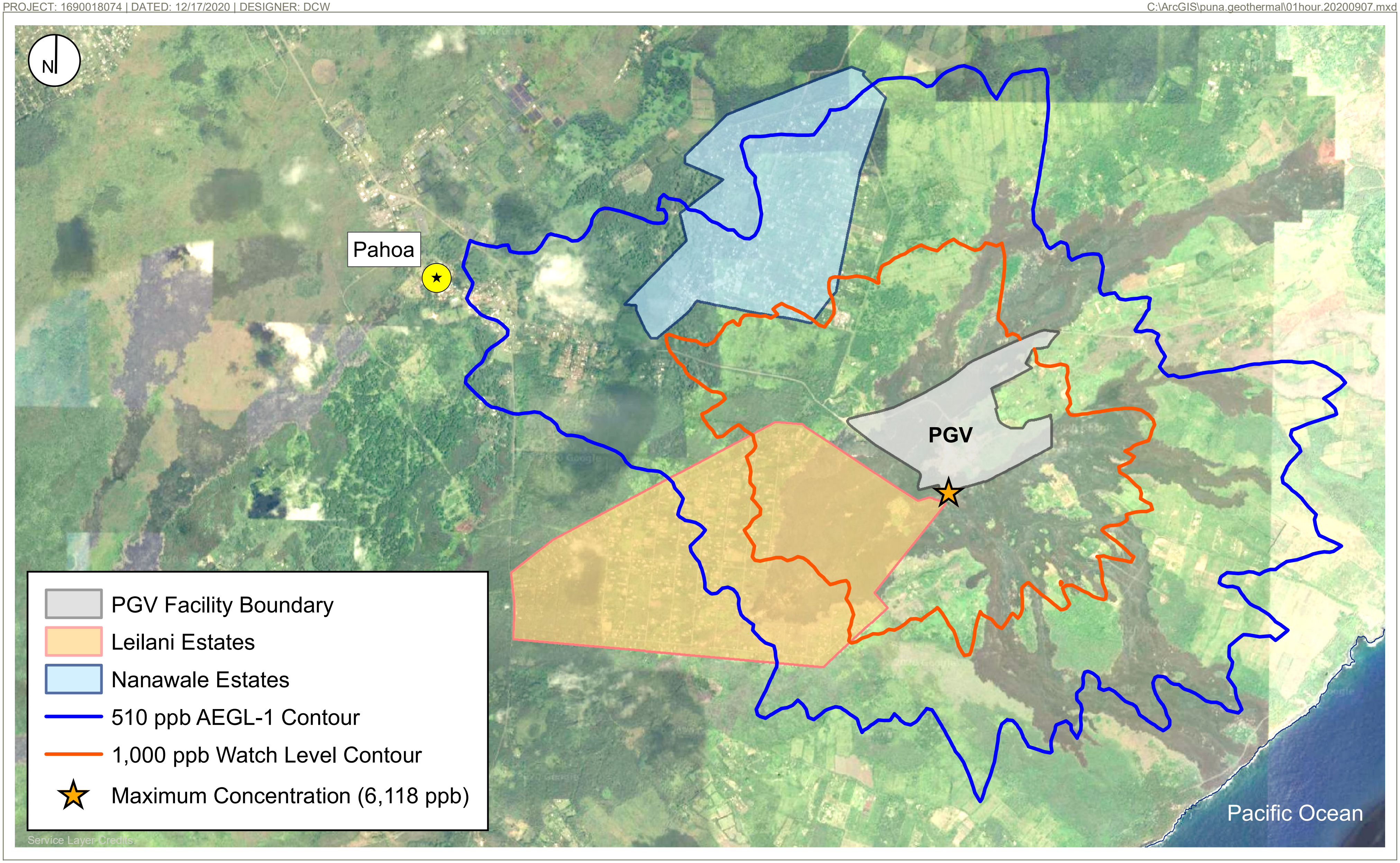
0 1.5 3 Miles

PUNA GEOTHERMAL VENTURE
SCENARIO 03 (448 LBS/HR)
30-MINUTE H_2S MODEL SIMULATION

14-3860 Kapoho-Pahoa Road
Pahoa, Hawaii

FIGURE A-5

RAMBOLL US CORPORATION
A RAMBOLL COMPANY

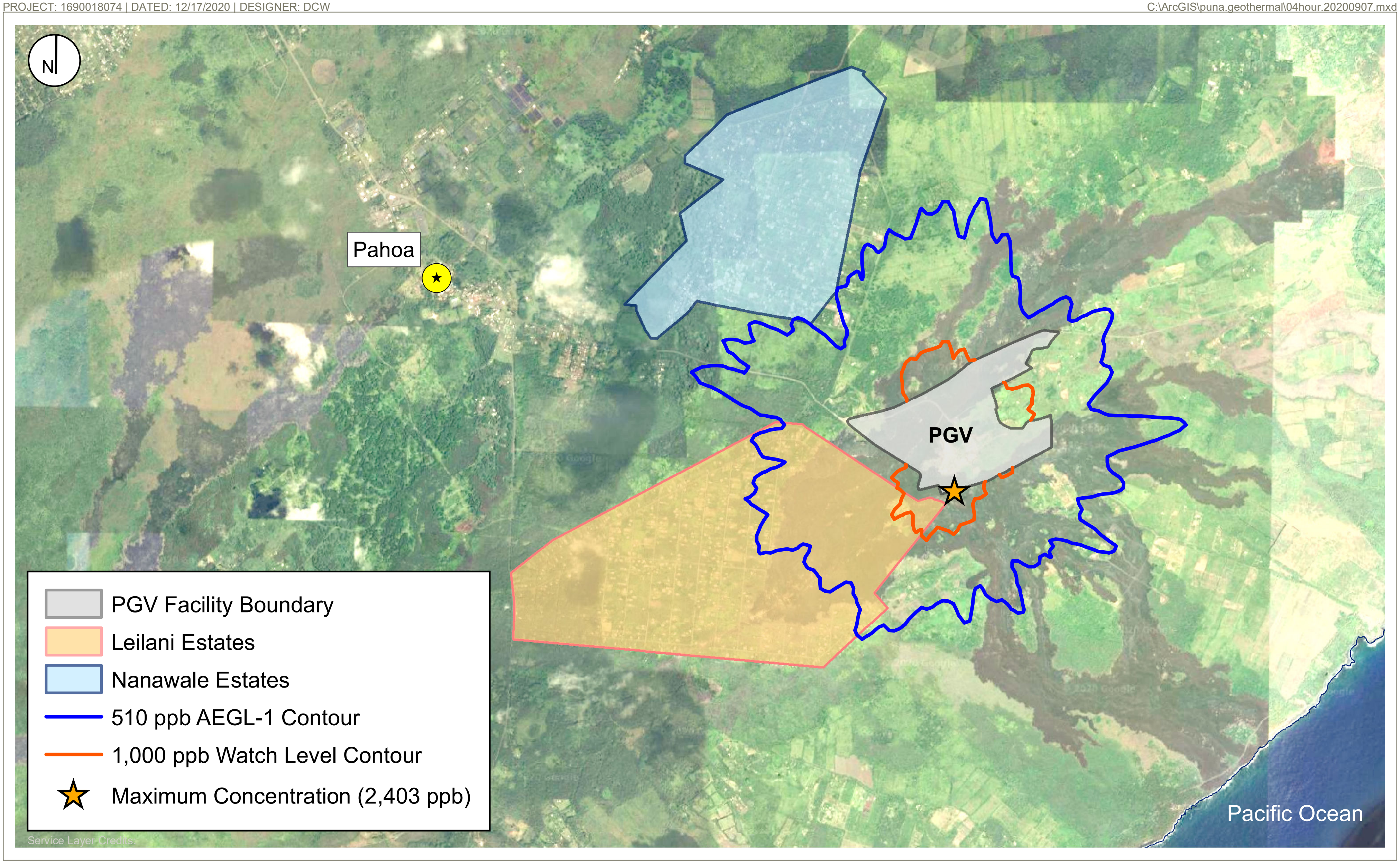


PUNA GEOTHERMAL VENTURE
SCENARIO 03 (448 LBS/HR)
1-HOUR H_2S MODEL SIMULATION

14-3860 Kapoho-Pahoa Road
Pahoa, Hawaii

FIGURE A-6

RAMBOLL US CORPORATION
A RAMBOLL COMPANY

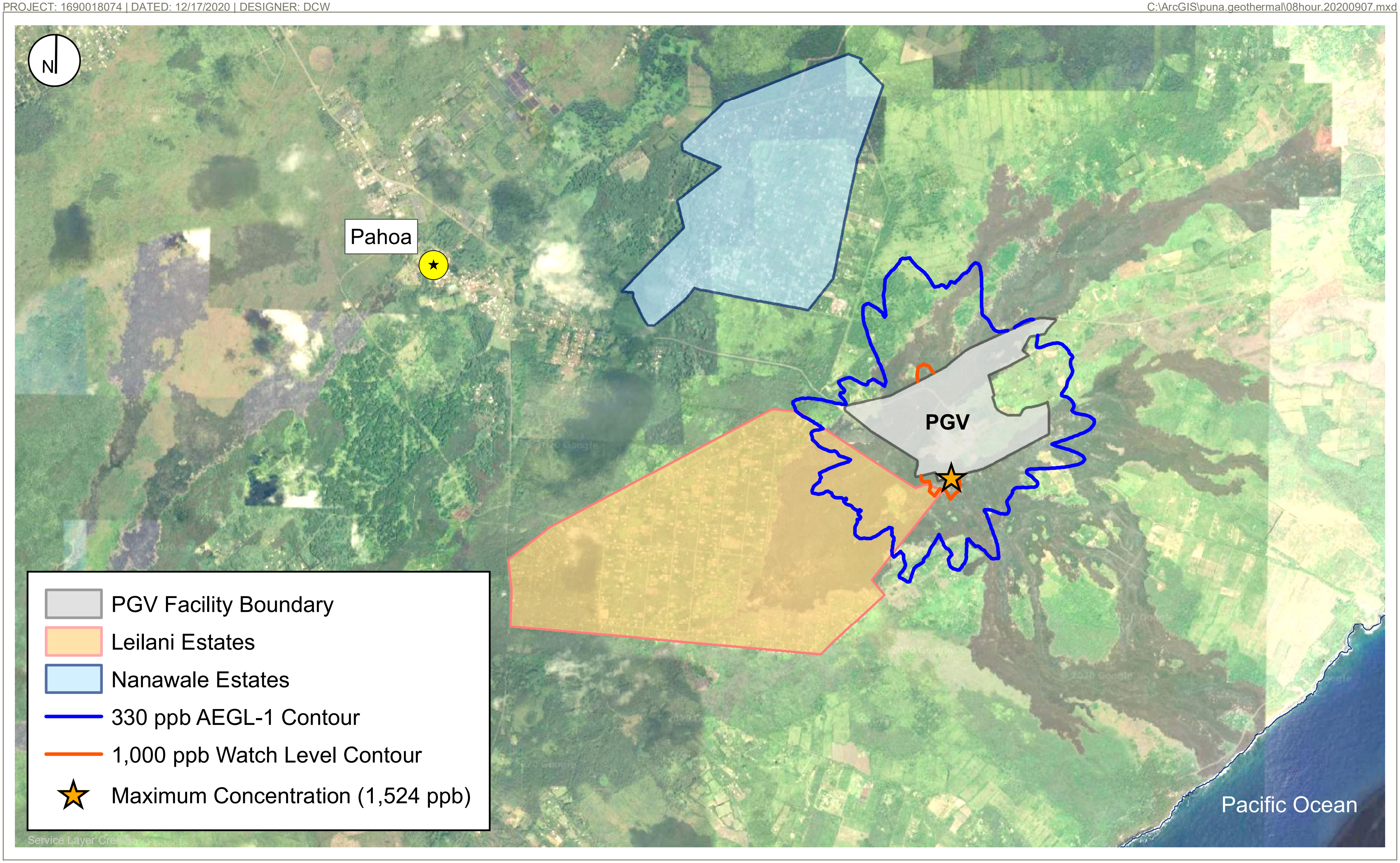


PUNA GEOTHERMAL VENTURE
SCENARIO 03 (448 LBS/HR)
4-HOUR H_2S MODEL SIMULATION

14-3860 Kapoho-Pahoa Road
Pahoa, Hawaii

FIGURE A-7

RAMBOLL US CORPORATION
A RAMBOLL COMPANY

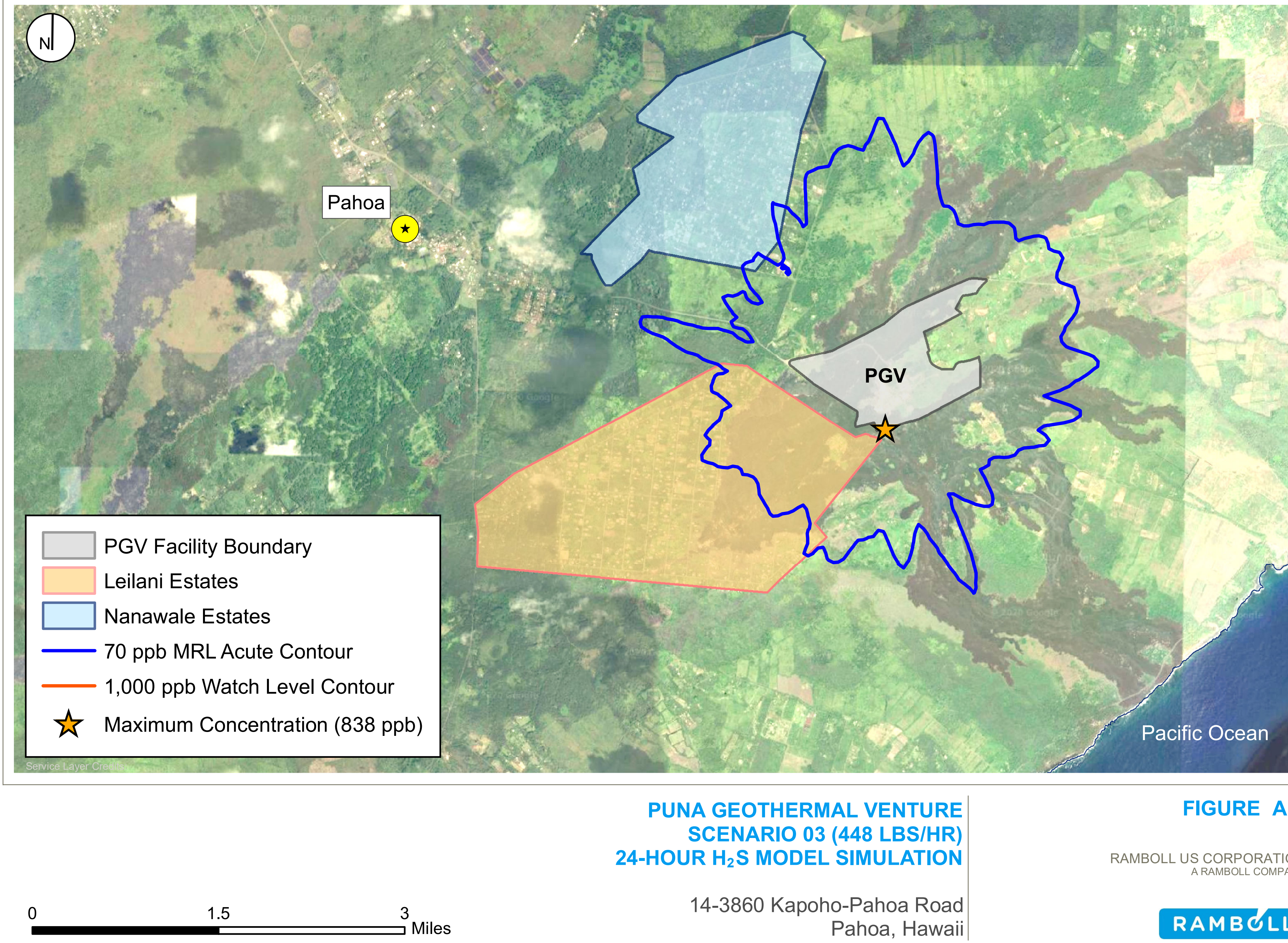


PUNA GEOTHERMAL VENTURE
SCENARIO 03 (448 LBS/HR)
8-HOUR H_2S MODEL SIMULATION

14-3860 Kapoho-Pahoa Road
Pahoa, Hawaii

FIGURE A-8

RAMBOLL US CORPORATION
A RAMBOLL COMPANY



