ENVIRONMENTAL MONITORING OF THE ST. LUCIA GEOTHERMAL PROJECT -- RESULTS OF SECOND VISIT

Prepared by:

Paul Dulin and Lee Hannah, Ph.D.
Associates in Rural Development, Inc.
110 Main Street, Fourth Floor
P.O. Box 1397
Burlington, VT 05402
U.S.A.
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ABBREVIATIONS AND ACRONYMS

AA	atomic absorption
AID	U.S. Agency for International Development
ARD	Associates in Rural Development, Inc.
CEHI	Caribbean Environmental Health Institute
CO_2	carbon dioxide
db	decibel(s)
EMP	Environmental Monitoring Program
EPA	Environmental Protection Agency
GOSL	Government of St. Lucia
H_2S	hydrogen sulfide
mg/m^3	milligrams per cubic meter
ml	milliliter(s)
MSA	Mine Safety Appliance
OSHA	Occupational Safety and Health Administration
ppm	parts per million
UNRFNRE	United Nations' Fund for Natural Resources Exploration

PREFACE

This is the second and final report on the Environmental Monitoring Program (EMP) for the St. Lucia Geothermal Project. The U.S. Agency for International Development (AID) awarded Associates in Rural Development, Inc. (ARD), a contract (number 538-0137-C-00-7035-00) on 13 April 1987 to provide technical assistance to the government of St. Lucia (GOSL), specifically the Ministry of Planning, Personnel, Establishment and Training.* This assistance was to focus on environmental monitoring of two geothermal exploration wells to be drilled in the Qualibou Caldera, located in southwestern St. Lucia (see Figure 1).

Much of the material discussed in this report is based on ARD's second visit to the St. Lucia Geothermal Project area from 24 September to 4 October 1987. The team for this field visit consisted of Mr. Paul Dulin, ARD's natural resources specialist and project manager for this effort, and Dr. Lee Hannah, an ARD environmental specialist. As ARD's second report on EMP activities, this document should be used as a follow-on to the first report.** Many of the findings and recommendations from the initial reconnaissance report are still applicable and have been reiterated here.

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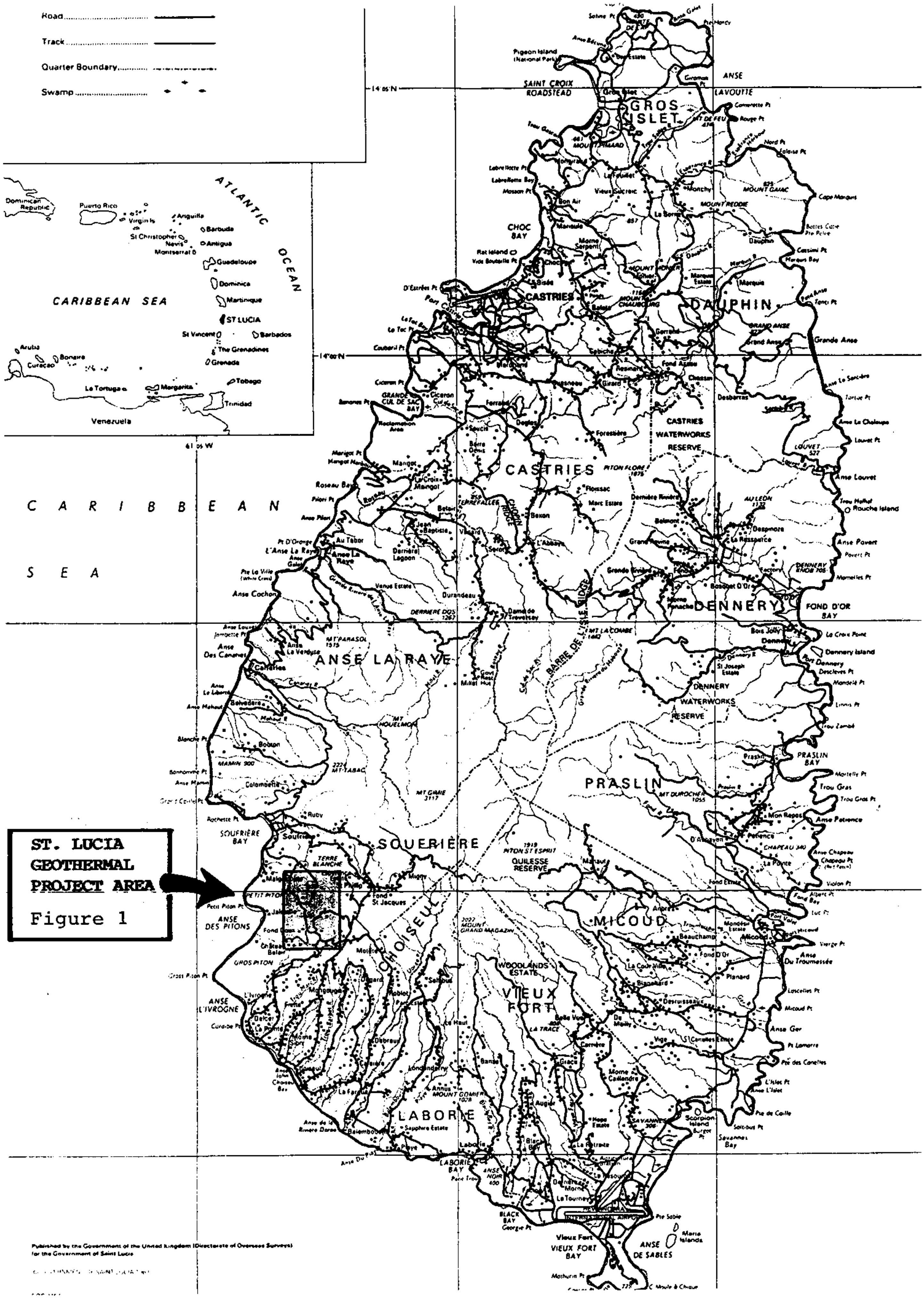
*Formerly the Ministry of Finance and Planning.

**Paul Dulin, Lee Hannah, and Tsvi Meidav, Environmental Monitoring of the St. Lucia Geothermal Project -- Results of Initial Reconnaissance Visit (Burlington, Vermont: ARD, 24 June 1987).



ST. LUCIA GEOTHERMAL PROJECT AREA

Figure 1

I. EXECUTIVE SUMMARY

This report discusses ARD's second field visit to St. Lucia to reassess the potential for environmental impacts associated with geothermal exploration activities in the Qualibou Caldera near Soufriere. The analyses herein focus on the site of the second well (SL-2) at Sulphur Springs. However, follow-up information on water- and air-quality monitoring relative to the first test well drilled at Belfond (SL-1) are also covered.

During this visit, EMP air- and water-quality monitoring strategies were reoriented to the Sulphur Springs site. Development of SL-2 entails the potential for impacts similar to those considered for SL-1. However, the geographical location of SL-2 will affect a different watershed/drainage system, and the air-quality problems could be more serious.

In this report, ARD also assesses the potential impacts of the geothermal exploration drilling and testing on land use and vegetative cover, marine and near-shore environments, flora and fauna, tourism and recreation, and cultural and archeological resources. Recommendations are made to the GOSL concerning implementation of a public awareness campaign to advise local residents about the process of geothermal development and safety considerations, and development of a contingency plan for dealing with possible emergencies.

GOSL and Caribbean Environmental Health Institute (CEHI) personnel are actively managing the monitoring program. Samples are being analyzed in the field or at CEHI's laboratory in Castries. EMP funds have improved the Institute's capability to conduct water, air and geothermal brine, gas and condensate sampling/analysis through the purchase of laboratory and field equipment.

EMP's primary concern continues to be waste disposal/management. No plans have been developed for waste disposal during the short- and long-term well-testing phases. Alternatives for waste disposal and management are examined in this report, and a series of recommendations and cautions provided. No appropriate waste management plan can be developed until the character of geothermal discharges (liquids, condensate, gases) from the well are analyzed for concentrations of heavy metals and other contaminants. Until then, any discharge from the well should be retained at the site in lined waste sumps.

II. INTRODUCTION

The GOSL has undertaken drilling of two geothermal test wells in the Qualibou Caldera, located in southwestern St. Lucia (see Figure 1). This effort is being supported financially and technically by the United Nations' Revolving Fund for Natural Resources Exploration (UNRFNRE) and AID's Regional Office for the Caribbean. Arrangements were made through a tripartite commission (consisting of the GOSL, UNRFNRE and AID) to contract for the technical assistance needed to implement the various aspects of this exploratory program.

