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ENVIRONMENTAL ASPECTS OF THE BERLÍN GEOTHERMAL POWER STATION IN EL SALVADOR

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ABSTRACT

Environmental legislation throughout the world has been created to protect and conserve the environment and human health. Within the legislation is included an environmental impact assessment (EIA) as a tool to decide between the benefits of development and an unchanged environment. Before the advent of EIA, decision makers often looked only to the economic or engineering aspects in their planning process. Geothermal development is considered to be a benign resource but the technology and management of the resource cause possible negative impacts on the environment and sometimes severe impacts on communities. Environmental aspects of the Berlín geothermal power project in El Salvador are presented is this report and the different steps that are needed for project execution are shown. In the absence of the legal instrument for the EIA process in El Salvador, the project was initiated by the Inter-American Development Bank (IDB) as part of a funding approval. Complementary environmental studies were carried out to create an action plan for the construction and operating phases. Social, cultural and economic data from these studies will help to develop a social service programme for the communities.

1. INTRODUCTION

1.1 El Salvador overview

El Salvador is located on the southwest coast of the Central American isthmus on the Pacific Ocean. It is situated to the north of the equator within the torrid zone in the north meridian. It is bounded to the north and west by Honduras, to the west by Guatemala, to the south for 321 kilometres by the Pacific Ocean coastline, and to the southeast by the Gulf of Fonseca which separates El Salvador from Nicaragua, (see Figure 1).

There are two seasons and one transition period during the year: a dry season and a rainy season with an approximately 30 day transition in between. The maximum temperatures are between 30 and 34°C and the minimum temperatures between 16 and 19°C.

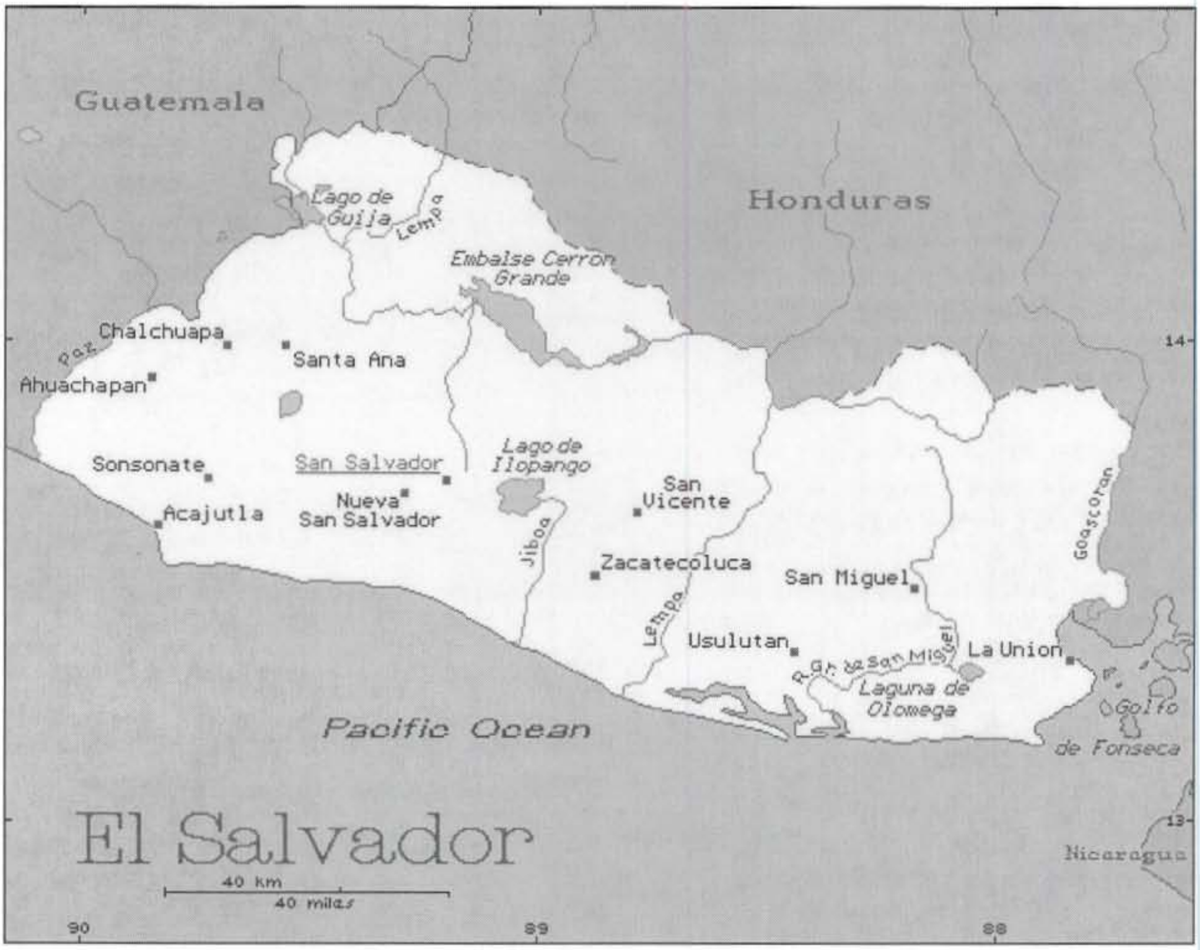

FIGURE 1: Location of El Salvador and the Lempa river basin

The country's river system is divided into ten different basins according to different geographical characteristics such as climate, geology and vegetation, and includes the following rivers: Lempa (extends over almost half the country and accounts for 68% of the hydraulic resources), Goascoran, Río Grande, Torola, Paz and Jiboa.

Most of the country´s topography is uneven due to volcanic and tectonic activity during the Tertiary era. The territory is divided into seven zones: Northern Boundaries, Northern Ranges, Central Ranges, Central Plateau, Central Plain, Costal Plain, Coastal Ranges and Valleys (El Salvador society, 1998). There are more than 25 extinct volcanoes in the territory with many small and large craters showing petrified lava flows. Among those, three are considered dormant since they show very little activity (scarce sulphur fumes).

1.2 General social, cultural and economic context

El Salvador´s official population in 1989 was 5.1 million, increasing at the rate of 2.1% per year with an average of 238 people per km^2. The people in El Salvador are 90% mestizo, a mixture of Spanish and Indian. About 5% are Indians, descendants of the Pipils and 5% are of European stock.

Most of the land is devoted to agriculture which accounts for about 25% of the GNP and 75% of exports, and employs about 40% of the labour force. The main crops are coffee, cotton, maize and sugar cane.

El Salvador experienced during the 1970's a period of unceasing unrest that culminated in a civil war in the 1980's. Finally in 1992, a peace agreement among the warring factions was reached. During the civil conflict period, important investments were not made in the energy sector and the electrical system suffered severe deterioration due to frequent sabotage (El Salvador society, 1998).

In 1994 loans totalling nearly USD 500 millions from the Inter-American Development Bank (IDB), which primarily provided funding of public sector entities for the design and execution of projects, were approved. These funds were dispersed and invested in roads, electricity generation, and public health projects such as rehabilitation and reconstruction measures following the conflict in the country.

The generation, transmission and energy conservation investments were priorities and a part of the Electrical II Program Development amounting to approximately USD 200 millions. The Berlín geothermal power project was considered a high investment priority (OLADE and IDB, 1994).

El Salvador continues its transition to a peacetime society after 12 years of civil conflict although general crime levels are high and safety is a concern. The area most affected by the war was the eastern part of El Salvador. The Berlín geothermal project is located in this zone of communities that were hardest hit in the conflict.