PUNA GEOTHERMAL VENTURE
SCENARIO 03 (448 LBS/HR)
24-HOUR H_2S MODEL SIMULATION

14-3860 Kapoho-Pahoa Road
Pahoa, Hawaii

FIGURE A-9

RAMBOLL US CORPORATION
A RAMBOLL COMPANY

ATTACHMENT B
TABLES

This attachment provides details regarding the 2020 H_2S hazard analysis dispersion modeling. Release parameters and emission rates are identical to those used in the prior 1992 PGV Facility Emergency Release Plan. These parameters were developed by PGV in in consultation with the Hawaii Department of Health and its consultants. Table B-1 provides point source release parameters and Table B-2 provides line source release parameters. Total emission rates for all scenarios are summarized in Table B-3. Table B-4 presents maximum H_2S concentrations for all averaging periods and scenarios. See Section 3.2.2 for a description of each operating scenario.

Table B-1. Point Source Release Parameters

Scenario	UTM Easting, Northing (m)	Elevation (m)	Height (m)	Temperature (K)	Release Velocity (m/s)	Stack Diameter (m)
Scenario 01	301513, 2154605	187	6.1	372.5945	5.2319	4.57
Scenario 02	301513, 2154605	187	6.1	372.5945	5.2319	4.57
Scenario 04	301513, 2154605	187	21.64	372.5945	0.2093	22.86
Scenario 05	301513, 2154605	187	21.64	372.5945	0.2093	22.86
Scenario 06	301513, 2154605	187	12.19	372.5945	0.1839	24.38
Scenario 07	301513, 2154605	187	0	372.5945	0.4709	15.24
Scenario 08	301513, 2154605	187	1.83	344.2611	0.0167	7.77
Scenario 09	301513, 2154605	187	0	344.2611	0.0167	21.55
Scenario 11	301513, 2154605	187	0	338.7056	0	1
Scenario 12	301513, 2154605	187	6.1	372.5945	14.3735	4.57
Source: Stack release parameters were developed in consultation with Hawaii Department of Health for the 1992 PGV Facility Emergency Response Plan.						

Table B-2. Line Source Release Parameters

Scenario	Start UTM Easting, Northing (m)	End UTM Easting, Northing (m)	Elevation (m)	Height (m)	Width (m)	Initial Vertical Dimension (m)
Scenario 03	301513, 2154443	301513, 2154767	192.78	19.81	38.1	9.14
Scenario 10	301513, 2154443	301513, 2154767	192.78	19.81	38.1	9.14
Source: Source release parameters were developed in consultation with Hawaii Department of Health for the 1992 PGV Facility Emergency Response Plan.						

Table B-3. Total Modeled Emission Rates for All Scenarios

Scenario	Hourly Emission Rate (lb/hr)
Scenario 01	44.8
Scenario 02	448
Scenario 03	448
Scenario 04	448
Scenario 05	448
Scenario 06	448
Scenario 07	448
Scenario 08	4.5
Scenario 09	4.5
Scenario 10	224
Scenario 11	4.9
Scenario 12	560

Source: These total emission rates were developed in consultation with Hawaii Department of Health for the 1992 PGV Facility Emergency Response Plan.

