DRAFT
Hawaii Geothermal Development:
Impact Issues and Analytic Approaches
ERCE Oct. 23, 1991

INTRODUCTION

At the request of the Hawaii Department of Business and Economic Development (DBED), ERCE undertook a limited information search and literature review to identify methodologies, criteria, case studies and governmental policies regarding determination of potential impact level thresholds near geothermal power plant developments (or similar facilities). Information regarding standards and criteria used in Hawaii was gathered, as well as projects and processes from elsewhere in the United States. Following consultation with DBED staff, ERCE prepared a brief scope of work. Principal tasks included internal discussions with other ERCE staff regarding potential sources of the desired information; contacts with knowledgable individuals outside the firm; and review of holdings of the University of California libraries related to topics of interest.

The work to date cannot be considered complete. The topic is broad and interdisciplinary. However, we believe that the research has identified some useful information for discussion, as well as sources for further review.

The information which follows is organized into five major topics: 1) air quality; 2) sound levels; 3) alternative project mitigation strategies; 4) recommended actions; and 5) references likely to contain applicable information regarding these issues.

Environmental issues associated with geothermal development can span the entire spectrum of topics, including potential impacts to biological and cultural resources, visual impacts, increased traffic, interference with existing or proposed land uses, changes in sound levels, light & glare, water quality/quantity issues, and air quality changes. For this particular geothermal development, the key issues appear to be impacts to air quality, sound levels, human health and safety issues associated with those physical changes, and related interference with residential "quality of life." We have therefore focused our review on air quality and sound level considerations.

AIR QUALITY

Constituents of Concern

The Draft Master Plan, Hawaii Geothermal Transmission Project (ERCE, 12/90) describes twenty-two substances associated with geothermal emissions, ranging from ammonia to vanadium (see Master Plan, Table 4-4, pp. 4-30 and 4-31).

Applicable Standards and Guidelines

Allowable concentrations of some of these substances (nitrogen dioxide, sulfur dioxide and suspended particulate matter) are regulated under federal and/or Hawaii Ambient Air Quality Standards (AAQS). These standards are summarized in Master Plan Table 4-2 (page 4-23). Workplace concentrations of other geothermal fluid constituents are regulated by the Occupational Safety and Health Administration (OSHA). These include ammonia, arsenic, boron oxide, carbon dioxide, hydrogen sulfide, mercury, nitrogen dioxide, sulfur dioxide, and vanadium (as vanadium oxide dust). OSHA standards for these materials are listed in Master Plan Table 4-5 (page 4-32).

Table 2a
Noncondensible Gases in Geothermal Fluids

Ammonia	Argon
Arsenic	Boric Acid
Carbon dioxide	Carbon monoxide
Helium	Hydrogen
Hydrogen Sulfide	Mercury
Methane	Nitrogen
Oxygen	Sulfur dioxide

Table 2b
Representative Concentrations of Non-condensible Gases in Geothermal Fluids

	Representative Concentrations, ppm	
Noncondensible Gases	When 5% of Total Gases	When 0.3% of Total Gases
Methane	80,000	1,500
Hydrogen Sulfide	20,000	1,100
Hydrogen	15,000	1,000
Ammonia	3,100	110
Arsenic	25	1.5

Discussion

From the air toxics/health and safety perspective, hydrogen sulfide appears to be the issue of most concern at local geothermal operations. The highest reading observed during the recent upset condition at Puna Geothermal Venture was 2.15 parts per million (ppm); general background conditions at the time of the surge were in the range of 0.1 to 0.2 ppm. As shown in Table 3, it appears that the the hydrogen sulfide problem is predominately a nuisance issue. However, acute health effects from transient exposure, and possibly long-term chronic exposure to emissions from periodic wellfield upset conditions could represent a problem. Data available on hydrogen sulfide identifies "low concentrations" as the range from 20-150 ppm. This is considerably higher than the monitored background range noted previously.

Table 3
Hydrogen Sulfide Effects on Humans

Concentration, ppm (parts per million)	Description of Effect
0.0007 to 0.30 ppm	Odor threshold
0.33	Distinct odor; can cause nausea and headaches
2.7 to 5.3	Odor offensive and moderately intense
20 to 33	Odor strong, but not intolerable
100	Can cause loss of sense of smell in a few minutes
210	Smell not as pungent, probably due to olfactory paralysis
667	Can cause death quickly due to respiratory paralysis
750	Virtually no odor sensation; death can occur rapidly, upon very short exposure.

Another potential issue is the release of radioactive elements. These are generally from geothermal fluids in low concentrations, and include uranium and thorium isotopes, radium and radon. Radon is a radioactive gas, and one of the products of radioactive decay. It is the most significant generally recognized radioactive compound in geothermal fluids. A survey that was performed in the mid-1970s by the U.S. EPA indicated a radon range of 13 to 14,000 pCi/L (picocuries per liter), with a median of approximately 510 pCi/L. At this time it is unknown whether radon emissions constitute an issue at Hawaiian geothermal sites.