1.3 Potential environmental problems in El Salvador

The potential environmental problems are soil erosion, deforestation, damage by pesticides and water contamination. Soil erosion by water and deforestation affect the drainage basins of the entire country which carry tons of sediment during the rainy season. It is estimated that deforestation continues at an annual rate of 4,500 hectares, the largest part of which is due to the demand for fuelwood by the growing population. Around 45% of the energy used in El Salvador is provided by firewood, increasing to 92.4% in the rural areas. The serious problems on the slopes and along the shores have caused problems of sedimentation in the Lempa river. The use of pesticides and other agrochemicals is a particularly acute problem in the coastal plain. High levels have been found in cattle, and vegetable products, but the most severe impact has been on marine life. The water system (surface and underground) of El Salvador is very contaminated with raw sanitary waste, agricultural chemicals and industrial waste. (OLADE and IDB, 1994).

Before the Environmental Law was approved in March 1998, all project development in El Salvador was assessed using the outlines of bank policy and procedures regarding environmental assessment and related types of environmental analysis due to Bank investment and lending operations. (Economic/Commercial section: Environmental Law 1998).

1.4 Environmental regulations and environmental impact assessment in the world

Environmental legislation throughout the world, such as that of the European Economic Community (EEC), National Environmental Policy Act (NEPA) in the U.S.A, The Nordic Council, UN Economic and Social Commission for Asia and the Pacific (ESCAP) etc. has been created to protect and conserve the environment and human health. These environmental regulations include requirements for preparing an environmental analysis for a proposed project, as well as specific laws designed to protect air, water, land and the socio-cultural environment. There is significant variation in the numbers of agencies involved in the environmental review of a project, and the amount of time required for application to project approval. (Thors et al., 1998).

The most important aspect of environmental regulations is the requirement for an environmental analysis report, called Environmental Assessment (EA), Environmental Impact Assessment (EIA), Environmental Impact Statement (EIS), or Environmental Impact Report (EIR), which is applied to any development project. The environmental impact assessment as a tool to decide between the benefits of development and unchanged environment has become an integral part of the general planning process in the developing countries (Morris and Therivel, 1995).

Before the advent of environmental impact assessment, decision makers often looked only at the economic or engineering aspects for their decisions. Such decisions systematically and unintentionally left out most, if not all, of the natural environmental consequences of man´s actions (Roberts,1991).

To have a good knowledge of what an Environmental Impact Assessment is, the following definition shows the relationship between man´s actions and his environment: "*Environmental Impact Assessment is a systematic examination of the environmental consequences of projects, policies, plans and programmes. Its main aim is to provide decision-makers with an account of the implications of alternative courses of action before a decision is made.*" (Morris and Therivel,1995).

Social, cultural and economic impacts are an integral part of EIA but are sometimes poorly covered in EIA reports, being regarded as intangible and difficult to assess.

Public participation in project design and implementation and, in particular, in the preparation of EIAs is important in order to understand both the nature and extent of any social or environmental impact and the acceptability of the proposed mitigation measures. The end product of an EIA study is the publication of an environmental consent or permit. The permit is usually approved with respect to the technical and social acceptability of the project.

The integration of social concerns into the decision, planning, and management of any project is mandated by international agreements, protocols, individual state laws and by the policies of bilateral agencies and financing institutions. However, the most important factor outside any legal imposition has always been the conscience of the project developer (De Jesus, 1995).

According to Roberts (1991) there are four types of areas for which EIA is particularly well suited:

Sensitive areas: These sensitive areas can be considered from the viewpoint of nature, human history and culture, or from that of ethnic and intellectual heritage.

Agricultural lands: In many countries demand for housing causes an explosive spread of urban landscape into some of the most productive agricultural lands.

Crowded areas: Competition for space exists in virtually every country. Agriculture, industry and residential permits identifying and evaluating competitive uses for a given geographic area are issued.

Growth inducing projects: There are some projects that in themselves seem to have only a very site- specific impact: pipeline running from one city to another; an electric transmission line extending from a dam site to a town, etc.

Each of these examples has some potential impact which is specific to the areas affected. But each is also capable of creating changes because of the services or utilities it provides. These infrastructure projects are usually growth inducing, and even when they have only limited site-specific impacts they often create, cause, or encourage growth of other land uses which would not have been affected otherwise.

2. ENVIRONMENTAL IMPACT ASSESSMENT - IMPORTANCE IN GEOTHERMAL POWER GENERATION PROJECTS

2.1 Geothermal regulations

The environmental regulations of different countries as regards geothermal development can be considered similar. All have regulations that require an environmental analysis of a proposed geothermal project, as well as specific regulations that define the quantities of pollutants that may be emitted to the atmosphere or discharged to land or water. For example, the European Economic Community (EEC) Directive in Italy, National Environmental Policy Act (NEPA) in the U.S, Presidential Decree (PD) in the Philippines, Resources Management (RM) Act in New Zealand, etc, are the legal bases for geothermal projects and include the EIA process.

Many developing countries with geothermal development do not have a formal system for environmental impact assessment, but have followed the U.S lead from the outset or adopted a recommendation on EIA from development and funding agencies that have set up EIA guidelines, e.g., the World Bank, the United States Agency for International Development, the European Bank for Reconstruction and Development, etc.

Most countries have developed or adopted criteria and guidelines to protect their own environment. In some cases measures have been taken to protect native species or ecosystems. Guidelines available throughout the world include: The US Environmental Protection Agency´s "Quality Criteria for Water" and related publications (USEPA), The World Health Organization´s "Guidelines for the European Region (WHO), The Canadian Council of Resource and Environment Ministers "Water Quality Guidelines" (CCREM), The Water Research Council´s "United Kingdom Water Quality Standard Arising from European Community Directives" (WRC).

Geothermal development is considered growth inducing and is, therefore, subject to the EIA process. For example, in Iceland all geothermal power stations of 25 MW raw energy or 10 MW installed power are subjected to EIA (Thors et al., 1998).

2.2 Geothermal environmental inspection summary

It is not the purpose of this section to list the potential hazards of geothermal development but rather to show that the resource itself does not create impacts, but the technologies development and the management of the resource can cause irreversible impact on the environment and the human communities. If a geothermal project is not subjected to the EIA process and a monitoring program, the consequences could be negative for the developer.

The geothermal fields of the world all contain heated fluids trapped beneath the earth, but the temperature and chemical characteristics of the resources can vary significantly. When these resources are exploited with the purpose of generating energy, surface management can cause an impact on the physical environment.

To understand the extent and nature of environmental impacts of geothermal development, Hietter (1995) considers the classification and characteristics of geothermal resources as important elements in identifying the effects. Her classification of geothermal resource characteristics and effects are shown in Table 1.

Temperature classification is most often used because temperature determines the type of geothermal development that can be effected, i.e. direct uses or electrical power generation. Both direct uses and electric power generation are associated with resource characteristics and their effects on the environment.

Hietter (1995) considers that environmental impacts from geothermal development will also vary between the various phases of the development. Preliminary exploration, deep exploration drilling and production and utilization phases are considered in geothermal energy projects.

Preliminary exploration: Environmental effects are usually small because only geological mapping, sampling and small areas for a drill rig are involved.

TABLE 1: Geothermal resource classification, characteristics and effects of the development on the environment (Hietter, 1995)

Types of classification	Resource characteristics	Effects
Temperature High temperature: Over 150°C Moderate temperature: 90-150°C Low temperature: Below 90°C	Temperature	Determines type of technology used (direct use, flash or binary power plant); determines whether there are emissions to the atmosphere.
Fluid-phase Vapour-dominated Liquid-dominated Dry rock	Chemical composition	Determines nature of air emissions and the nature of the fluids that may be discharged.
Heat-source Deep circulation of groundwater, Volcanic heat	Depth and rock formation	Depth to reservoir determines the size of drill rigs required to extract from the resource. Type of rocks encountered determines drilling duration.
Resource-application Electric-power generation, Direct use	Areal extent	Size of the reservoir determines how many power plants may be developed, with accompanying impacts and surface disturbances.