Table B-4. Maximum Modeled Concentrations for All Scenarios

Scenario	Averaging Period	UTM East, North (m) [a]	Modeled Concentration [b]	
			ppb	µg/m³
Scenario 01	10-minute	301608.50, 2154297.36	12	17
	30-minute	301598.86, 2154294.70	36	50
	1-hour	301410.68, 2154353.36	61	86
	4-hour	301618.14, 2154300.03	51	71
	8-hour	301627.78, 2154302.69	43	61
	24-hour	301598.86, 2154294.70	31	43
Scenario 02	10-minute	301608.50, 2154297.36	122	171
	30-minute	301598.86, 2154294.70	358	501
	1-hour	301410.68, 2154353.36	614	859
	4-hour	301618.14, 2154300.03	508	712
	8-hour	301627.78, 2154302.69	433	606
	24-hour	301598.86, 2154294.70	309	432
Scenario 03	10-minute	301666.34, 2154313.34	1102	1543
	30-minute	301560.31, 2154284.05	1727	2418
	1-hour	301541.03, 2154278.73	6118	8566
	4-hour	301608.50, 2154297.36	2403	3364
	8-hour	301608.50, 2154297.36	1524	2134
	24-hour	301560.31, 2154284.05	838	1173
Scenario 04	10-minute	301410.68, 2154353.36	131	184
	30-minute	301598.86, 2154294.70	377	528
	1-hour	301410.68, 2154353.36	672	940
	4-hour	301618.14, 2154300.03	529	740
	8-hour	301627.78, 2154302.69	457	639
	24-hour	301598.86, 2154294.70	341	478
Scenario 05	10-minute	301410.68, 2154353.36	131	184
	30-minute	301598.86, 2154294.70	377	528
	1-hour	301410.68, 2154353.36	672	940
	4-hour	301618.14, 2154300.03	529	740
	8-hour	301627.78, 2154302.69	457	639
	24-hour	301598.86, 2154294.70	341	478

Table B-4. Maximum Modeled Concentrations for All Scenarios (continued)

Scenario	Averaging Period	UTM East, North (m) [(a)]	Modeled Concentration [(b)]	
			ppb	µg/m^3
Scenario 06	10-minute	301608.50, 2154297.36	127	178
	30-minute	301598.86, 2154294.70	369	517
	1-hour	301410.68, 2154353.36	651	912
	4-hour	301618.14, 2154300.03	521	729
	8-hour	301627.78, 2154302.69	447	626
	24-hour	301598.86, 2154294.70	331	463
Scenario 07	10-minute	301598.86, 2154294.70	92	129
	30-minute	301589.22, 2154292.04	249	349
	1-hour	301598.86, 2154294.70	434	607
	4-hour	301608.50, 2154297.36	399	558
	8-hour	301598.86, 2154294.70	319	446
	24-hour	301608.50, 2154297.36	190	266
Scenario 08	10-minute	301410.68, 2154353.36	20	29
	30-minute	301365.01, 2154346.30	58	82
	1-hour	301194.30, 2154486.62	81	113
	4-hour	301185.43, 2154504.42	37	52
	8-hour	301185.43, 2154504.42	27	37
	24-hour	301656.70, 2154310.67	10	14
Scenario 09	10-minute	300967.03, 2154644.61	5	7
	30-minute	302050.00, 2154425.00	14	19
	1-hour	300984.02, 2154634.04	23	33
	4-hour	301196.29, 2154466.83	14	20
	8-hour	301194.67, 2154456.98	10	15
	24-hour	301704.89, 2154323.98	4	6
Scenario 10	10-minute	301666.34, 2154313.34	551	771
	30-minute	301560.31, 2154284.05	863	1209
	1-hour	301541.03, 2154278.73	3059	4283
	4-hour	301608.50, 2154297.36	1201	1682
	8-hour	301608.50, 2154297.36	762	1067
	24-hour	301560.31, 2154284.05	419	587

Table B-4. Maximum Modeled Concentrations for All Scenarios (continued)

Scenario	Averaging Period	UTM East, North (m) [(a)]	Modeled Concentration [(b)]	
			ppb	µg/m³
Scenario 11	10-minute	301403.83, 2154355.96	120	168
	30-minute	301345.60, 2154341.48	336	471
	1-hour	301190.64, 2154495.91	493	690
	4-hour	301194.30, 2154486.62	163	228
	8-hour	301185.43, 2154504.42	84	118
	24-hour	301656.70, 2154310.67	35	50
Scenario 12	10-minute	301598.86, 2154294.70	63	88
	30-minute	301600.00, 2154275.00	127	178
	1-hour	301608.50, 2154297.36	373	522
	4-hour	301608.50, 2154297.36	253	354
	8-hour	301589.22, 2154292.04	216	302
	24-hour	301598.86, 2154294.70	123	172

Notes:
a) Max modeled locations reported for UTM Zone 5 projection, NAD83 datum, in meters.
b) Concentration in µg/m³ assumes H_2S conversion of 1 ppb to 1.4 µg/m³.