AID awarded ARD a contract to provide technical services for the design and development of the St. Lucia EMP to assess the current and potential impacts of geothermal development activities during the exploration and testing phases. At the conclusion of each visit of the ARD team leader and consultants to the project area, recommendations concerning adherence to certain environmental and safety standards as well as mitigative measure designed to ameliorate environmental and cultural resources degradation were developed and presented to drilling contractors and the tripartite commission. ARD made initial reconnaissance visits to the project area from 22 April to 1 May and 11 to 15 May 1987. The findings and recommendations from those visits are detailed in a previous ARD report, Environmental Monitoring of the St. Luica Geothermal Project -- Results of Initial Reconnaissance Visit, which was published on 24 June 1987.

Project developers originally planned to drill the two wells at Belfond (SL-1) and Etangs. Thus, the initial focus of ARD's monitoring program was oriented toward those two sites. Drilling on the first well started in April 1987, but by August, after drilling to a depth of over 7,000 feet, the well was deemed "nonproductive." A high-level seminar was then convened to study the data from the first well, and a consensus was reached to abandon plans to drill at Etangs. Instead, the second well (SL-2) was to be drilled at a completely new site in Sulphur Springs, close to the surface geothermal manifestations there.

In early September, the access road and pad preparation for SL-2 were begun. ARD was contacted in late August and prepared for a second trip to St. Lucia. Mr. Dulin, ARD's home-office project manager for this effort and a natural resources specialist, and Dr. Hannah, an ARD environmental specialist, visited St. Lucia from 24 September to 4 October.

Because of the new location for SL-2, ARD had to repeat most of the reconnaissance work and investigative activities that had been done during the initial visits to St. Lucia. The team had studied both the Belfond and Etangs sites during the initial

III. RESPONSES TO INITIAL RECONNAISSANCE REPORT

Copies of the ARD report on the monitoring team's initial reconnaissance visit were sent to the project managers for AID, Aquater and GOSL on 25 June 1987. No response or request for discussions was ever received from any of these organizations regarding the series of recommendations provided in that report on various aspects of well-site and community safety, erosion control, water quality, noise control, public awareness and other concerns, but more importantly, on cautions and recommendations about short- and long-term testing procedures, and waste disposal and management. **Some of these recommendations are critical for the mitigation of potentially negative impacts during the testing phase of the St. Lucia Geothermal Project.**

A. AID

The ARD home-office project manager called AID's geothermal project manager in August 1987 to solicit a response to the initial reconnaissance report. The AID project manager said the report had made drilling engineers take a harder look at the issues involved. He also said that Aquater representatives were preparing a written response to the report and suggested that the ARD monitoring team contact Aquater directly the next time they were in St. Lucia to discuss Aquater's response.

B. Aquater

On arriving in St. Lucia in late September, the ARD environmental monitoring team's first activity was to visit the SL-2 site, which was under preparation at the time. Aquater's project manager and chief drilling engineer were also contacted at their headquarters in Soufriere. The ARD team explained the objectives of its second visit and suggested a debriefing on the initial reconnaissance report. At this meeting, each finding and recommendation from the initial report was reviewed and Aquater's response noted.

Aquater accepted the recommendations regarding revegetation and site reclamation at Belfond, road repairs and improved waste-oil disposal. Aquater's project manager also mentioned that mufflers could be attached to the diesel water pumps to reduce noise levels, as recommended in the ARD report. When asked about off-site safety, contingency planning and public awareness for the surrounding communities, Aquater responded that this was the GOSL's responsibility.

By far, the greatest area of **nonresponse** was in regard to ARD's recommendations concerning drilling standards, the design

IV. SPECIFIC IMPACT AREAS

The following subsections discuss specific areas where there is the potential for negative impacts associated with the St. Lucia Geothermal Project that should be avoided or mitigated. Their organization follows that used in ARD's first report on environmental monitoring of the project. In many cases, findings and recommendations noted in that initial report for the Belfond and Etangs sites are entirely or partially applicable to the development of SL-2 at Sulphur Springs.

A. Vegetative Cover, Land Use and Watershed Management

1. Potential Impacts

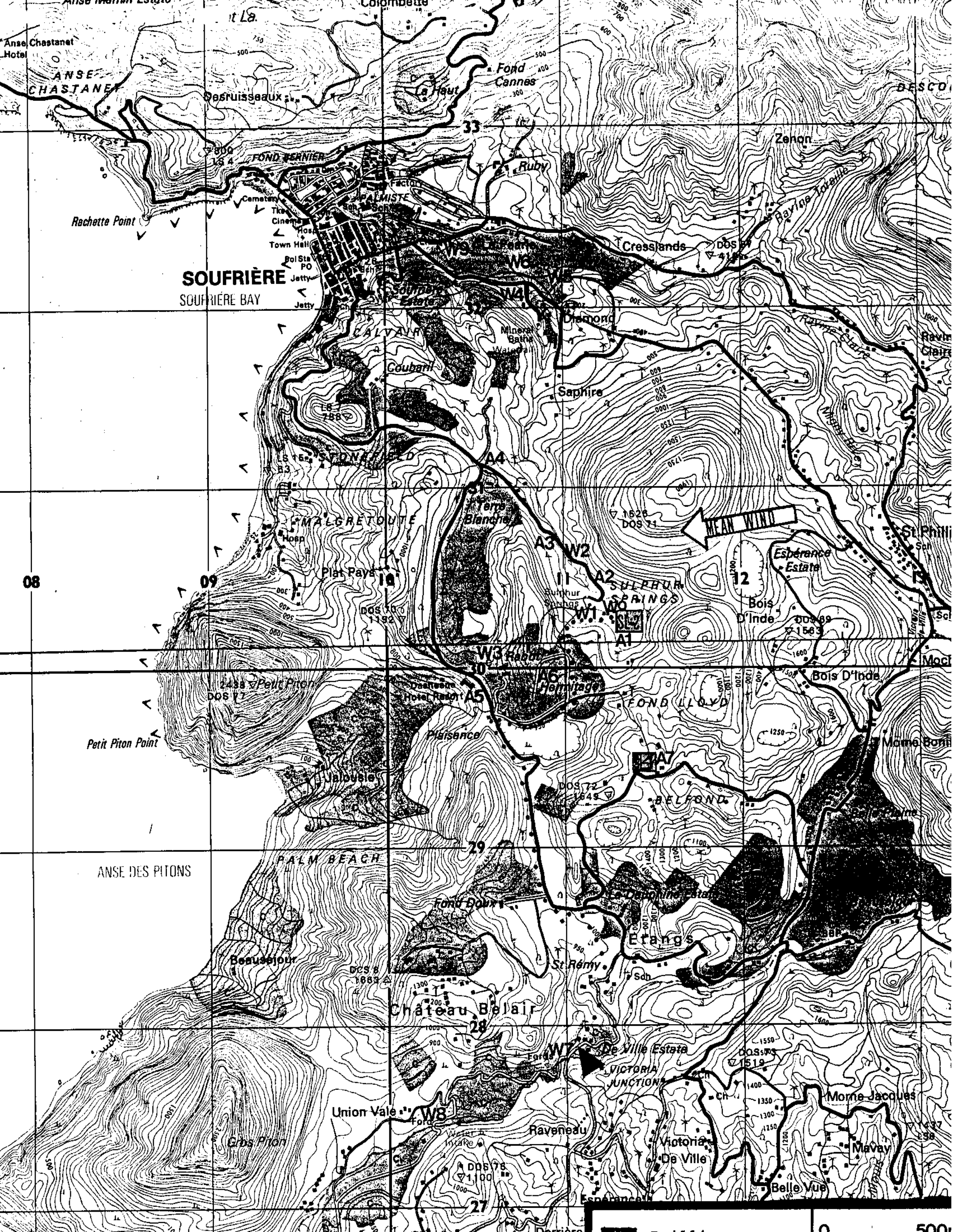
Three construction activities related to the development of SL-2 require consideration:

- laying a freshwater pipeline from Etangs to Sulphur Springs,
- improving the existing Sulphur Springs access road, and
- preparing the drill pad.

To bring drilling water to the site, the freshwater pipeline that was originally directed to Belfond (SL-1) was rerouted from Etangs to Sulphur Springs along the Vieux Fort-Soufriere highway (see Figure 2). Laying the pipe required trenching along the apron of the roadbed, mostly on the bottom or sides of the drainage running parallel to the roadway. Thus, the disturbance of this construction activity is linear, affecting only a swath of land approximately one meter wide.

The access road from the turnoff of the highway to Sulphur Springs had to be widened and the bridges reinforced to accommodate transportation of drilling equipment to the pad. Heavy machinery was used to cut and fill the roadbed along 1.2 kilometers of this sinuous road. On several tight curves, large volumes of cut and fill had to be moved, which interfered with established drainage along the road. Some of the fill slopes were notably unstable and appeared prone to erosion from oncoming rains. The remnant of paved and graveled access was lost to earth graders.