Deep exploration: The environmental issues related to deep exploration of a geothermal resource include: effects of surface disturbances from well pads and roads, emissions to the air, discharge of drilling muds, cuttings, and geothermal fluids, noise from construction work all during drilling and testing, loss of habitat and potential disturbance of vegetation and wildlife, potential health effects for project workers from exposure to geothermal fluids and possible H_2S emissions and potential effects on nearby residences, recreation areas, etc.

Production and utilization phase: Probably this has the greatest impact on the environment. According to Ármannsson and Kristmannsdóttir (1992), the main impacts on the environment are the following:

Surface disturbances: Boreholes and pipelines are probably the most specific signs of geothermal energy production. A drillsite is usually between 200-2500 m^2 in area. In some cases of space heating and industrial use, exploitation sites require long pipelines. Drill rigs and ponds may be prominent features during drilling. The danger of landslides may place constraints on the placement of wells and other constructions. Untidiness in the vicinity of boreholes and other constructions can cause unacceptable eyesores. The scenery needs attention, since due to their very nature geothermal manifestations are frequently situated in areas of outstanding natural beauty, may be of historical interest and are tourist attractions.

Physical changes due to fluid withdrawal: Fluid withdrawal may cause subsidence and lowering of the groundwater table, and there are reports that this or the complementary process of re-injection may induce seismicity. Subsidence takes place as the fluid mass withdrawn exceeds the natural inflow. Then loose formations on top of the withdrawal site, especially clays and sediments, become compacted. These effects are local, but care has to be taken with constructions such as pipelines, and also the possible formation of ponds or even cracks in the ground. The lowering of the groundwater table may cause the mixing of fluids between the aquifers, and cause difficulties such as the deterioration of piped water.

Noise: Specific to geothermal development are drilling noises which rarely exceeds 90 dB and the noise from the discharge of boreholes which may exceed 120 dB. Boreholes discharging dry steam tend to be more difficult to silence. Workers are advised to use ear protectors both during drilling and discharge tests.

Heat: In general the heat efficiency of geothermal utilization is poor, especially in power production. A considerable part of the waste heat can be saved by re-injection of the spent fluids. The evaporation of water is the most economic means of dissipating the spent heat to the environment. If excess heat enters the environment via geothermal steam, it may affect cloud formation and even cause changes in local weather. Where waste water is piped into a stream, a river, a lake or even local groundwater, it may seriously affect the biology of the local environment and eventually the whole ecological system.

Chemical Discharge: Chemicals are discharged to the atmosphere via steam and into the groundwater system via the liquid portion. H_2S is the major gas that causes the greatest concern due to its unpleasant smell and toxicity at moderate concentrations. CO_2, which is usually the major constituent of geothermal gas, and CH_4 have been causing concern because of their role as greenhouse gases. Geothermal gas is a negligible source of methane emissions. Minor gases that cause concern, Hg, Rn, NH_3, and B have not been found in dangerous concentrations in geothermal gas, but need to be watched. The potential pollutants in the liquid effluent are: H_2S, As, B, Hg and other trace metals. The direct disposal of such water may be hazardous and has been known to cause damage. Furthermore, substances such As and Hg may accumulate in sediments and organisms.

Social and economic effects: Due to its nature, geothermal energy is frequently exploited in remote, sometimes relatively undisturbed places. A temporary increase in employment and the import of an outside workforce calling for various services, may put a strain on traditional way of life and leave a scar when the construction work is finished. The building of roads will open up the area and most probably make it attractive to tourists, thus, creating a new industry.

2.3 Geothermal power generation

After the exploration phase when the type of resource has been identified and it has been determinated which type of power plant is warranted by the resource, the development has to be subjected to the EIA process and an EIA report should be incorporated in the feasibility document requiring agency approval.

Geothermal power generation requires the construction and operation of a power plant, steam gathering and a special infrastructure for waste management, access roads, transmission lines, and even additional production or injection wells that may need to be drilled, causing surface disturbances. When construction is complete, the environmental impacts may constitute air emission, noise from power plant operation, and visual intrusion on the landscape (Hietter, 1995).
The potential environmental effects of geothermal plants depend on the characteristics of the geothermal fluids (see above) and the technology used. A comparison between different types of power plant and environmental remarks are presented in Table 2.

TABLE 2: Comparison of geothermal power plant generation technologies (Hietter, 1995)

Type of power plant	Size (MW)	Optimum temperature range (°C)	Environmental remarks
Dry steam	25 or more	215	Surface disturbances from wells, pipelines, power plants, and transmission lines. H_2S is an air emission of concern (worker safety, public nuisance odour). Most discharge is returned to the reservoir. Emission of CO_2, NO_x, and SO_x is negligible. Minor effects on community from plant construction work force.
Single / Double flash	30 / 25 or more	175	Single and double flash emit dry steam. Well pads larger than for dry steam plants due to containment of drilling and production geothermal fluids. H_2S the air emission of concern (primarily as a public nuisance). Worker protection may be required for Hg and As exposure. Effects on community from plant construction work force possible. Water is disposed of by injection into the reservoir.
Binary	1-30	105-175	No geothermal fluids are discharged to surface environment, a closed system. Water is disposed of by injection into the reservoir. This type of plant requires only a small land use footprint. There are some hydrocarbon emissions from working fluid. Minor effects on the community from plant construction work force.

3. ENVIRONMENTAL PROGRAMME FOR THE BERLIN GEOTHERMAL PROJECT

3.1 Environmental regulations and environmental impact assessment in El Salvador

El Salvador, as a developing country, has up to now lacked an environmental law. There are, however, sections within the Political Constitution, the master existing legislation, that relate to the protection of the environment, but their application is not effective. These sections are concerned with the management and conservation of natural resources. At the beginning of this year and after four years of consultation with the public, the environmental law was approved by parliament and a government Environmental Ministry was created. The minister in charge will oversee the fulfilment and application of the law to protect the environment and human health. (Economic/Commercial section: Environmental Law, 1998).

Therefore, the environmental impact assessment as a regulating process is in its early stages yet, and the absence of a legal instrument to facilitate the implementation of the policy means that the environmental impact assessment process cannot be carried out effectively. In addition, the El Salvador law requires each general plan to include an accompanying EIR to cover all the major governmental and private projects.

Environmental control of geothermal development within El Salvador is therefore subject to the requirements of both specific legislative instruments that relate to different aspects of the environment, and the environmental law.

3.1.1 Environmental impact assessment for the Berlín condensing power plant

The Berlín condensing power station environmental impact assessment was prepared in an ad hoc manner by the Inter- American Development Bank (IDB) as part of a funding approval process, because at the time, El Salvador had no legal instrument for this type of process.

The guide prepared by OLADE and IDB (1994) presents a fairly comprehensive discussion on the environmental impacts associated with geothermal development projects and proposed mitigation measures. The criteria and guidelines to protect the environment were based on World Bank guidelines.

The Berlín condensing power station EIA report was prepared by an Italian private consultant in 1994 and the report was incorporated into the feasibility document for the Bank´s approval. The proposed geothermal project was classified by the Bank as Category III, because the project could have diverse and significant environmental impacts according to the Environment Committee assessment of the Bank.

3.1.2 The Inter-American Development Bank environmental requirements

The environmental work of the IDB on the Berlín field started with a field visit of an expert from the National Laboratory, Los Alamos USA, under the auspices of the Bank. She recommended a series of environmental measures before the start of project work, the most important of which are the following:

i) Geotechnical survey of the condensing power plant site, because one of the most important characteristics of the Berlín geothermal field is the steep topography and the presence of landslides, scarps and deposits.
ii) Environmental monitoring programme design and implementation, during project execution and power plant operation, because this condition was not defined clearly in the EIA report.

It is important to know that in El Salvador, the Comisión Ejecutiva Hidroeléctrica del Río Lempa (CEL) was the executor of the Berlín Condensing power plant project through the Geothermal Generation Division (GGD) with the purpose of complying with the Bank´s measures. At the end 1995, the environmental unit within the GGD staff was created.

3.2 Berlín condensing geothermal power project description

This section summarises the well and steam-water gathering system, the power generation system, and other facilities such as household (including recreational area) and roads.