Source: Ramboll, 2021

HAZARD ASSESSMENT

OFF-SITE CONSEQUENCE ANALYSIS

2021

PUNA GEOTHERMAL VENTURE

An ORMAT Company

Offsite Consequence Analysis for Puna GCCU and Puna Expansion

Normal Pentane

Worst Cases: **Rupture of OEC Vaporizers (without containment)**

- 10,338 lbs *(n-C_5H_{12} @ 226°F) Puna GCCU Vaporizer*
- 13,658 lbs *(n-C_5H_{12} @ 346°F) Puna Expansion, Level 1 Vaporizer*
- 19,400 lbs *(n-C_5H_{12} @ 292°F) Puna Expansion, Level 2 Vaporizer*
- Estimated distance to 1 psi overpressure *(Puna GCCU)* = 0.2 miles (per RMP*Comp online)
- Estimated distance to 1 psi overpressure *(Puna Expansion, either vaporizer)* = 0.2 miles (per RMP*Comp online)

Rupture of pentane storage tank (filled to 90% of water capacity)*

- 9,607 gal *(n-C_5H_{12})* x 90% x 5.23 lbs/gal = 45,219 lbs *Puna GCCU*
- 12,566 gal (*n-C_5H_{12})* x 90% x 5.23 lbs/gal = 59,146 lbs *Puna Expansion*
- Estimated distance to 1 psi overpressure *(Puna GCCU)* = 0.08 miles (per RMP*Comp online)
- Estimated distance to 1 psi overpressure *(Puna Expansion)* = 0.08 miles (per RMP*Comp online)

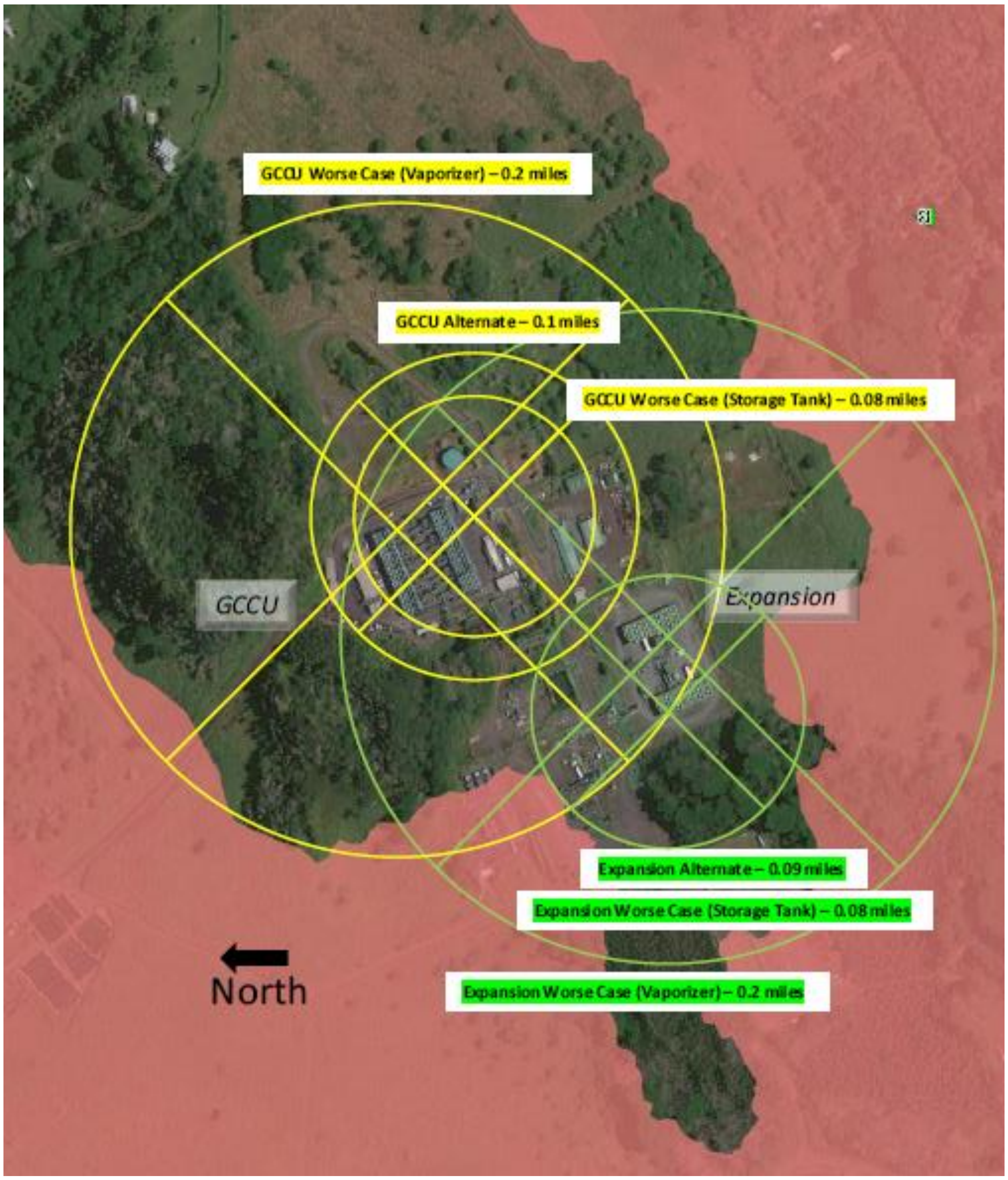
**Note: Both GCCU and Expansion have containments for storage tanks. This was factored in the calculation.*

Alternate Case: - Hose rupture occurs while transferring between a pentane truck and storage tank. Occurs for 10 minutes before system isolation valves closed.