Establishment of the drill pad disturbed approximately 2.5 acres. This area (see Figure 2) was previously an extensive unproductive pasture, characterized by poor drainage, marshy



Anse Chastanet Hotel
ANSE CHASTANET
Colombette
Desruisseaux
Fond Cannes
La Haut
Fond Bernier
Rachette Point
Cemetery
Cinema
Hosp
Town Hall
PO
Jetty
SOUFRIÈRE
SOUFRIÈRE BAY
PALMISTE
Factory
Soufrière Estate
CALVAIRE
Couban
Mineral Baths
Waterfall
Diamond
Saphire
Cresslands
Zenon
Ravine Claire
Ravine Touraille
Ruby
STONEFIELD
MALGRETOUTE
Hosp
Terre Blanche
Plat Pays
Sulphur Springs
SULPHUR SPRINGS
MEAN WIND
Espérance Estate
Bois D'Inde
St Phillip
Rabot
Hermitage
FOND LLOYD
Hotel Resort
Plaisance
Jalousie
Petit Piton
Petit Piton Point
ANSE DES PITONS
PALM BEACH
BELFOND
Morne Bonin
Fond Doux
La Dauphine Estate
Etangs
St Rémy
Beausejour
Château Belair
De Ville Estate
VICTORIA JUNCTION
Morne Jacques
Union Vale
Raveneau
Gros Piton
Victoria
De Ville
Mavay
Belle Vue
Espérance
Derrière
W1
W2
W3
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conditions and secondary growth. A moderate amount of drainage from the surrounding hills flowed perennially through the eastern portion of the site. Grading activities cut down several small hills on the south side, leaving some local villagers with a direct view of drilling operations, although owners were compensated for the land lost. The most serious problem at the site is water. SL-2 sits directly at the bottom of a geological bowl, with drainage from three sides flowing to the middle, the location of the drill site. A bypass canal was cut from the southeast at the base of the surrounding hills to the northwest, circumventing the site and emptying into the natural drainage toward Sulphur Springs Creek.

All of these construction operations are temporary, but necessary, disturbances of vegetative cover and drainage. If revegetated and properly protected, they will not have any serious, lasting impact.

Drilling pad preparation for SL-2 at Sulphur Springs. The site sits at the bottom of a topographic "bowl", creating problems of drainage and potential problems of dispersal of gases emanating from the well.

However, another potentially more serious problem is possible impacts on local vegetation and agricultural crops of the release of boron and other elements that are toxic to plant life when the well is vented during testing. Depending on the

B. Water Quality

As discussed in ARD's initial reconnaissance report, pollution of both surface water and groundwater may result from drilling activities and the disposal of waste fluids and condensates or accidental discharges. Groundwater contamination may be caused by infiltration of waste fluids or seepage from contaminants in waste sumps.

Upon learning that Aquater was considering Sulphur Springs Creek as an alternative for waste disposal, ARD's team undertook a more vigorous assessment of potential water-quality impacts. With Mr. Cornelius Fevrier and Mr. Francis Isidore, representing the GOSL and CEHI, respectively, the ARD team walked the length of Sulphur Springs Creek to its confluences with the Diamond Springs Creek and Migney (Soufriere) River, and then followed the Soufriere to the bay (see Figure 2). In an informal door-to-door survey, people living near these streams were asked if they used the water. The only uses recorded by the team are as follows:

- tourists visit Diamond Falls and the mineral baths, but do not bathe directly in the stream--the baths are supplied by an isolated spring that is about 60 meters above the stream's floor;

- some residents (though an unspecified, presumably minor number) do use the stream for medicinal baths or bathing;

- local residents catch crayfish in the Soufriere River for personal consumption and local sale;

- people from Soufriere occasionally wash clothes in the lower Soufriere River near the town;

- Copra Manufacturers, Ltd., a soap and oil factory located in Soufriere, uses approximately 18,000 imperial gallons of water a day from the Soufriere River to cool its processing machinery;

- at the mouth of the Soufriere, residents routinely bathe for recreation on the town's beaches (see Section IV.C on the marine and near-shore environments); and

- as far as could be determined, these streams are not used as a source of potable water anywhere along their routes.

Obviously, if especially toxic levels of heavy metals or other caustic compounds are introduced into these streams, the extent of negative impacts would include occasional users of minute and pumps it to the drilling site. While the volume of the St. Remy is sufficient for this dewatering and continued extraction to the Delcer potable-water filtering facility, shortfalls were mentioned by farmers who use the St. Remy for irrigation (this diversion is now used by the project). Dewatering of the lower Ivrogne River, especially during the dry season, adversely affects downstream users in the Union Vale area who depend on this source for potable water, but the number of users and extent of this impact is unknown.

1. Monitoring of SL-1

Ten surface-water sampling stations were originally established in the vicinity of the drilling site, but one was later abandoned. Samples have been taken weekly at each station and analyzed for selected parameters using a Hach DREL-5 spectrophotometric field kit and other portable instruments. For stations W_1 through W_9, data for the parameters analyzed in the field using the Hach kit are shown in Tables A through J in Appendix A. These parameters are temperature, pH,* conductivity, turbidity, phosphates, nitrates and nitrites. The first sample was taken on 22 May 1987, but regular sampling did not begin until 23 June, after a formal arrangement was made with the GOSL and CEHI. Turbidity data were collected using a CEHI meter. The nutrient data--phosphates, nitrates and nitrites--were gathered during the latter half of the sampling period after the DREL-5 and other supplies were received.

In addition, five preserved samples were collected during the week of 11 May from Sulphur Springs Creek (W_2), Weber Spring (W_3), Rabot Lake West (W_4), St. Remy intake (W_7) and the upper Ivrogne River (W_6). These were returned to Biospherics Laboratory in the United States for extensive atomic-absorption (AA) analysis. The results of the Biospherics analysis are shown in Table 1 on the following two pages. As expected, the levels of metals were high in the Sulphur Springs runoff and relatively low for the other samples. For Sulphur Springs, mercury and boron were in excess of Environmental Protection Agency (EPA) safe drinking-water standards. No physical parameter in the other samples exceeded safe drinking-water standards. The laboratory analysis also found anomalously high iron levels in the water from W_3 and W_4, which may indicate some hydrologic communication between these surface manifestations. The U.S. laboratory and HACH field determinations were in good agreement--the laboratory findings were within a 90 percent confidence

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*The pH data may not be very reliable as the pH pen malfunctioned during the first day of use, probably due to moisture absorption from continuous rains, and subsequent data from a CEHI meter may not be accurate either. A new pH pen was dispatched to CEHI.

Table 1. (continued)

SAMPLE Sample Id	Test:HG_CV mg/l	Test:K_FLA mg/l	Test:MF_FC CFU/100 ml	Test:MG_FLA mg/l	Test:MN_FUR mg/l
Little Ivrogne 04 WATER 4	<0.0004	5.1		7.6	0.010
Delcer 05 WATER 5	0.0007	4.0		12.3	0.204
Union Vale 06 WATER 6			800		

SAMPLE Sample Id	Test:NA_FLA mg/l	Test:NO2 mg/l NO2 N	Test:NO3 mg/l NO3 N	Test:PB_FUR mg/l	Test:SE_FUR mg/l
Sulphur Springs 01 WATER 1	48.9			<0.002	<0.042
Weber 02 WATER 2	18.5			<0.002	<0.042
Rabot 03 WATER 3	9.0			<0.002	<0.042
Little Ivrogne 04 WATER 4	19.3			0.004	<0.042
Delcer 05 WATER 5	17.0			0.002	<0.042
Union Vale 06 WATER 6		<0.02	0.13		

SAMPLE Sample Id	Test:SULFUR (%)?	Test:TI_FUR mg/l
Sulphur Springs 01 WATER 1	98.1	0.468
Weber 02 WATER 2	3.4	<0.003
Rabot 03 WATER 3	4.0	0.015
Little Ivrogne 04 WATER 4	*	<0.003
Delcer 05 WATER 5	2.6	<0.003

pH

As already noted, these data may not be reliable, but they seem to indicate that stations in the region of the springs (W_1 through W_5) are more acidic than W_6 through W_9. Of course, W_2 is the lowest as it is most directly affected by runoff from Sulphur Springs. At Rabot Lake, W_4 and W_5 may show lower pH values as a result of their proximity to the springs, but another factor may be the aquatic vegetation that almost covers the lake. As with temperature, the downstream stations W_8 and W_9 have higher pH values than W_6 and W_7.

Also similar to the temperature data, the trends for W_1 through W_5 are not as clear, as these stations all have different characteristics. W_1 and W_3 both show a peak on 7 July and a subsequent decline on 17 July to relatively stable levels. W_6 through W_9 all show a comparable pattern, relatively stable values with a low on 17 July. These may or may not be true reflections of actual pH values.