Sixteen wells of approximately 2300 m depth were drilled: ten production wells and six for re-injection purposes. Due to the uneven topography the drilling was directional and there are 3 or 4 wells in each pad. Steam and water are separated at the wellhead through cyclone separators situated in each pad. Steam is collected from the wells and piped under gravity through pipes on the surface to the power plant and waste water will flow to ponds through the channels to the cold re-injection wells. The geogas is released to the atmosphere through the cooling towers. All the waste water from the power plant process is piped under gravity to a re-injection well.

The power generation system includes the building housing the modular turbines of 2×30 MWe capacity, pumps, condensers, ejector system and the two banks of the two cooling towers. A transmission line of 115 kV, 5.5 km in length, will be connected to the national distribution system.

To guarantee power plant operation, 24 householders, 6 apartments and one guest house were built for the engineering and technical staff. Approximately 24 km of roads have been paved and repaired to facilitate the movement of vehicles and equipment.

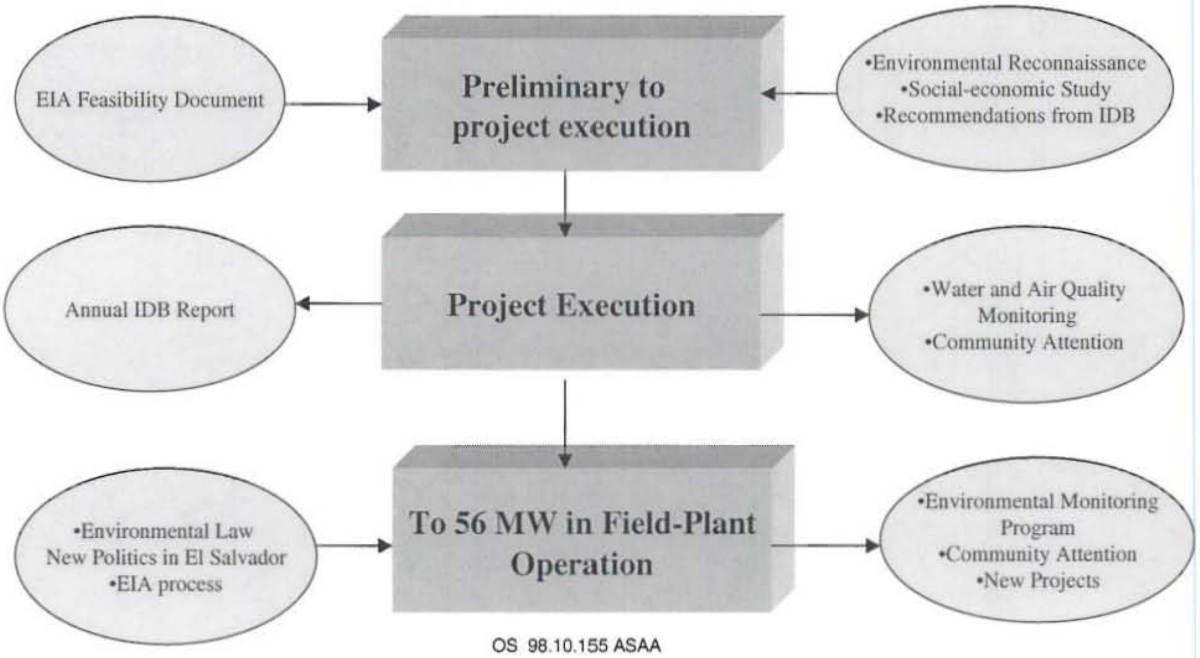

FIGURE 2: Environmental programme structure of the Berlín geothermal power station project

3.3 Berlín geothermal project environmental programme structure

An overview of the Berlín geothermal project structure is presented in Figure 2. This shows the environmental activity relationship at each stage of the Berlín geothermal project.

The environmental activities correlated at each stage are described briefly in Subsections 3.3.1, 3.3.2 and 3.3.3. The second and third stages are discussed in more detail because in the next chapter they will be the basis for the introduction of the social, cultural and economic aspects of concern.

3.3.1 Activity prior to project execution

When IDB approved the Berlín geothermal project execution including the environmental recommendations of the expert from Los Alamos, the GGD environmental unit considered it necessary to immediately set up two important studies with focus on possible impacts of the project with a view to preventing any damage to people´s health and to provide safety measures. The main reasons why the staff carried out these studies, were the following:

- The EIA project was based only on a general and conceptual evaluation, due to the short time that the consultant had to do it in and only at a preliminary engineering design stage of the project. So, there was a general lack of real data, and almost all the impact assumptions were based on calculations.
- The baselines especially for the population, economics, infrastructure, flora, fauna, etc., in all the project areas were not updated. Reliable statistical data after the last census in 1989 and the collection of other relevant data are limited.
- The EIA was not submitted to public consultation according to a proper EIA process, and no national public agency decided whether the project could have a significant effect on the environment; it was only reviewed by the IDB agency in El Salvador.

EIA report in feasibility document

The main role of the environmental unit staff at this stage was to act as a link between the project management and the consultant to provide support for the data base used for preparing the environmental assessment for the project. Environmental Impact Assessment Guidelines for Geothermal Exploitations were used as guide for the consultant. The main environmental mitigation measures suggested in the EIA report were:

- Specifically, all residual fluid wastes from the gathering condensing power plant need to be reinjected into the reservoir accompanied by a good microseismic monitoring program.
- It is essential to make all ponds created by drilling and well testing waterproof with a 0.50 cm thick layer of compacted clay to avoid contamination of shallow aquifers.
- If total loss occurs during drilling, fresh water must be used to avoid contamination of the shallow aquifers.
- Non condensate gas emissions will be dispersed through cooling towers to remain below the concentration maximum of 1,778 $\mu g/m^3$ H_2S at floor level to safeguard workers' health.
- Employment of a local work force during the main civil works at each project construction stage. The total construction period could be 2.2 years.
- Development of a good monitoring programme for springs and rivers in the geothermal field valley and air quality measurements during the construction and operating phases could be required.

Environmental inventory results

The environmental inventory was carried out with the aim of characterizing current environmental factors with an emphasis on areas where the project might have a severe impact on local communities. In addition, the resources were quantified considering a detailed project design. Three months' field work and the interpretation of data collected was the methodology used for this purpose. Two community leaders were voluntarily incorporated into the environmental work team constituting an important source of information that was used for predicting impacts upon the community. The main environmental resources characterized were cover vegetation, hot and cold springs, domestic wells, natural drainage, existing peripheral conduits, land and landowners. A chemical data base for surface water bodies and H_2S and noise level measurements were carried out in each project area. Tables 3 and 4 show the data bases obtained from the inventory (López,1996).

TABLE 3: Vegetation cover and land characteristics quantified in the Berlín geothermal project areas

Work	Vegetation cover (units)*	Construction area (m^2)	Number of landowners
Power plant station site	337	32,930	7
Production well sites, new and old platforms	14,793	33,285	Company
Re-injection well sites, new and old platforms	50	15,600	2
Extending and constructing roads	6,270	13,500	Company
Transmission lines 115 kV (5.5 km length)	50	225	15
Household and recreational area	130	8,800	2 + company
Pipeline routes (16 km length)	1,500	45,240	30

* Including old trees and coffee plants; there is one (unit) coffee plant per m^2

TABLE 4: Surface water characteristics of the Berlín geothermal field and its surroundings

Water body	Temperature range (°C)	Selected chemicals (ppm)	Microbiological conditions	Uses
Hot springs	40-60	B: 1-6 As: 0.01-0.3	Faecal positive	Local
Cold springs	25-32	B: ≤ 1 As: ≤0.01	"	Local and distribution system PLANSABAR
Domestic shallow wells (5-25 m deep)	31.8-40.2	B: ≤ 1 As: ≤0.01	"	Family
Public wells (60-66 m deep)	27.3-29.6	B: ≤ 1 As: ≤0.01	"	Distribution system ANDA
San Simon and Lempa rivers	31-34.6	B: ≤ 1 As: ≤0.01	"	Local

At each worksite the most characteristic existing vegetation are fruit trees, coffee plants and trees useful for wood, the majority of them being between 5 and 50 years old. The production wells lie in steep topography with abundant coffee plantations. The coffee plant areas in El Salvador are considered to be an artificial forest because they contribute to the pushing of the native flora and fauna towards extinction. They also aid in avoiding soil erosion, keeping shallow aquifers filtered and retaining surface water during the rainy season. The household and recreation areas lie in a high dense vegetation zone. The vegetation is mostly confined to fruit trees, and trees useful for wood (age between 30 and 40 years), but a small area is used for cereal plants such as maize and red beans during the rainy season and as a pasture terrain in the summer time. The majority of landowners are village people with a lack of economic resources, but others have obtained support from Salvadorean emigrants. The sale of some of this land was negotiated; in some cases, unreasonable prices resulted. Most of the coffee plant areas are the property of CEL but are presently being rented.