- Liquid pool forms that catches fire
- Release rate: 1,650 lbs/min *Puna GCCU*
- Release rate: 833 lbs/min *Puna Expansion*
- Estimated distance to heat radiation endpoint of 5 kw/sq meter = 0.1 miles *Puna GCCU*
- Estimated distance to heat radiation endpoint of 5 kw/sq meter = 0.09 miles *Puna Expansion*

(per RMP*Comp online)

	Elevation (feet)	Latitude (North)			Longitude (West)		
		Degrees	Minutes	Seconds	Degrees	Minutes	Seconds
GCCU	668	19	28	40.75	-154	53	16.76
Expansion	615	19	28	34.55	-154	53	23.49



Legend	
Fissure	22
Lava Flow of 2018	

Normal pentane
Puna GCCU
Vaporizer
Worst Case Release Scenario

RMP*Comp (online)
Results of Consequence Analysis
Chemical: Pentane
CAS #: 109-66-0
Category: Flammable Liquid
Scenario: Worst-case
Quantity Released: 10,338 pounds
Release Type: Vapor Cloud Explosion
Liquid Temperature: 226 F
Release Rate to Outside Air: 1,690 pounds per minute
Quantity Evaporated in 10 Minutes: 10,300 pounds
Estimated Distance to 1 psi overpressure: 0.2 miles (0.3 kilometers)
--------Assumptions About This Scenario---------
Wind Speed: 1.5 meters/second (3.4 miles/hour)
Stability Class: F
Air Temperature: 77 degrees F (25 degrees C)

Normal pentane
Puna Expansion
Vaporizer Level 1
Worst Case Release Scenario

RMP*Comp (online)
Results of Consequence Analysis
Chemical: Pentane
CAS #: 109-66-0
Category: Flammable Liquid
Scenario: Worst-case
Quantity Released: 13,658 pounds
Release Type: Vapor Cloud Explosion
Liquid Temperature: 346 F
Release Rate to Outside Air: 2,240 pounds per minute
Quantity Evaporated in 10 Minutes: 13,700 pounds
Estimated Distance to 1 psi overpressure: 0.2 miles (0.3 kilometers)
--------Assumptions About This Scenario---------
Wind Speed: 1.5 meters/second (3.4 miles/hour)
Stability Class: F
Air Temperature: 77 degrees F (25 degrees C)

Normal pentane
Puna Expansion
Vaporizer Level 2
Worst Case Release Scenario

RMP*Comp (online)
Results of Consequence Analysis
Chemical: Pentane
CAS #: 109-66-0
Category: Flammable Liquid
Scenario: Worst-case
Quantity Released: 19,400 pounds
Release Type: Vapor Cloud Explosion
Liquid Temperature: 292 F
Release Rate to Outside Air: 3,180 pounds per minute
Quantity Evaporated in 10 Minutes: 19,400 pounds
Estimated Distance to 1 psi overpressure: 0.2 miles (0.3 kilometers)
--------Assumptions About This Scenario---------
Wind Speed: 1.5 meters/second (3.4 miles/hour)
Stability Class: F
Air Temperature: 77 degrees F (25 degrees C)

Normal pentane
Puna GCCU
Storage Tank in Containment
Worst Case Release Scenario

RMP*Comp (online)
Results of Consequence Analysis
Chemical: Pentane
CAS #: 109-66-0
Category: Flammable Liquid
Scenario: Worst-case
Quantity Released: 45,219 pounds
Release Type: Vapor Cloud Explosion
Liquid Temperature: 68 F
Mitigation Measures: Dike
Diked Area: 816 square feet
Dike Height 3 feet
Release Rate to Outside Air: 114 pounds per minute
Quantity Evaporated in 10 Minutes: 1,140 pounds
Estimated Distance to 1 psi overpressure: 0.08 miles (0.13 kilometers)
--------Assumptions About This Scenario---------
Wind Speed: 1.5 meters/second (3.4 miles/hour)
Stability Class: F
Air Temperature: 77 degrees F (25 degrees C)

Normal pentane
Puna Expansion
Storage Tank in Containment
Worst Case Release Scenario

RMP*Comp (online)
Results of Consequence Analysis
Chemical: Pentane
CAS #: 109-66-0
Category: Flammable Liquid
Scenario: Worst-case
Quantity Released: 59,146 pounds
Release Type: Vapor Cloud Explosion
Liquid Temperature: 68 F
Mitigation Measures: Dike
Diked Area: 736 square feet
Dike Height: 3 feet
Release Rate to Outside Air: 103 pounds per minute
Quantity Evaporated in 10 Minutes: 1,030 pounds
Estimated Distance to 1 psi overpressure: 0.08 miles (0.13 kilometers)
--------Assumptions About This Scenario---------
Wind Speed: 1.5 meters/second (3.4 miles/hour)
Stability Class: F
Air Temperature: 77 degrees F (25 degrees C)

Normal Pentane
Puna GCCU
Alternate Case Release Scenario

RMP*Comp (online)
Results of Consequence Analysis
Chemical: Pentane
CAS #: 109-66-0
Category: Flammable Liquid
Scenario: Alternative
Release Duration: 10 minutes
Release Type: Pool Fire
Storage Parameters: Pipe
Initial Operational Flow Rate: 85 gpm
Cross Sectional Area of Pipe: 7.07 in2
Operational Pipe Pressure: 14.7 psia
Change in Pipe Elevation: 3 feet
Release Rate: 1,650 pounds per min
Mitigation Measures: None
Estimated Distance to Heat Radiation Endpoint (5 kilowatts/square meter): 0.1 miles (0.2 kilometers)
--------Assumptions About This Scenario---------
Wind Speed: 3 meters/second (6.7 miles/hour)
Stability Class: D
Air Temperature: 77 degrees F (25 degrees C)