Conductivity

Conductivity was greatest at W_2 as the result of a high concentration of ions in the Sulphur Springs runoff. The lowest values were noted for the Rabot Lake stations, presumably due to the absorption of ions from the water by vegetation in the lake. W_1 and W_3 are similar. W_6 seems to have lower conductivity than W_7. These two merge, and the conductivity remains consistent at W_8 and W_9.

This parameter is probably affected by both runoff and rainfall. W_1 fluctuates widely and appears to follow a pattern similar to W_6, W_8 and W_9. W_2 fluctuates, but at higher levels. W_3, W_4 and W_5 have a much reduced range, the former as a result of relative protection from the changing environment and the latter two because of the size of the water mass and likely effects of vegetation. For W_6 through W_9, W_7 seems to be the most stable. W_1, W_6, W_8 and W_9 show highs and lows that generally coincide. The amplitude of the oscillations are higher at W_1 and W_6, compared to W_8 and W_9, indicating that the former are closer to the source (i.e., rainfall and runoff effects).

Turbidity

As expected, turbidity values and fluctuations were lowest at W_3. W_1, W_4 and W_5 all showed maximum turbidity on 5 August. In comparison, W_2 showed a minimum on that date. Assuming that changes in this parameter are due to rainfall and increased erosion, this would still have a reducing effect at W_2, where the turbidity was normally very high. W_6 through W_9 also showed a program. The new water-quality sampling stations are designated W_0, W_4, W_5, W_6 and W_9 (see Figure 2).

W_0 is located next to the access road to the site at the same elevation as the existing W_1 station--it intercepts immediate site drainage. W_4 is located on Diamond Springs Creek just above its confluence with the Soufriere River. It monitors combined drainage from the Sulphur and Diamond springs. W_5 is on the Soufriere River just above its confluence with Diamond Spring Creek and monitors water quality in the river prior to the entry of discharge from Sulphur Springs drainage. W_6 is also located on the Soufriere River just below its confluence with Diamond Springs Creek. It monitors the impact of Sulphur Springs drainage on the Soufriere. Finally, W_9 is on the Soufriere River at the entrance to the town of Soufriere to monitor water quality just prior to discharge into Soufriere Bay.

The water sampling stations retained from the SL-1 monitoring program include W_1, which monitors water quality above Sulphur Springs, and W_2, a natural spring in the Sulphur Springs community. W_3, W_7 and W_8 were retained for follow-up monitoring of SL-1 at Weber Spring, the Delcer intake (St. Remy) and upper Ivrogne River, respectively.

The integrated SL-2 monitoring program tracks the entire drainage of Sulphur Springs and the reach of the Soufriere River that is likely to be affected by any emissions from the drilling site. In addition, sampling stations immediately below the site and Sulphur Springs permit ongoing assessment of natural and project-related emissions into the system.

3. Recommendations and Follow-Up

The GOSL and CEHI should continue to maintain the monitoring program throughout the period leading up to discovery of steam/brine at SL-2. If the well is potentially productive and testing is scheduled, the first step should be to obtain a sample of the brine/condensate and undertake a full-scale analysis for heavy metals and other elements to determine their concentrations. This sample should be sent by courier to a U.S. laboratory for analysis, while CEHI performs all of the analyses it can currently handle in the laboratory at Castries. Short-term testing should await the results of these analyses to permit an assessment of potential impacts.

If short-term testing is carried out, all of the liquid and condensate waste should be directed to a lined waste sump to prevent any potential contamination of surface water or groundwater. Testing should not exceed the sump's capacity to hold waste liquids. If any waste liquids or condensates are directed into Sulphur Springs Creek, either accidentally or

Rachette Point, where a series of four large and a few smaller submarine pitons occur, rising from a depth of 50 to 60 feet up to the surface. There are also a number of small submarine caves and crevices, including one crevice that opens into a bat cave. The development of hard and soft corals and sponges along with fairly abundant pelagic fauna make this location one of the most popular diving sites in St. Lucia.

The reef drops off to occasional coral-encrusted rocks off the beaches of Soufriere Bay, then slowly picks up again just southwest of the town. However, the reef ecosystem is highly stressed by sediments and pollutants emanating from the Soufriere River. The reef is struggling to keep up, with noticeably fewer corals and sponges. Dead coral and remnants were noted throughout this area. Just south of Stonefield, the effects of contamination from the Soufriere River are no longer in evidence, and from this area out to and around Petit Piton Point, the quantity, quality and color of the corals and sponges, and abundance and activity of sea-life is again equal to Rachette Point.

Petit Piton Point is a very popular diving location that is important for tourism as well as a favored spot for Soufriere fishermen. There and at Rachette Point, game fish were observed, such as bonita, king mackerel, grouper, yellow fin, hind and numerous jacks, as well as various species of eel, squirrel fish, wrasses, gobis, Caribbean rock crab, coral-banded shrimp, parrot fish, and a host of diverse anemones, sponges, and hard and soft corals. All of Soufriere Bay and the two points are included in a marine reserve that the GOSL has declared for most of southwestern coastal St. Lucia.

If exceptionally warm water is suddenly introduced into Soufriere Bay in large volumes, it could increase phytoplankton and algae production that would reduce oxygen levels in the water (i.e., a red-tide effect) and result in fish kills. If certain contaminants were discharged into the bay in high concentrations and volumes, this could also have a devastating effect on the bay's ecological balance. Boron could effectively wipe out phytoplankton and other aquatic plants, ultimately affecting reef organisms (corals and sponges) and other species further up the food chain. High levels of lead and mercury could end up as residuals in fish tissues, which would ultimately be consumed by humans, with potentially devastating physiological impacts.

noncondensable because they remain after the water vapor has been removed from the gaseous phase by cooling, include carbon dioxide (CO_2), nitrogen, H_2S, sulphur dioxide and mercury. Noncondensable gases typically constitute 0.3 to 5.0 percent of the total gases in flashed geothermal fluids. However, the levels of noncondensable gases can vary depending on the nature of the resource--hot brine or wet or dry steam. Of particular concern is H_2S, which may be present in geothermal gases in concentrations of up to 30,000 parts per million (ppm) or three percent. Mercury vapor is also a potential problem, especially relative to human physiology.

1. Monitoring of SL-1

To monitor the impact of drilling activities at SL-1 on air quality in the surrounding area, ARD established a air-monitoring network of 10 stations. The locations of these air-sampling stations are specified in ARD's initial reconnaissance report. Each station includes a chemical detector tube that reacts to H_2S by undergoing a color change. The tubes are sensitive to H_2S at one ppm over a 10-hour sampling period, which exceeds Occupational Safety and Health Administration (OSHA) standards for occupational exposure.

Regular sampling for H_2S with LaMotte air pumps was also conducted at the SL-1 drilling site and Dasheene Hotel. Additional air-pump sampling stations were established (i.e., for SL-2) as additional air pumps were received. The LaMotte system is sensitive to H_2S at the most stringent U.S. standards for ambient concentrations.

Periodic sampling for H_2S is being conducted with a Mine Safety Appliance (MSA) hand-held meter with alarm. The MSA instrument is sensitive to H_2S for a range of one to 200 ppm, the point at which health effects begin to occur. Spot sampling with the MSA meter was being conducted primarily in the Sulphur Springs area and at the SL-1 drilling site. After well completion, this meter will serve as the H_2S alarm system at the wellhead.

Periodic sampling for mercury vapor is also being conducted with a Sensidyne-Gastec hand-held impinger-pump/detector-tube system. This system is sensitive to mercury vapor as low as 0.05 milligrams per cubic meter (mg/m^3), which is equivalent to the OSHA occupational exposure standards.

Detector tubes were being read twice weekly by EMP staff, and the stations at Sulphur Springs and the Dasheene Hotel monitored daily by volunteers. Air-pump samples were being collected twice a week by staff members. MSA H_2S and Gastec average of less then .006 ppm was recorded. On 26 August, a four-hour average of .006 to .01 ppm occurred. These low values are consistent with the history of periodic H_2S odor at the Dasheene.

Table 4. H_2S Air Pump -- Dasheene (four hours)

Date	Comparator Value
19-5-87	N.A.C.
23-6-87	N.A.C.
30-6-87	slight color, but less than #1
17-7-87	N.A.C.
22-7-87	N.A.C.
29-7-87	N.A.C.
05-8-87	N.A.C.
11-8-87	N.A.C.
18-8-87	N.A.C.
26-8-87	between #1 and #2

The results of mercury-vapor monitoring with a hand-held impinger pump at Sulphur Springs are presented in Table 5. In and immediately adjacent to the Sulphur Springs emissions, mercury vapor was present at 0.5 to 0.6 mg/m^3. These significant levels decline to below the detection limit at 100 meters away, indicating nearly immediate dilution and dispersal. The mercury levels present at Sulphur Springs are not harmful in terms of short-term exposure to the diluted emissions. However, the presence of mercury confirms the existence of this element in the Sulphur Springs geothermal system and warrants continued monitoring, primarily of well emissions.