The data in Table 4 show that the water source quantified was very important for knowledge of potential water uses during project construction and the operating phase. Samples for chemical analysis were collected from hot and cold springs, domestic wells and rivers, all of them in an area of 25 km^2 surrounding the geothermal field (See Figure 3). Some of the sampling locations were studied for a geochemical purpose as geothermal field controls. The total number of locations monitored was 24, divided thus: six cold springs, six hot springs, two deep wells, 10 domestic wells and locations in the San Simón and Lempa rivers.

The results of chemical analysis for each water body showed, in most cases, concentrations permissible for human consumption although high boron and arsenic concentrations with regard to drinking water criteria, were observed in some hot springs. Cooled water is used by the village people for drinking when the water temperature is above 35°C (López,1996). Microbiological analysis was made at the 24 points monitored and the results are faecal positive, a coliform group presence being from 2400 - >16000 as PMN/100 ml Index, highest mostly in the storage tank for distribution from the cold spring mentioned above.

Springs. Two of the cold springs that are used as potable water supplies to 17 villages lie 300 m and 3 km from the existing geothermal power plant, respectively, and the water is distributed through pipelines to storage tanks situated near the communities. Bacteriological treatment is not available for this system because the community is ignorant of such schemes and do not have government assistance.

Domestic wells. The public wells are at a distance of 3 km to the north of the Berlín power station. The wells are exploited by the government with a good distribution system and bacteriological treatment.

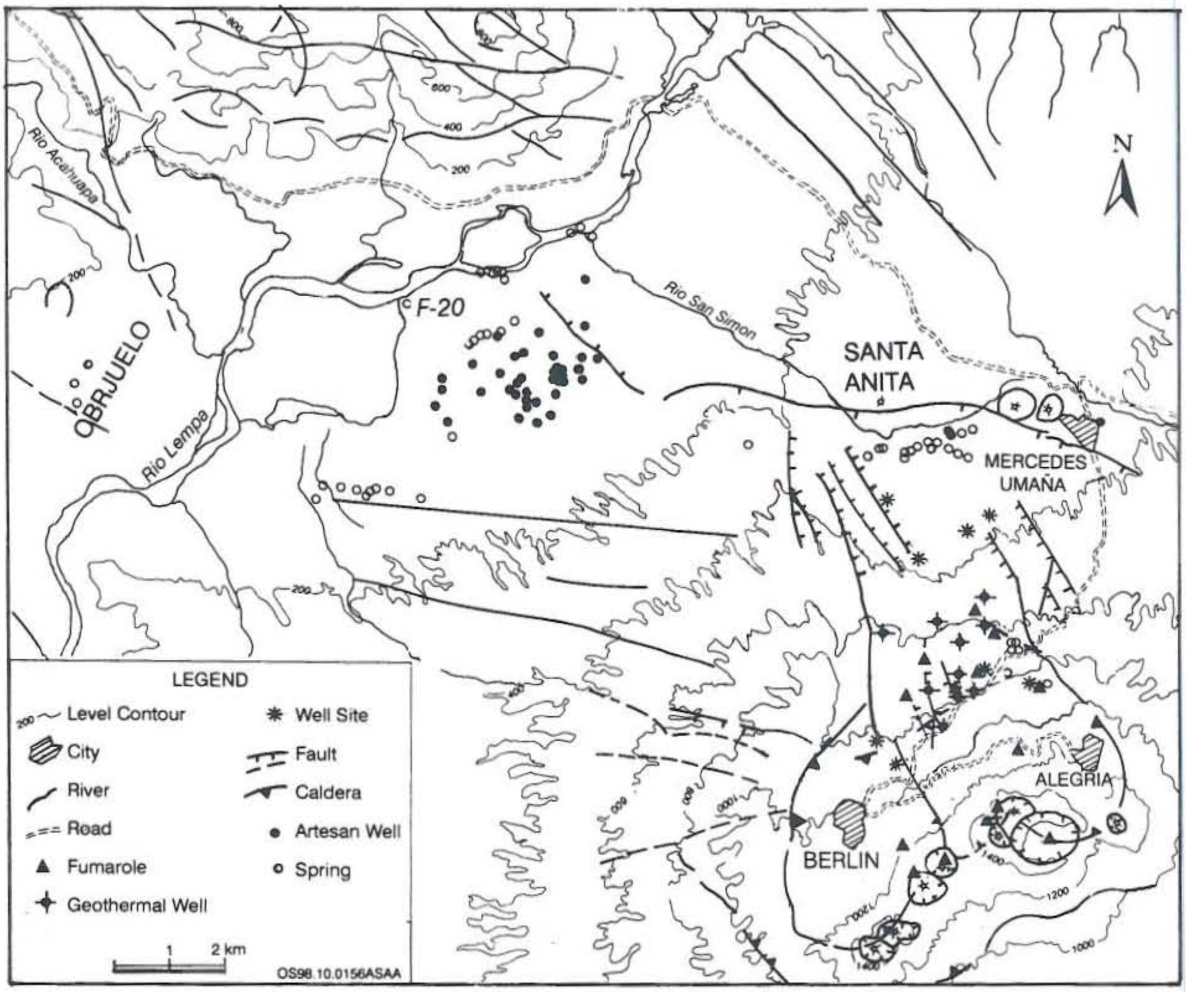

FIGURE 3: Berlín geothermal field and hydrothermal system

Water from 60 and 66 m depth is pumped at a rate of 76 l/s to Mercedes Umaña and Berlín districts through metallic pipelines. The water supply to the existing geothermal power station is through this system. The majority of domestic wells are on homegrown. The water is not treated and is mainly used for drinking, washing and bathing. Domestic wells are 5-25 m deep.

Hydrology. Guallinac, El Salto, El Mentiroso, El Mono and Agua Caliente are natural drainage basins located in the geothermal field. Primary and secondary drainage is from the San Simon micro basin, approximately 25 km^2 in area. The results of the inventory predicted that any contamination from the geothermal field could have direct impact upon the Lempa river through the San Simón river drainage system.

Comments on the environmental inventory are the following:

- Do an exhaustive review on the design of the project works to minimize loss of vegetation cover in the native species zone.
- The inventory results helped to define the best alternative to road construction to re-injection site TR-11, because it minimized the impact on vegetation, housing and negotiation for land.
- Several "pathways" were incorporated into the pipeline route preliminary design because according to the first drawings it would intercept many neighbourhood roads.
- Build dams or gabion structures in the El Salto natural drainage area to slow down water velocity from the upper geothermal zone thus avoiding flooding local communities during the rainy

season. Particular care must be taken due to the unstable terrain and high rainfall areas in the Berlín geothermal field.