SOUND LEVELS

Acoustical Concerns

Acoustical concerns related to geothermal development include noise related to facility construction, including traffic of construction vehicles; noise during power plant testing; plant operational noise; and noise levels associated with possible "blowout" upset conditions.

Applicable Standards and Guidelines

Long term sound level standards used by U.S. EPA are compiled in Table 4 on the next page. These standards have been the basis for many state and local standards. EPA guidelines and U.S. Geologic Survey regulations for geothermal operations on federal lands are consistent, requiring that noise not exceed Ldn of 65 at the lease boundary or one-half mile from the source, whichever is greater (EPA 1978). This level is comparable to approximately 55 dBA. County of Hawaii Geothermal Noise Level Guidelines are based on EPA criteria, and specify residential area limits of 55 dBA during the day, and 45 dBA at night (7 p.m. to 7 a.m.).

Table 4
Yearly Average Equivalent Sound Levels Identified as Requisite to Protect the Public Health and Welfare With an Adequate Margin of Safety

	Measure	Indoor Activity Interference	Indoor Hearing Loss Consideration	Indoor To Protect Against Both Effects (b)	Outdoor Activity Interference	Outdoor Hearing Loss Consideration	Outdoor To Protect Against Both Effects (b)
Residential with Outside Space and Farm Residences	L_{dn}	45		45	55		55
	$L_{eq(24)}$		70			70	
Residential with No Outside Space	L_{dn}	45		45			
	$L_{eq(24)}$		70				
Commercial	$L_{eq(24)}$	(a)	70	70(c)	(a)	70	70(c)
Inside Transportation	$L_{eq(24)}$	(a)	70	(a)			
Industrial	$L_{eq(24)}$(d)	(a)	70	70(c)	(a)	70	70(c)
Hospitals	L_{dn}	45		45	55		55
	$L_{eq(24)}$		70			70	
Educational	$L_{eq(24)}$	45		45	55		55
	$L_{eq(24)}$(d)		70			70	
Recreational Areas	$L_{eq(24)}$	(a)	70	70(c)	(a)	70	70(c)
Farm Land and General Unpopulated Land	$L_{eq(24)}$				(a)	70	70(c)

Code:

a. Since different types of activities appear to be associated with different levels, identification of a maximum level for activity interference may be difficult except in those circumstances where speech communication is a critical activity. (See Figure D-2 for noise levels as a function of distance which allow satisfactory communication.)
b. Based on lowest level.
c. Based only on hearing loss.
d. An $L_{eq(8)}$ of 75 dB may be identified in these situations so long as the exposure over the remaining 16 hours per day is low enough to result in a negligible contribution to the 24-hour average, i.e., no greater than an L_{eq} of 60 dB.

Note: Explanation of identified level for hearing loss: The exposure period which results in hearing loss at the identified level is a period of 40 years.

*Refers to energy rather than arithmetic averages.

The U.S. Department of Housing and Urban Development (HUD) identifies an exterior sound level of 65 Ldn as "acceptable. " Sound levels between 65 and 75 Ldn are acceptable to HUD provided that mitigation to sound levels of 65 Ldn or below is feasible. Exterior sound levels above 75 Ldn are "clearly unacceptable" to HUD.

Discussion

ERCE acoustical staff has reviewed these guidelines, and found them to be reasonably consistent. The following observations are made relative to DBED's requested categorization of problems. Project noise levels less than 55 Leq (County of Hawaii) or 60 Ldn (HUD) can be considered negligible problems. Above 55 Leq, and from 60-65 Ldn, would be considered a nuisance situation. At levels from 65-75 Ldn, HUD would require mitigation to 65 Ldn or below. Levels above 75 Ldn would be "clearly unacceptable" to HUD, and would require relocation. Project compliance with the applicable guidelines it is believed, would protect public health and safety. Anticipated acoustical effects from the project exceeding these guidelines need to be identified, and mitigated.

ALTERNATIVE PR0JECT MITIGATION STRATEGIES

Introduction

Several categories of actions can be utilized to make a potentially problematic facility more palatable to persons or communities who may be directly affected. These include identifying and providing mitigation of anticipated impacts; compensation for any actual damages that accrue due to the proposed facility; and rewards (also called "host fees") to a community in exchange for accepting the facility and any associated risks or unmitigated impacts. Another action could be to cede to the affected community a certain degree of facility oversight, in an effort to assure community members that their concerns will be heard and acted upon.

Mitigation programs can either be incorporated into the initial project description, or can be identified as a result of environmental impact analysis. They may include features such as buffer zones between a facility and other nearby uses; modification of operational procedures and equipment; visual screening of facilities from nearby sensitive uses; delineation and implementation of procedures to be used during any facility emergency situations; public education programs; etc.

Compensation must be tied to actual damages incurred, and can include programs to guarantee property values near the facility; protection for community members in case of facility accident, by means of insurance, trust funds, performance bonds, etc.; mitigation of unemployment, etc. One problem with such compensation for some types of facilities is that, in some cases, the extent of impacts and the associated damages may be difficult to establish.

Reward programs are not based on actual damages or impacts, but on an offer of benefits in exchange for accepting a risk of possible impacts. Rewards may include direct monetary payments to the community; provision of community infrastructure such as roads, sewers, parks, schools; provision of services needed by the community, such as power or fire protection; tax incentives; and assumption of liability.