Table 5. Mercury (Impinger Pump) -- Sulphur Springs

26 May 1987		
upwind (from access road)	0.0 mg/m^3	
downwind (from access road)	0.0 mg/m^3	
23 June 1987		
large crater to back	0.6 mg/m^3	(average 5 pulls)
midpoint	0.5 mg/m^3	(5 pulls)
hill just beyond bridge	0.5 mg/m^3	

E. Rare and Endangered Species of Flora and Fauna

1. Potential Impacts

As discussed in ARD's first report, little significant impact is expected on local fauna and flora in relation to the construction activities at Sulphur Springs. Improvement of the access road, pipeline construction and drill pad preparation will have temporary impacts in terms of noise disturbances, dust and sedimentation of local streams. Some individual animals may be affected in very local settings.

The testing phases pose potentially more serious impacts depending on how well testing and waste disposal are handled. The release of noncondensable gases, steam and fluids could cause the death of the few individuals that come in direct contact with these compounds (i.e., birds flying over, amphibious or aquatic organisms in streams). If waste liquids from the well are intentionally or accidentally introduced into Sulphur Springs Creek, the impacts would depend on the volumes released and concentrations of potential toxins.

An inventory has not been done of the flora and fauna (aquatic or terrestrial) along the length of Sulphur Springs Creek down through Diamond Falls to the Soufriere River. No information apparently exists concerning these local ecosystems. The extent to which the introduction of hot water, boron, heavy metals and other toxic compounds into these streams would negatively affect local flora and fauna cannot be estimated, but is a valid concern, especially in a worst-case scenario.

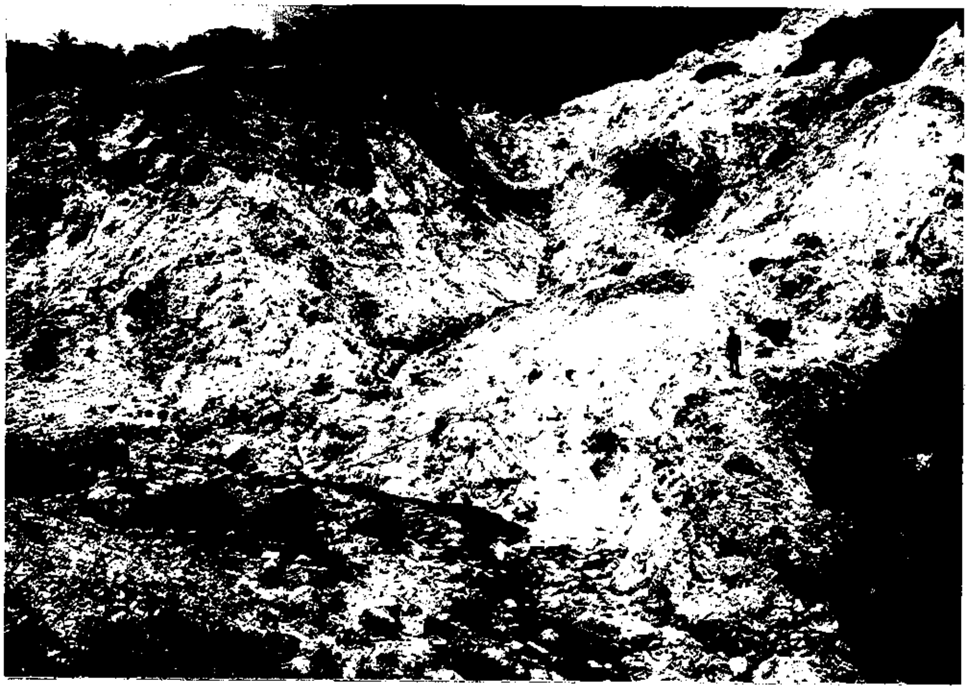
2. Recommendations and Follow-Up

A walking inventory along the stream courses should be done to evaluate existing flora and fauna associated with this ecosystem. A terrestrial ecologist or botanist and fisheries specialist should be requested by the GOSL and seconded to EMP from the St. Lucia Naturalists' Society and Fisheries Management Division, respectively. A brief report should be prepared to characterize the species diversity in this ecosystem to permit an assessment of any potential impacts.

F. Tourism and Recreation Resources

1. Potential Impacts

The site preparation and drilling operations at Sulphur Springs will affect tourism at the springs. While the drill pad could be reduced, thereby affecting the food chain of the reef system. Also, pelagic species could either be destroyed or would leave the area because of the water's toxicity.



The hot springs at Sulphur Springs attract a fair number of tourists on a continual basis. In the foreground flows Sulphur Springs Creek.

2. Recommendations and Follow-Up

In cooperation with Aquater, the GOSL or its selected collaborator should prepare a vantage point for potential tourists to the Sulphur Springs drilling site. The guides that normally take tourists around Sulphur Springs could also show them to this vantage point, which would be far enough away from drilling operations to protect tourists and avoid distracting drill-site personnel. Interpretive placards describing the geology of the caldera area and geothermal development operations should be prepared and posted at the visitors' station at the entrance to Sulphur Springs.

If Sulphur Springs Creek is used temporarily to dispose of liquid wastes during short-term testing and the levels of contaminants are too high, residents and the operators of Diamond Mineral Baths should be warned not to bathe in the creek. In all cases, the disposal of large quantities of liquid wastes, depending on their content, will not be allowed in the creek so sharp piercing sounds. At the SL-2 site, noise concerns in the surrounding community had not yet been addressed because drilling operations had not begun. Construction activities, primarily road grading and pad construction using bulldozers and dump trucks, have already created a noise level that annoys residents living in close proximity to the site. This disturbance was expected to last approximately 30 days until pad preparation was complete. With the beginning of drilling, the response to noise by residents of the communities around Sulphur Springs is expected to be similar to the results presented in ARD's first report for the communities surrounding Belfond. This report found that noise was not a serious problem except for residents whose homes were within 500 meters of the site.

For SL-1, noise was monitored with a DuPont Mark 2 audio dosimeter. Noise sampling consisted of surveying the site perimeter twice a week and constructing a monthly iso-decibel map for each pumping station. Noise at the perimeter of the site did not appear to exceed the OSHA threshold value of 80 decibels (db) at any time.

Noise levels were also monitored at the perimeter of the SL-1 site and pump station 3 (the approach to Belfond). While no noise in excess of the OSHA threshold was detected at the site's perimeter, it did exceed OSHA safety standards at points closer than two meters to the pump, as assessed by the eight-hour projected exposure function of the Dupont Mark 2 audio dosimeter (see Table 6). Because of these high levels of noise in excess of OSHA standards, ARD procured ear protection (earplugs) for the pump guards. ARD also recommended that all diesel-operated pumps be fitted with mufflers, but this was not done.

Table 6. Noise Levels at Water Pumping Station 3 near Belfond

Distance from Pump	North	South	East	West
one meter	95 db	95 db	100 db	100 db
three meters	91 db	91 db	95 db	95 db

As in the case of SL-1, a house-to-house survey was conducted for the area within a one-kilometer radius of the SL-2 site at Sulphur Springs. Of the 33 residences surveyed, 27 reported they could already hear drilling and pump noise from SL-1 at Belfond. It is expected that this figure will increase somewhat with SL-2, as this site lies in closer proximity to all those surveyed (see the results presented in Section IV.I). It is also expected that most of the residents of Sulphur Springs and some of those in Fond Lloyd will find the noise levels to be access road and community of Bois d'Inde (see Figure 3). The results for the expanded survey combined with those for the related communities surveyed earlier are shown in Table 7.

Similar to the findings presented in ARD's first report, the survey results indicate that nearly one-third of all the residents surveyed within a one-kilometer radius of Sulphur Springs did not know what the project was for. This indicates an inadequate effort on the part of the GOSL to inform area residents of a project that could ultimately affect them. Even after ARD made numerous suggestions in its initial reconnaissance report that the GOSL and Aquater hold meetings at the SL-1 site to educate local citizens about the need for and process of geothermal development, as well as to discuss safety and emergency contingencies, **this was not done.**

Almost all of those surveyed could hear the noise of the drilling and water pumping associated with SL-1. Nevertheless, residents were not particularly bothered by the noise levels. This will presumably be somewhat different for Sulphur Springs residents who will suffer amplified noise levels because of the location of SL-2 in a geological bowl. The survey found that nearly all residents are accustomed to the noxious odors of Sulphur Springs, so any increase in these odors associated with the drilling and testing at SL-2 should not be a major problem, provided that H_2S levels do not increase substantially or reach toxicity thresholds for humans. It is expected that complaints from Sulphur Springs residents will increase due to their concerns about safety, potential contamination of water supplies and fear of damage to their crops. This is based on their experience with earlier geothermal exploration at the same site.