- Adequate water channel system for the civil works during construction of the power plant, household and recreational areas, production and re-injection well pads and extensions and roads, should be prepared in such a manner as to avoid recharge in the same natural drainage.
- Several special areas were assigned to debris collection and disposal of other solid wastes from the civil works.
- Stability of cut slopes and fill slopes in the construction work, are both recommended in order to avoid landslides due to steep terrain.

Social and economic study results

The social and economic study was carried out at the same time as the environmental inventory. The main objective was to characterize local communities directly influenced by the geothermal condensing project. The study was done in 1996, using the personal interview method of home by home. During the interviews 25% of the total population of 3,100 inhabitants was covered.

The data collected in the communities was refereed with general reference to family groups, infrastructure, transportation, economic activity, land use, type of housing and public services, such as water, electric energy, education and health. The field information reported on a special form was completed by health workers in the zone and other government office sources. Results from this study will be seen in more detail in Chapter 4 as this is one of the main objectives of this report.

3.3.2 Activity during project execution

In the EIA report, measures were recommended by the expert from Los Alamos with reference to her findings and both the studies mentioned above helped to develop an environmental action plan during the project construction phase (Figure 4). The action plan was designed in order to comply with the mitigation measures included in bidding and contract documents.

FIGURE 4: Overview of geothermal condensing power station during the construction phase

The focus of the environmental action plan was in three areas: one of engineering that considers the civil and drilling works control; community attention, this relates to land negotiations, family displacement and environmental education programme development at schools; and lastly the monitoring programme for air and water quality.

Engineering part

- During the preliminary civil works the main parameters monitored were deforestation areas, assignment of control sites for final deposition of debris, preventive accident signs in work areas, stability of slopes and fill compacting, surface drainage channels for rain water, adequate management of solid wastes from human activity, adequate storage of construction materials and volume of traffic.
- During drilling the main control parameters were noise level, measured at well pads and their surroundings, waterproofing of mud ponds, uncontrolled and unintentional liquid discharges from the injection test well, oil residue discharges, control of solid wastes from human activity, water supply for drilling and workers' safety measures.

Community attention

The environmental staff started community attention activity, on its own initiative, before 1995 with an awareness and education programme aimed at five schools near the existing geothermal power plant station, but the programme was extended during project execution.

The environmental programme was designed to avoid accidents and to protect the geothermal infrastructure. Robberies and destruction of the geothermal installations caused serious economic problems for the company. Conflicts between communities and the company arose due to geothermal water discharges during well tests upstream of the communities, false promises during land negotiations, etc.

In addition, a programme was developed in the schools utilizing "a puppet show" with the purpose of finding the balance between geothermal development and the communities as a strategy to increase public involvement. A great effort was put into this programme because the adult population considered geothermal development a government profit making venture without due consideration of their interests.

To incorporate past experiences into the new project, the following actions were taken during the construction phase:

- Contacting relevant government and non-government organisations such as town council, communal leaders, social promoters, teachers and others to discuss the civil works in the area and possible benefits for the communities.
- Consultations and dialogues with landowners held to discuss the negotiation for land and family displacement.
- Awareness and education programs continued.
- Verification of the preventive accident signs in the project zone influence.
- Critical areas outside project works were reforested with help from the teenagers of the schools visited.

Monitoring programme

The monitoring programme was suggested as a measure by the bank for project approval, but the monitoring programme implementation was not defined in detail in the EIA report. Four months later when drilling had started the monitoring programme was ready to be carried out. It was designed by the consultant who did the EIA for the project. Its most important aspect was that of establishing criteria by which the effects of the project could be assessed during the construction and operating phases. The consultant suggested the acquisition of precision equipment to guarantee reliable measurements concerning air quality. Also, a graphic furnace could be a good tool to detect heavy metals when assessing the quality of water. Although the geothermal company has a specialized laboratory, it was not created to develop methods for environmental monitoring but for geochemistry and quality control in the power plant.

The purpose of this report is not to show details of the monitoring programme results but to briefly consider the relevant data obtained. The results helped in predicting discharges, and local land and water uses. The main parameters monitored in the geothermal field are listed in Table 5. H_2S concentration and noise level measurements during this stage were made with the existing equipment; new equipment was only acquired this year. Nevertheless, measurements of H_2S concentrations showed no changes at the sites monitored, Hg measurements were not carried out. Obviously, noise levels rose from 46 dB to 95 dB, on average, mainly at the drill pads and the power plant constructions due in both places to relocating heavy earth-moving machinery and construction equipment.

TABLE 5: General recommendations for a monitoring programme in the Berlín geothermal power plant

Monitoring	Recommendations
Air quality	a) H_2S and Hg determined monthly at well pads and the village communities b) Noise level measured
Water quality	a) Monthly collection of samples from all the hydrological bodies in the project influence zone, those of concern to the environmental inventory. b) Chemical analysis of each sample collected will include: boron, arsenic, mercury, heavy metals and TDS.
Soil quality	a) Solid waste management from drilling (cuttings and sediments) b) Soil erosion due to the deforested areas. c) Landslides and microseismicity

The effects of contamination on human health, domestic animals and wildlife were of particular concern as regards boron, arsenic, and mercury in the above mentioned water bodies. Table 6 shows that the Hg content of Lempa river water is probably not from a geothermal source.

TABLE 6: Mercury concentration in ppm over Lempa and San Simon rivers

	Upstream of Lempa river	Ahead of San Simón river mouth	Downstream of Lempa river
1997 Hg (ppm)	0.002	0.001	0.002
1998 Hg (ppm)	0.0047	0.0024	0.0047

Annual report to IDB

In fulfilment of clause 4.01(c) sentence iii, in the IDB 838/OC-ES loan, at the end of every year CEL sent an annual report whose contents are the environmental results of the project execution. The environmental results are presented in a simple form with the mitigation measures contained in the EIA report and the control parameters of the environmental inventory seen above.

Environmental results related to environmental actions and fulfilment stages of civil and drilling works, the monitoring programme and the public participation results are required by the Bank according to the report (Arévalo, 1998).

Before the results were sent to the Bank, the environmental unit staff had a meeting with the project management and engineering staff for discussion and evaluation of all environmental results and verification of the mitigation measures with their respective analysis of deficiencies, and actions to correct them. The contractors were present at the meeting because they are considered to be an essential part of the project execution.

An example of a simple form of the report is shown in Table 7. With this simple form the report is reduced to 6 pages including photos of results of the mitigation measures.

TABLE 7: Simple form of the environmental annual report for the IDB.

Civil or drilling work (parameter of control)	Mitigation measures	Fulfilment situation
Stability of slopes	Slopes at 45° steep (1:1). Install suitable drainage directed away from slopes. If needed, vegetate.	Actually only 50% in TR-4 well pad is satisfactory
Well tests	Fluids must be disposed to the mud pool and then into re-injection wells.	During the test on TR-11 all the fluid was discharged into El Mono natural drainage in the direction of the San Simon river.

3.3.3 Projected activity during condensing power plant operation

With the imminent passage of an environmental law strengthening the Environment Ministry, geothermal activity will be subjected to new environmental politics and strategies concerning the environmental management system of the country.

An environmental management system that will be established for all environmental units operating in the country, will be directly responsible for implementation and follow up of environmental policies, plans, programmes and projects. It is also responsible for compliance to environmental regulations, codes and standards to prevent the pollution of air, water and soil.

Within this institutional framework, geothermal development might establish environmental control procedures and standards to ensure reasonable environmental safeguards included in a Quality Plan as suggested by the consultant from Los Alamos.

Environmental activity at the Berlín condensing power plant will be subjected to environmental audits from the Environment Ministry and the monitoring programme and community attention must be continued in a systematic manner. Direct participation through EIAs for new geothermal projects will be an opportunity for the environmental unit staff to improve their skills.