Mechanisms which give affected communities some measure of facility oversight and control have been used for some projects. For example, a Laidlaw Company landfill near Denver incorporates

a mechanism by which the local community monitors landfill operations and communicates observed problematic situations with the company for action.

Limited information regarding mitigation, relocation, and compensation practices for other various types of projects is described below.

Highway Development

Development of interstate and other highways often requires relocation of residents and businesses anticipated to be within the needed right-of-way. Relocation procedures utilized by the U.S. Department of Transportation and various state highway departments once properties requiring relocation have been identified may be useful to consult. However, the most common relocations are for those properties expected to be directly crossed by the highway or its right-of-way, unlike the geothermal issue of impacts at some distance from the plant itself.

Airport Noise/Safety Zone Impacts

Airport authorities have had to deal with relocation of residential and other uses near either new airports, or such uses near older facilities which, as air travel and aircraft noise increased, were subject to noise and safety impacts. Aircraft operational procedures at many airports are subject to strict controls to minimize such impacts, including direction of takeoffs and landings, prescribed ascent paths and power levels, and hours of operation. Beyond such measures, some airports have purchased properties, and also retrofitted homes with noise control materials to minimize noise impacts to nearby residents.

Hazardous Waste Facility Siting

The Massachusetts Hazardous Waste Facility Siting Authority Act of 1975 provides for incentive compensation to host communities for agreeing to accept hazardous waste processing facilities. The Act requires first, that an agreement be negotiated with the host community, and that steps be taken to mitigate anticipated facility impacts. If there are residual, unmitigable impacts, then compensation to the host community is deemed appropriate. The State in this process acts as facilitator or mediator in the discussions, and provides technical assistance grants to communities to prepare their case. Compensation under this Act can be either monetary or "in kind" services. Monetary payments could be tied to volume processed, while in-kind compensation has involved provision of free disposal services to community residents and businesses, fire protection, and medical training.

Powerplant Siting

In at least one case, for the proposed Gray Rocks powerplant in Wyoming, the proponent utility set up a $7.5 million trust fund for preservation of sensitive habitat in perpetuity. The power company also agreed to pay property taxes from initiation of construction, instead of from power plant completion.

RECOMMENDED ACTIONS

Clearly, potential air quality health and safety impacts are the major project issue to be addressed, relative to both long-term operations and to potential "upset" conditions. In order to provide a better understanding of likely impacts of specific noncondensible gas concentrations at the project boundary and in adjacent downwind areas, ERCE recommends that an atmospheric tracer gas

study be conducted. This action would quantify vented chemical species in the downwind area for use in subsequent health risk assessment (HRA) analysis. Atmospheric tracer gas studies involve the controlled release of a non-toxic gas, sulfur hexafluoride, subsequent downwind sampling over time, and dispersion analysis. Anticipated concentrations of the chemical species of concern in this project could then be calculated.

In addition, ERCE recommends that a site-specific health risk assessment be conducted for the project, using California methods prescribed under A.B. 2588 for air toxics "hot spots." Such a study should be based upon the identification of individual chemical substances of concern (i.e., noncondensible gases at the wellhead); anticipated concentrations; prevailing site-specific meteological and topographic conditions; and local demographic data. This effort should be coupled/correlated with the atmospheric tracer study results to enhance tailoring of the air quality dispersion model selected as most appropriate for this assessment. ERCE has the capability to conduct both such studies .

As noted previously, geothermal noise level standards of the County of Hawaii are expected to protect public health and safety. If it has not already been done, ERCE could undertake noise level calculations to identify which properties, if any, would be subject to project noise levels in excess of those standards.

Due to the short time available for preparing this paper, no detailed review was conducted regarding specific procedures used by other agencies for determining which uses or residences would require relocation for various projects. If desired, such review could be conducted concurrently with any air quality, health risk assessment or noise analyses. Other useful research might address:

- o How other geothermal developments have dealt with such issues
- o Relocation and compensation issues at fossil-fuel and nuclear power plants;

REFERENCES

Although the scope of this effort precluded a review of many specific studies and analyses, a bibliography for possible further research has been compiled. Reports and articles listed below address the following topics:

- o Geothermal power plants
- o Socioeconomic impact assessment - general
- o Economic impact assessment
- o Social impact assessment
- o Socioeconomic impact mitigation and management
- o Specific management measures - compensation and incentives
- o Socioeconomic impact assessment - energy conversion projects

Primary source of entries for the first topic, geothermal power plants, was holdings from all University of California libraries, mostly dating from 1981. Library locations and call numbers are provided for these entries, in case they are needed in further research. ERCE has access to all these documents through the University of California, San Diego, and the University system interlibrary loan program.

Primary source for remaining entries was a bibliography on social impact assessment, prepared by F. Larry Leistretz in 1984. The title of that publication is Social Impact Assessment: An

Annotated Bibliography. Fifty-three, or approximately 5%, of the entries in that bibliography have been identified as most pertinent to efforts relating to this geothermal project.

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