2. Recommendations and Follow-Up

ARD still recommends that GOSL and Aquater representatives conduct a series of public meetings to inform local communities about the intent and process of the geothermal project. Officials could answer the numerous questions local residents may have, dispelling fears with a better understanding of the project, while also explaining the risks involved and presenting a plan for emergency contingencies (see Section IV.K).

J. Well Testing and Waste Disposal/Management

1. Potential Impacts

As stated in ARD's first report, waste disposal is the primary environmental concern associated with geothermal development in St. Lucia. Improper waste disposal/management can

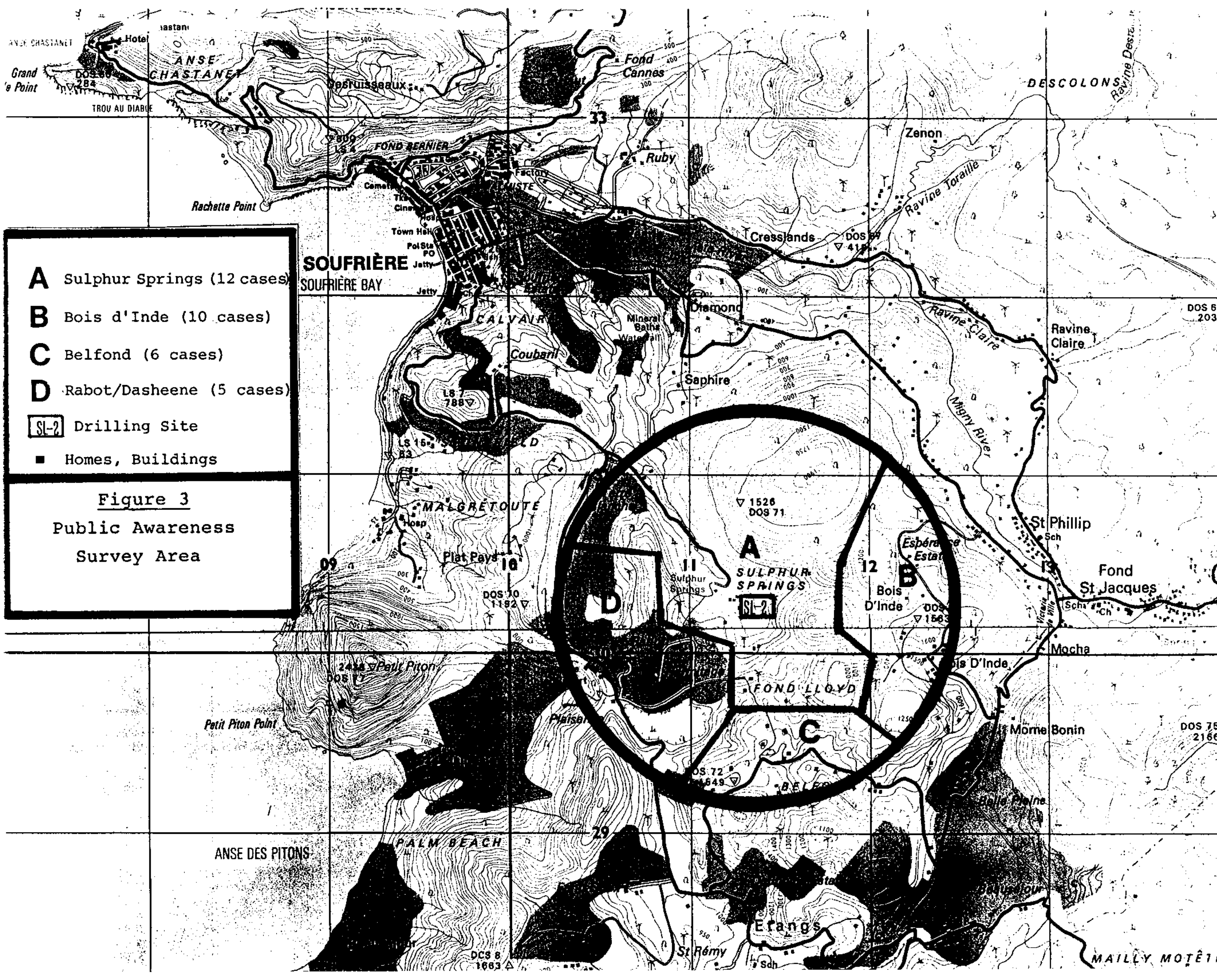


Figure 3
Public Awareness
Survey Area

Table 7. Results of House-to-House Survey on Public Awareness of St. Lucia Geothermal Project

Question	Response by Area*: Sulphur Springs/Fond Lloyd (12 cases)	Bois d'Inde (10 cases)	Belfond (6 cases)	Rabot/Dasheene (5 cases)
1. Do you know of the drilling program?	yes (10) no (2)	yes (10)	yes (6)	yes (5)
2. Do you know what it is for?	yes (7) no (5)	yes (7) no (3)	yes (6)	yes (4) no (1)
3. How or when did you find out about it?	site development (4) neighbors/friends (3) radio/newspaper (3) not applicable (2)	site development (5) neighbors/friends (3) don't know (2)	site development (3) two meeting (2) neighbors/friends (1)	neighbors/friends (3) radio/newspaper (2)
4. Do you hear noise from the Belfond drill site or water pumps at Etangs and Belfond?	yes (9) no (3)	yes (8) no (2)	yes (6)	yes (4) no (1)
5. What do you think about this project? (negative or positive)	positive (6) no opinion/don't know(6)	positive (7) no opinion/don't know(3)	positive (2) no opinion (2) negative (2)	positive (4) no opinion/don't know(1)
6. Does anything bother you about the project? What?	no (10) worried (2)	no (9)	no (2) noise (2) house shakes (1) harm to humans (1)	no (2) air pollution (1) explosion (1) noise (1)
7. Do you ever smell odors from Sulphur Springs? How often? How strong?	every day(7) strong(10) frequent (3) faint (2) infreqnt.(2)	frequent(10) strong(6) faint (4)	frequent (4) strong(4) infreqnt.(2) faint (2)	almost every day(3) strong(2) infreqnt.(2) faint (3)
8. Do you remember or know anything about geothermal wells drilled at Sulphur Springs in 1975/75? What?	damaged crops (9) noisy (8) roof damage (2) ruined spring (1)	yes (6) no (4) it blew up (4)	no (2) explosion (2) noise (2) damaged crops (1) damaged water qual. (1)	unsuccessful (3) no (2) very loud (1)
9. Where do you obtain your potable water?	roof catchment (9) local spring (4) tap or Soufriere (2)	public tap/ roof catchment (10)	roof catchment (5) public tap (4) spring (1)	Weber Spring (4) roof catchment (1)
10. Do you have any questions you want answered or comments about the geothermal project?	Affect Sulphur Springs?(1) Cause eruption? (1) Drilling at Sulphur Springs? (1)	Produce electricity? (3) Blow up? (2) Contaminate water? (1) Damage roof? (1) Kill crayfish in Soufriere River? (1)	Affect quality of rainwater? (3) Explode? (3) Harm crops? (3) Evacuation plan? (1) Harm roof? (1)	Effects on water/air? (3) Affect Sulphur Springs?(1) Volcanic eruption? (1) Where will waste be dumped? (1)

*Correspond to geographical areas shown in Figure 3. Numbers in parentheses indicate total number of responses; in some cases, multiple responses given.

potential impacts and permit a final decision on the viability of waste disposal in Sulphur Springs Creek.

ARD's findings for SL-2 are the same as for SL-1--reinjection of waste fluids is the best of all the options and ultimately recommended for the disposal of waste from long-term testing. Effluent would be injected at a sufficient depth, below which contamination of existing freshwater aquifers would be avoided. If injected into the producing reservoir at an adequate distance from the producing wells, it could also increase reservoir longevity.

GOSL's Cornelius Fevrier, CEHI's Francis Isidore and ARD's Lee Hannah investigating locations for water quality sampling stations near the confluence of Diamond Springs Creek and Soufriere River.

be developed. Because high levels of heavy metals would require special disposal plans and represent an imminent health hazard until they are disposed of, testing must not proceed before a waste-disposal plan has been finalized, even if the liquid waste will be fully contained at the site. Gas-discharge recommendations also await the fluid composition analysis, since concentrations of certain elements (notably boron) will determine the optimal disposal techniques.