Normal pentane
Puna Expansion
Alternate Case Release Scenario

RMP*Comp (online)
Results of Consequence Analysis
Chemical: Pentane
CAS #: 109-66-0
Category: Flammable Liquid
Scenario: Alternative
Release Duration: 10 minutes
Release Type: Pool Fire
Storage Parameters: Pipe
Initial Operational Flow Rate: 85 gpm
Cross Sectional Area of Pipe: 3.14 in2
Operational Pipe Pressure: 14.7 psia
Change in Pipe Elevation: 3 feet
Release Rate: 833 pounds per min
Mitigation Measures: None
Estimated Distance to Heat Radiation Endpoint (5 kilowatts/square meter): 0.09 miles (0.14 kilometers)
--------Assumptions About This Scenario---------
Wind Speed: 3 meters/second (6.7 miles/hour)
Stability Class: D
Air Temperature: 77 degrees F (25 degrees C)

Offsite Consequence Analysis Additional Backup

Worst Case Release Scenarios

- The greatest amount of motive fluid in a single vessel would be present in the Motive Fluid Storage Tanks. Inventory in the Motive Fluid Storage Tank is limited to 90% of water capacity per SOP-7 at Puna. Since these tanks are in containment that will hold the entire vessel quantity, the offsite impact will be mitigated.
- The vaporizers at both GCCU and the Expansion contain less motive fluid than the storage tanks, but they are uncontained and result in the greatest distance to endpoint from each process.
- Ambient conditions used to evaluate the distance to the overpressure endpoint are the default conditions, selected because they are allowed by regulation and utilized by RMP Comp. Rural topography is utilized.

Alternate Case Release Scenarios

- The alternate release scenario of a transfer hose rupture was selected as the most likely scenario given the frequency of operational transfers that utilize transfer hose. Transfer between a delivery truck and storage tank involved the largest transfer rate via hose.
  - Shutdown of flow on the delivery truck side would occur immediately, as the delivery personnel stand by at the remote shut off valve. Closure of the automated isolation valve at the storage tank will be activated remotely by the CRO. A plant operator also stands by during offloading and can alert the CRO of the need to close the isolation valve. The electrical actuation components of the isolation valve are classified for operation in a Class I, Div 2 electrical hazardous area and will function in the presence of motive fluid vapor.
  - A conservative time estimate of 10 minutes to achieve isolation is assumed. The actual time will likely be shorter.
- The following alternate release scenarios were considered, but not selected:

Scenario	Comment
Process piping releases because of a failure at a flange, joint, weld, valve and valve seal, drain or bleed	System tightness checks upon startup and pipe construction per ASME B31 codes render this scenario highly unlikely
A process vessel or pump releases because of a crack or a failure of a seal, drain, bleed or plug	Process vessels and pumps manufactured to ASME and/or API standards. Rotating equipment utilizes double mechanical seals with barrier fluid system (Seal system contains motive fluid leakage and isolates rotating equipment).
A vessel overfills and spills, or over-pressurizes and vents through a relief valve or rupture disc	Operator monitoring during filling and high level alarms make the occurrence of this scenario highly unlikely.
A shipping container is mishandled and thereby breaks or is punctured leading to a spill	Not applicable.

- Other considerations:
  - No accidental releases were identified that exceeded the selected alternative release scenario.
  - The PHA identified all selected and considered alternate release scenarios.
- Ambient conditions used to evaluate the distance to the overpressure endpoint are the default conditions, selected because they are allowed by regulation and utilized by RMP Comp. Rural topography is utilized.

Public Receptors

- Residential Population within Worst Case Release Zone: 0
  - Method for Determining Number of Public Receptors: Inspection of Google Earth Image
- Residential Population within Alternative Case Release Zone: 0
  - Method for Determining Number of Public Receptors: Inspection of Google Earth Image
- Public Receptors within **Worst Case** Release Zone (Schools, residences, hospitals, prisons, public recreational areas, commercial/office/industrial areas).
  - Receptors identified: **None**
  - Method for Identifying Public Receptors: Inspection of Google Earth Image
- Public Receptors within **Alternate Case** Release Zone (Schools, residences, hospitals, prisons, public recreational areas, commercial/office/industrial areas).
  - Receptors identified: **None**
  - Method for Identifying Public Receptors: Inspection of Google Earth Image

Environmental Receptors

- Environmental Receptors within **Worst Case** Release Zone (National or State Parks, Forests or Monuments, Officially Designated Wildlife Sanctuaries, Preserves or Refuges, Federal Wilderness Areas)
  - Environmental Receptors identified: **None**
  - Method for Identifying Environmental Receptors: USGS Topographic Map
- Environmental Receptors within **Alternate Case** Release Zone
  - Environmental Receptors identified: **None**
  - Method for Identifying Environmental Receptors: USGS Topographic Map