4. SOCIAL, CULTURAL AND ECONOMIC ASPECTS OF THE BERLÍN FIELD

In Section 3.3.1 the limitations of the EIA report for the Berlín condensing power project were mentioned, mostly the lack of reliable social and economic data. Furthermore, the EIA for the project was not submitted to public consultation but it was suggested that the Bank present a follow-up plan of community participation in the annual report. Nevertheless, the studies carried out by the GGD environmental unit complementary to the EIA, aided the identification of affected sectors in a direct and

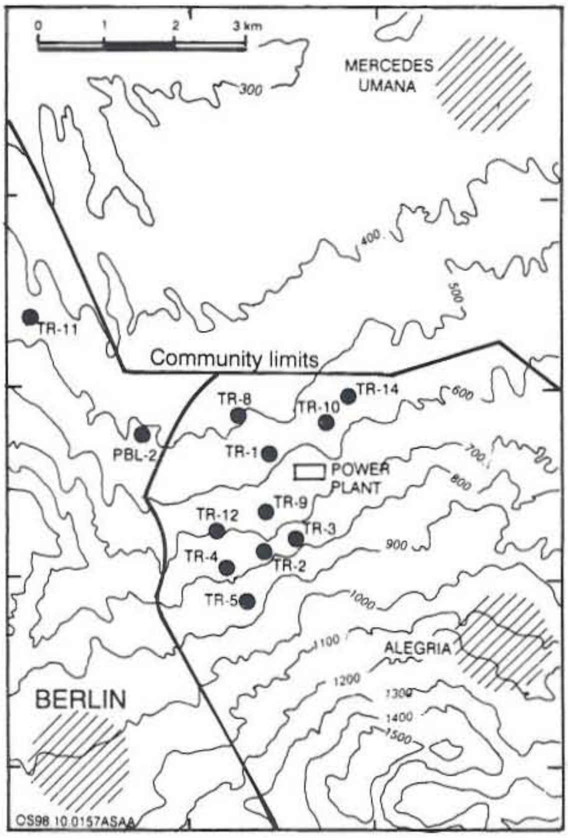

FIGURE 5: The location of the Berlín geothermal field

an indirect manner by the project development. As a part of the social, cultural and economic study this chapter will deal in detail with the characteristics of the impact zone local to the Berlín geothermal project.

4.1 Berlín condensing power station location

The Berlín geothermal field development impact zone extends to six townships in the Alegría, Berlín and Mercedes Umaña towns, see Figure 5. Types of project work and their position on the impact communities are shown in Table 8. Temporal and permanent impacts during the construction and operation phases, respectively, could help. The majority of the infrastructure of geothermal development is concentrated in Alegría town which has caused discrepancies between Berlín and Alegría municipality authorities because the real geographic location of the power plant station is in Alegría town.

4.2 Social, economic and cultural data

This section will show a summary of social and economic aspects of data collected during the interviews mentioned above. Additional data on historical sites and some customs of the communities is presented with the aim of promoting a sense of national identity associated with Berlín geothermal development. Section 4.4 is concerned with the significant impacts experienced by the residents during the operation of the existing 10 MWe geothermal power station (Lemus and Zavaleta, 1996).

TABLE 8: Direct influence on local areas by Berlín geothermal project development

Town / township	Work of the project	Distance to the community
Alegria San José Montañita El Zapotillo Apastepeque	3 re-injection wells, power plant station, household and recreation area, 8 production wells	100-500 m
Mercedes Umaña Montañita Jícaro Santa Anita	2 re-injection wells, transmission line, extended road access	100 m from well pads, Some houses under the transmission line
Berlín El Recreo	3 re-injection well pads, pipeline for residual water, extension of road access	20 m from the well pads, 50 m behind some houses and a school, houses on both sides of extension road

4.2.1 Population

The total population of the project´s neighbouring communities is 3,100; the average household size is 5 persons. Distribution of the population is shown in Table 9. Each township is directly influenced by the project because the distance between the community and the geothermal installations is less than 20 m in some cases. The majority of the population lives within the project area.

TABLE 9: Distribution of the population near the Berlín geothermal field development

Town / township	Population (inhabitants)	Dwellings (units)
Alegria		
San José Montañita	643	129
El Zapotillo	467	93
Apastepeque	30	6
Mercedes Umaña		
Montañita Jícaro	630	126
Santa Anita	732	146
Berlín		
El Recreo	598	118
Total	**3,100**	**617**

4.2.2 Infrastructure

Before the start of the project a network of five roads linking the 6 townships was built. The main roads are made of paved stone and others of gravel, mostly those in El Zapotillo and El Recreo. Both sides of the main road of San José Montañita are protected with a containing wall to avoid flooding in the rainy season because the major dwellings are located downstream of the El Salto drainage.

There is only one collective transportation system within the 6 townships with a 3 times a week service from San José Montañita to Berlín town. Actually some village people are at present being transported by the contractors´and companies´ vehicle services.

The majority of the dwelling units for the approximately 617 households are made of sun-dried brick, mostly in the San José Montañita and Montañita Jícaro townships, others of mud such as in El Recreo township, and others of wood or light construction materials such as in El Zapotillo. Eighty-two percent of the houses are privately owned. There is no municipal sewer system in any of the townships and individual systems are used by single households or shared between households.

4.2.3 Economic activity

Agriculture and farming related activity are the main economic sources. Approximately 80% of the families are landowners but the other 20% are tenant farmers. The main products cultivated are maize, maizillo and beans.

Several families run small scale kitchen gardens, livestock and chicken fowl. The majority of the families sell the products which provide about half their income, around USD 70 month, but a few people are carpenters, bricklayers, or photographers and/or obtain some income from small groceries or aid from relatives abroad in order to raise their standard of living. A minority of farmers are engaged in banana and orange cultivation, 50% of the population of El Recreo and Santa Anita townships are in this category (Lemus and Zavaleta, 1996).

Of the total population, 0.01% work in administrative and technical services for the existing 10 MW geothermal power station.

4.2.4 Public services

Water
In the inventory study it was mentioned that cold springs, domestic and deep public wells, are the main water supply sources for the communities. The water supply for 6 townships is from the Guallinac and Reventazón cold springs whose characteristics were described. The distribution system from the springs is through pipelines to storage tanks and from these by pitcher or oxcart.

Electricity and other energy uses
About 80% of the population of the area enjoy electrical service. In the 1970´s San José Montañita, Montañita Jícaro and Santa Anita townships benefited from an Electrification Rural program with government investment. People without electrical services use a car battery system to listen to radio or watch TV. The majority use fuelwood for cooking; the firewood comes from coffee plantations (priding and share trees). Some even cut down trees in the area.

Education
All the townships have a combined elementary and secondary school except El Zapotillo and Apastepeque whose children attend a nearby school, 1 km from their village. There are about 1200 pupils and 25 teachers in all the schools. Sometimes, three grades are the responsibility of one teacher. Young people who have finished secondary school have two chances: to hold up their education and take up agriculture, or to emigrate to the USA. A few young people continue their high school education in Berlín town but they need money to cover the cost.

Health
There is no medical centre. There are health workers but no doctor. In emergency cases, people are brought to the municipal health clinic or the hospital 40 km away from the townships. The most common cause of illness reported in the six townships is upper respiratory tract infection; another problem is malnutrition in children aged between 1 month and 10 years (Lemus and Zavaleta, 1996). For the last 2 years the Healthy Schools Programme has provided the primary schools with improved food with parents´ help.

4.3 Important natural resources in the geothermal field surroundings

Obviously the main natural resource of the zone is the geothermal resource. The geothermal resource consists of ten fumaroles and six areas of hydrothermal alteration, 36 km^2 in extent The geothermal resource is accompanied by a hydrology system, parts of which are considered ecological protection zones, being in the San Simón river catchment basin. These are the following:

La Cascada: Waterfall in Alegría town 3.5 km southeast of the condensing power station.
La Laguna: Small lake with high sulfur concentration probably the main recharge to the geothermal field, in Alegría town 2.1 km south of the condensing power station. Several legends have been written concerning this lake - the men that bathe in it disappear due to the beautiful lady who lives underwater
La Sabana and El plan de Quimela: Forest zone with centenary species such as cedro, conacaste and laurel.
Las Piscinas: Called "La Reventazón" and consists of an area containing 5 cold springs with extensive

vegetation and native wildlife and wild animals in danger of extinction, located 1.5 km north of the condensing power station at the boundary of the three towns. The stream is a tributary to the San Simón river and constitutes a water supply for several villages.