For gaseous emissions, SL-2 is particularly problematic. The topographic bowl where the site is located will tend to collect such emissions. It also greatly complicates wind patterns and predictability, making the prediction of emission dispersal difficult. The coordination of testing with optimal weather conditions for emission dispersion will be especially critical at this site.

Well reinjection is the suggested and preferred disposal option for liquid waste from a production test. Aquater's project manager has informed ARD that there is currently no budget for the design of reinjection wells, drilling of those wells or the production test. It is imperative that these issues be addressed as rapidly as possible so that production testing, if warranted, may proceed in a timely and environmentally sound manner.

Through its water-quality monitoring program, EMP can assess the potential impacts of waste disposal into Sulphur Springs Creek. Disposal in the creek could be acceptable for the short-term testing, strongly contingent on analysis of the waste's composition, but the disposal of production test effluent in the creek is most likely **unacceptable** because of the potential impacts on downstream and marine/near-shore environments that are important to fisheries and tourism. **For this reason, planning for the timely development of reinjection options should proceed immediately. A comprehensive plan and budget for production testing should be developed immediately and circulated for comment.** If possible, preliminary engineering studies of reinjection options should also be funded.

It is also likely that scrubbing for H_2S will be necessary during any production testing at SL-2. The configuration of the drilling site lends itself to the accumulation of gases, and even under dispersal conditions, overpowering concentrations of H_2S could jeopardize the tourism value of Sulphur Springs. Procurement planning for H_2S-scrubbing systems should be initiated. Prospective suppliers should be identified and polled on delivery time, as ARD has identified one supplier that has a waiting time of eight weeks.

These individuals will act as liaisons between GOSL/ project management and local residents. These liaisons will be further oriented regarding safety and contingency planning in case of an emergency.

Third, ARD suggests two "alert stages" in the community contingency plan that roughly approximate those in the well-site plan. Stage A would occur when an alert for 20 ppm of H_2S or dangerous levels of CO_2 or another potential intoxicant requires that work at the site be temporarily interrupted and a siren sounds. The closest residents should hear the siren (especially those directly downwind), indicating they should remain indoors and not venture to the well site. Residents should also be aware that this is not necessarily a life-or-death situation, but is a precautionary alert. An all-clear signal at the well site (the sirens stop sounding) would indicate that the situation was temporary or a test, and conditions are now back to normal.

A Stage B alert occurs when a problem arises at the site that becomes increasingly serious--such as an uncontrolled blowout, high-level continuous release of gases, toxic waste spill or H_2S level that is greater than 20 ppm and does not stabilize--and drilling workers are evacuated from the site. The next step would be that the appointed safety officer at the site advises the liaisons in the communities where there may be the most immediate impact (i.e., those downwind). If air quality is the concern, the safety officer at the drilling site would check the wind indicator and refer to the area map to determine which communities may be potentially affected.

The safety officer would then send a representative to advise the liaisons only if evacuation procedures are warranted. In the case of a waste spill or spewing of contaminating brine during testing, liaisons should be informed so they can advise people in their communities against using certain water sources and ingesting crops that may have been contaminated. The "all-clear" signal for this type of alert is not as straightforward. Presumably, the GOSL/project management would have mobilized resources to deal with the emergency. The all-clear signal would entail a similar admonishment to community liaisons that the situation is back to normal and any intoxicants or other negative effects had been ameliorated unless indicated to the

V. TRAINING

ARD's initial reconnaissance visit was used to lay the groundwork for a continuous program of environmental monitoring in St. Lucia. The GOSL's environmental program coordinator, Mr. Fevrier, and CEHI's principal laboratory technician, Mr. David Shim, were trained in the use and calibration of air- and water-quality and noise monitoring equipment purchased by ARD with EMP funds. Since May 1987, these two individuals have collected all the data, portions of which are presented in this report. They have gained a demonstrated capability to gather data and maintain the monitoring program without further supervision--one of EMP's original goals.

AID was asked to provide funds to hire an additional full-time technician to be assigned to CEHI with responsibility for EMP activities. Mr. Isidore was hired and trained during ARD's second visit in September 1987. He was also trained by CEHI staff to operate monitoring equipment and perform selected spectrophotometer and wet-chemistry analyses as part of his responsibilities. With the addition of sensitive monitoring equipment and training in its use, St. Lucian staff members at the CEHI laboratory and Ministry of Planning, Personnel, Establishment and Training now have the capability to carry out monitoring as a continuous program during the production test phase and ensuing production, if the well at SL-2 is successful.

VI. LABORATORY ANALYSIS OF WATER, SOIL AND CONDENSATE

Thus far, there has been no need to test samples of water and soil beyond establishing existing background levels of various elements to provide a baseline for future comparisons with samples affected by geothermal development. Water quality has been sampled in the field and laboratory with equipment and reagents supply by ARD through EMP. The results of this sampling program were discussed in Section IV.B. Samples have also been sent to a U.S. laboratory for extensive analysis, and the results compared favorably with samples analyzed in St. Lucia by CEHI.

Soil samples have been taken from the SL-2 site at Sulphur Springs and banks of the Soufriere River and are stored at the CEHI laboratory. Parallel water samples are also being taken and stored at CEHI. A U.S. laboratory still holds background soil samples for SL-1 that were to be used for comparison with samples after well testing there was completed.

With ARD's facilitation, the CEHI laboratory has purchased and installed an AA spectrophotometer. Several element lamps relevant to geochemistry are in stock or on order. The presence of this equipment in St. Lucia will permit highly accurate and rapid sample analysis. At the time of ARD's second visit to St. Lucia, CEHI had still not received all the lamps necessary to perform all of the analyses. For this reason, ARD will assist with the transfer and analysis of samples of geothermal brines (liquid discharges) to the United States to determine their exact chemical composition and the concentrations of potential pollutants. These results can be compared to parallel samples collected by CEHI that are analyzed for selected parameters in their laboratory at Castries.

With the provision of equipment, reagents, other supplies and training, the CEHI laboratory is now much better able to provide analytical services to the GOSL, Aquater, AID or any other organization. While certain delays in the arrival of CEHI's equipment (e.g., spectrophotometer lamps) have forestalled the laboratory's complete readiness, it already has the installed capability to do a broad range of analyses necessary for environmental monitoring of the geothermal drilling project. This will also be very useful in the future for St. Lucia, especially if SL-2 turns out to be a productive well.

The GOSL and Aquater should assist CEHI in financing at least part of the cost of spectrophotometer lamps by contracting for future services with the laboratory. In this way, funds can be made available immediately for the purchase of any remaining equipment (e.g., arsenic lamp and generator) needed to analyze other parameters associated with geothermal development.

VII. PROCUREMENT OF MONITORING AND LABORATORY EQUIPMENT

Since April 1987, ARD has continually been purchasing scientific and laboratory equipment for the St. Lucia environmental monitoring effort. The bulk of air- and water-quality monitoring instruments was delivered within 24 days of award of the contract.

Chemicals and reagents needed to outfit the CEHI laboratory in Castries were procured with much difficulty due to the loss of one shipment by a freight forwarder. Other problems were encountered in that various pieces of equipment and supplies, beyond ARD's originally proposed procurement list, were purchased and delivered due to obvious oversights on the part of drilling project planners (e.g., safety equipment) or because an urgent need was indicated by project personnel (e.g., fluorescein for a hydro-geological tracer study). Customs clearances in St. Lucia also delayed the delivery of certain supplies.

As of January 1988, the following equipment had been purchased, packaged, shipped and delivered to St. Lucia as part of ARD's technical assistance contract:

Water-Quality Monitoring

- 1 conductivity meter
- 1 pH meter
- 1 rain gauge
- 7 fluorescein (pounds)*
- 2.5 activated charcoal (kg)*
- 1 nylon mesh (roll)*
- 1 Hach DREL-5 kit
- 1 10-ml graduated cylinder
- 1 50-ml graduated cylinder
- Saran filter cloth

Air-Quality Monitoring

- 6 Model BD air-sampling pumps
- 300 dosimeter tubes (H_2S)
- 30 mercury impinger tubes
- 1 mini H_2S indicator/reader*
- 1 recording anemometer*
- 12 air bags
- 1 barometer*
- 1 wet/dry bulb thermometer
- 3 calibration gas canisters
- 1 calibration gas regulator
- 1 high/low thermometer

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*Equipment that ARD did not originally intend to purchase, but did so because of safety needs or the GOSL or Aquater requested it.

nitraver
nitraver 5 powder pillows
nitrogen
nutrient BFR solution
periodate oxidation method (100 tests)
phosver 3 powder pillows
potassium (1, 2, 3)
potassium acid phthalate
potassium chromate
potassium cyanide
potassium hydroxide
Rochelle Salt-PVA
silica 1
silver nitrate
silver (1,2) powder pillows
silver sulfate
sodium periodate
sodium thiosulphate
sulfamic acid
sulfaver 4
sulfide (1, 2, 3, 4, 5)
sulfosalicylic acid
sulfuric acid
titraver 0.0716m
titraver hardness
titraver titrant
toluene ACS
triton X-100
univer 12 hardness

VIII. RECOMMENDATIONS AND FOLLOW-UP FOR PRODUCTION PHASE

If the geothermal resource at SL-2 is proven and mobilization begins for the production phase, EMP should be included as an integral part of this development. The production phase will entail a much broader set of environmental and socioeconomic concerns than were treated during the exploratory and testing phases. For this reason, **ARD recommends that project planners consider environmental monitoring and assessment as an essential part of geothermal energy development.** The following recommendations should be considered if SL-2 proves to be productive.

First, **a separate environmental impact assessment should be carried out as an integral part of the planning and design for the production phase.** Such an assessment should build on the work already begun by ARD during the exploratory/test phase and reconsider each specific impact area covered in ARD's first and second reports with reference to design alternatives for the production phase. This assessment should consider the following:

- power-plant siting,
- power-line corridors and rights-of-way,
- access roads and rights-of-way,
- watershed protection and management and land use,
- impacts of prolonged noise,
- greater potential for effects on air and water resources,
- effects on wildlife,
- marine and near-shore environments and fisheries,
- detraction and/or enhancement of the quality of tourism and recreational resources,
- existence of and effects on significant cultural and archeological resources,
- public health and physiology,
- public awareness and concerns,
- waste disposal and management, and
- safety and contingency planning.

APPENDICES

APPENDIX A

SL-1 Water-Quality Monitoring Data

Table A. Station W1, Upper Sulphur Springs

Date 1987	Temp °C	pH	Conductivity mmhos/cm	Turbidity NTU	Phosphate mg/l	Nitrates mg/l	Nitrites mg/l
5/22	26	6.1	250	--			
6/23	27	--	240	--			
6/30	27	7.7	220	12			
7/7	27	8.0	250	--			
7/17	27	7.1	250	3.8			
7/22	27	7.2	260	0.6			
7/29	28	7.2	270	0.6	0.48	1.02	0.01
8/5	29	7.1	180	25.5	2.5	0.75	0.0085
8/11	29	7.2	260	1.5	0.45	1.5	0.01
8/18	29	7.2	200	17.0	1.2	0.3	0.005
8/26	29.5	7.4	260	2.4	1.8	0.09	0.003

Table B. Station W_2, Lower Sulphur Springs (under Bridge)

Date 1987	Temp °C	pH	Conductivity mmhos/cm	Turbidity NTU	Phosphate mg/l	Nitrates mg/l	Nitrites mg/l
5/22	35	2.6	>2000	--			
6/23	39.8	--	>2000	--			
6/30	42.5	6.6	1270	68			
7/7	43	6.9	1210	--			
7/17	39	6.3	1350	46.5			
7/22	42.2	7.2	1150	62			
7/29	42	7.1	1070	59.9	0.21	0.01	0.025
8/5	41	5.0	1320	21	0.88	0.0	0.031
8/11	40	7.1	1020	63	0.25	0.1	0.005
8/18	41	6.9	1040	70	0.42	0.0	0.02
8/26	41	7.4	1110	61	--	0.0	0.051

Table E. Station W_5, Upper Rabot Lake

Date 1987	Temp °C	pH	Conductivity mmhos/cm	Turbidity NTU	Phosphate mg/l	Nitrates mg/l	Nitrites mg/l
5/22	26.2	--	102	--			
6/23	30.5	--	100	--			
6/30	32.8	7.2	97	27			
7/7	30	7.4	102	--			
7/17	32	6.6	97	11			
7/22	30	7.1	92	19			
7/29	33.6	7.5	93	12.5	0.2	0.5	0.011
8/5	31	7.0	100	56	0.3	0.2	0.011
8/11	35	7.4	100	42.5	2.65	0.5	0.75
8/18	32	7.2	100	46.5	0.2	0.0	0.005
8/26	36	7.2	90	34.5	0.0	0.0	0.0

Table F. Station W_6, Little Ivrogne at Ford (Victoria)

Date 1987	Temp °C	pH	Conductivity mmhos/cm	Turbidity NTU	Phosphate mg/l	Nitrates mg/l	Nitrites mg/l
5/22	25	7.1	260	--			
6/23	26.9	--	250	--			
6/30	27	8.2	198	21			
7/7	28	8.3	230	--			
7/17	28	7.3	210	10			
7/22	29	8.3	270	2.9			
7/29	29	8.0	260	5.1	0.46	1.0	0.011
8/5	27	7.9	180	26.5	2.5	2.2	0.004
8/11	28	8.0	240	7.4	1.6	1.4	0.050
8/18	28.5	7.9	180	22	>2	0.4	0.004
8/26	28	7.8	220	10	>2	0.05	0.002

Table I. Station W_9, Lower Union Vale

Date 1987	Temp °C	pH	Conductivity mmhos/cm	Turbidity NTU	Phosphate mg/l	Nitrates mg/l	Nitrites mg/l
5/22	25.8	8.0	290	--			
6/23	29	--	290	--			
6/30	28.4	8.4	260	23.5			
7/7	29	8.75	290	9			
7/17	29.5	7.5	290	17.5			
7/22	29	8.3	300	9.3			
7/29	30.2	8.2	300	10	2.5	0.75	0.001
8/5*	28	8.1	250	20.5			
8/11	29	8.2	300	5.8	0.94	0.8	0.002
8/18	29	8.1	250	39.5	2.6	0.0	0.004
8/26	29.5	8.0	290	9.2	1.6	0.2	0.023

*No electricity on that day.

Table J.

Geothermal Data -- Water Sampling up to August 1987

	Temp		pH		Conductivity		Turbidity		Nitrates		Nitrites		Phosphates	
	MN	SV	MN	SV	MN	SV	MN	SV	MN	SV	MN	SV	MN	SV
W1	27.8	1.6	7.2	0.5	240.0	29.0	7.9	9.2	0.7	0.6	0.01	0.003	1.3	0.9
W2	40.5	2.1	6.3	1.4	1321.8	352.7	56.4	15.9	0.02	0.04	0.03	0.02	0.4	0.3
W3	26.8	0.7	6.9	0.3	237.8	8.3	3.3	2.6	1.7	0.5	0.01	0.004	1.2	0.9
W4	30.8	2.6	6.7	0.3	101.2	7.6	16.9	11.6	0.05	0.09	0.003	0.004	0.6	0.5
W5	31.7	2.6	7.2	0.3	97.5	4.1	31.1	16.5	0.2	0.3	0.16	0.33	0.8	1.1
W6	27.7	1.1	7.9	0.4	227.0	32.1	12.1	8.2	1.0	0.8	0.02	0.02	1.7	0.8
W7	27.3	1.2	7.8	0.4	294.5	16.9	11.7	10.4	1.1	0.9	0.21	0.44	1.6	0.6
W8	28.2	1.3	8.0	0.4	282.7	18.5	16.1	11.7	0.5	0.7	0.004	0.001	2.2	0.3
W9	28.8	1.1	8.2	0.3	282.7	19.5	16.0	10.7	0.4	0.4	0.0003	0.001	1.9	0.8

APPENDIX B

Key Contacts

Secondo Balducci	geologist, Aquater
Al Barthelmy	project coordinator, Ministry of Planning, Personnel, Establishment and Training, Central Planning Unit, GOSL
Paul Beale	mud engineer, N.L. Baroid
Rudolf Blaha	manager, Dasheene Hotel
Silvano Brunetti	project supervisor, Aquater
Deborah Bushell	hydrologist, Agricultural Engineering Division, Ministry of Agriculture, Lands Fisheries, GOSL
Paul Butler	ecologist and forester, Forestry and Lands Department, Ministry of Agriculture, Lands and Fisheries, GOSL
Gabriel Charles	chief forest and lands officer, Forestry and Lands Department, Ministry of Agriculture, Lands and Fisheries, GOSL
Robert Devaux	director, St. Lucia National Trust; secretary, St. Lucia Archaeological and Historical Society
David Dunham	project manager, Big Chief Drilling
Andre Edward	laboratory technician, Caribbean Environmental Health Institute
Cornelius Fevrier	chemical engineering advisor, Ministry of Finance and Planning, GOSL
Daniele Giusti	chemist, Aquater
Hagen Hole	project coordinator, UNRFNRE
Francis Isidore	laboratory and monitoring technician, CEHI
Nigel Lawrence	acting director, Fisheries Management Division, Ministry of Agriculture, Lands and Fisheries, GOSL