San Simón river: Five km north of the condensing power station. Diminished annual average flow has been observed: 332 l/s in 1995, 268 l/s in 1996 and 132 l/s in 1997. It is considered the most important resource for the communities for fishing and water supply. Soon the municipal authorities, ONG´s and the community will start a recovery program for the river (Gonzalez, pers. comm.).

4.4 Historical sites and customs

After the Spanish conquest the fusion of two cultures (Pipiles and Spanish) is evident not only in the colonial sites but also in modern day customs of the people. Any religious procession will reveal the often bizarre interpretation of Christian and pre-Hispanic beliefs which are among other things manifested in healing ceremonies performed in churches or shrines.

4.4.1 Customs

Alegría, Berlín and Mercedes Umaña are predominantly Roman Catholic towns and most of the holidays and customs have religious origins. The festival day of Michelangelo the patron saint of the zone is popularly celebrated. A patron saint is one that serves as a spiritual protector for a region. The event is not complete without a fair, parades with floats, the crowning of a queen, fireworks and candies. Celebrations in the churches are never missed and are the most emotional and pleasant part of the beloved festivities of the town. Other celebrations are held during the week preceding Easter and on Christmas Eve with fireworks at midnight. The passion, death and resurrection of Jesus Christ are celebrated in Holy Week (this is the most relevant religious activity during which the main street is strewn with colourful carpets made of sawdust and flowers). A special custom derived from the Mayan culture is the "atoladas" hot drink made of maize and milk to celebrate the maize crop at a party celebrated with neighbouring communities (Gonzalez, pers. comm.).

4.4.2 Historical sites

In Alegría town there is an important historical site related to the writer Alberto Mansferrer (1868-1932). Located 4 km from the geothermal power station the writer´s home is considered a national archeological monument in El Salvador.

In Alegría, too, the first teacher´s college attended by several people from other countries was established. A few years after the Spanish conquest Alegría was called "Gueymenique" meaning Stone´s lake and later "Tecapa" which means whistle site due to the that it is located at 1,500 m a.s.l. Both words Gueymenique and Tecapa are Nahuatl in origin (Gonzalez, pers. comm.).

4.5 Key impacts

The deep exploration phase of the Berlín geothermal development started in 1978-1981 followed by an interval due to the civil war. But in 1990 it was intensified and culminated in a 10 MWe installed power station. During these stages of the project no environmental assessment was made but there were significant effects on the communities. The company and the contractor did not consider themselves to be generating negative effects and refused to conduct any dialogue with the people (Lemus and Zavaleta, 1996).

All the significant effects were discovered during interviews in 1996. The main impacts considered by the village people during the geothermal development were the following:

- **Land use**: More than 50 landowners sold their land for geothermal development and in some cases the negotiations for the land were drawn out and the land kept uncultivated in the meantime without compensatory measures. A reduction in agricultural activity and the food resource base were the negative effects of land use.
- **Alteration hydrology**: Most of the well pad drainage was channelled in the direction of the orange and coffee plantations, the effects on the households being severe in the rainy season.
- **Burn accidents**: Several burn accidents occurred during the injection of residual water, mostly to children. The pipelines from the power plant were not insulated and some of the neighbourhood paths were intersected by the pipeline.
- **Geothermal water discharges**: These occurred mostly during well tests and when pools were full. Unintentionally, situations of emergency were created when hot water was discharged downstream in the direction of the communities, causing negative effects to maize fields and kitchen gardens.
- **Drilling mud discharges**: Small pools were designed and all the drilling liquid and solid wastes were discharged to the natural drainage which is connected to some cold springs used by the communities.
- **Instability of slopes**: Irregular excavations were made during the civil works close to the local communities with a danger of landslides over the households.

5. BENEFITS FROM THE BERLIN PROJECT

The following section briefly provides the most important economical benefits of the project to sub-contracted companies, staff developing company and the local work force.

National level
- Contribution to the national electric distribution system of 56.2 MWe using natural resources.
- Injection of deep geothermal residual water and directional drilling technology contribute to minimizing the potential environmental problems of deforestation and water contamination at a national level.
- Eight Salvadorian companies were sub-contracted to support Japanese and Canadian contractors to install the 2x28.1 MWe generators in the Berlín condensing power station. Details of the Salvadorian labour force are shown in Table 10 (Gonzalez, 1998).

TABLE 10: Salvadorian labour force working under contractor service

Contract	Type of work	Salvadorian labour force
Power Station	Design and supervision, associated civil and mechanical works	24 engineers 11 technical staff 450 miscellaneous workers*
Drilling wells	Drilling wells and associated civil works	10 engineers 2 geologists 150 miscellaneous workers
Pipeline systems for steam and residual water	Mechanical and associated civil works	6 engineers 10 technical staff 300 miscellaneous workers

*Miscellaneous: Carpenters, bricklayers, drivers, and administrative staff

Institutional level

- Transfer of technology from drilling sub-contractors concerning directional, air and foam drilling provided a practical experience to a staff of 25 Salvadorian engineers before and during the project execution.
- The geothermal project structure required 81 employers of which 35 were permanent staff, with the benefits of complementary salaries due to their professional services during the civil and drilling works. Attractive salaries were obtained for 2.2 years for 46 temporary employees in different categories. Of the total, 43% were engineering staff, 25% technical staff and 13% administrative and local service staff.

Local community level

- During the main project activity, 98% of the total work force came from the immediate locality and enjoyed the benefits for 2.2 years. The local people were employed as unskilled workers.
- Berlín town, which is 3 km from the power station, has been most successful in renting guest houses, storing constructional materials (e.g pipelines, etc), restaurants, etc.
- Twentyfour km of extended paved and repaired roads are accessible to 6 townships and these will contribute to a transport system for the communities. Emigrants from the communities resident in the USA are hoping that the geothermal project will end their need to send more economic aid for social development programmes back home.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Though El Salvador has not until this year had a valid environment law including the EIA process, the Electrical Company (CEL) has used the environmental outlines of the Inter-American Development Bank (IDB) in order to minimize potential environmental problems at a national level due to the geothermal project resulting in 56 MWe power production.

Four environmental studies were made before the execution of the project. If all the mitigation measures recommended are effective, the Berlín condensing geothermal project will probably be a model project that shows in action the balance between development and environment.

The experience of the geothermal development of 10 MWe in Berlín left severe impacts on the communities from the social, economic and cultural viewpoints because the project was not subjected to environmental assessment before, causing uncertainty among the village people about the 56 MWe power expansion.

Environmental studies carried out by the environmental unit staff helped to define four potential problems regarding the affected study zone which were not related to geothermal development. These are the following:

i) In the 1960´s and 1970´s most of the land was utilized for cotton crops with intense pesticide treatments that affected the fauna on San Simón river severely.

ii) The water systems (surface and underground) for drinking, bathing and washing are contaminated according to microbiological analysis which show faecal positive coliform counts.

iii) The cooking of food in rural areas is an "open fire" system employing firewood and the kitchens, are shared as bedrooms. The frequent smog is the real cause of the respiratory tract infection problems in the children.

iv) The Hg concentration levels have risen in the Lempa river, obviously due to another source according to the monitoring program carried out by CEL.

Experience gained by the environmental staff from the execution of the 56 MWe geothermal project will make them capable of developing an EIA process and enforcing the environmental regulations, codes and standard practices according the new environmental law.

At the moment, the monitoring programme carried out since 1996 at 24 sites (cold springs, domestic wells, rivers, etc.) in the geothermal project´s neighbourhood has not revealed contamination from deep fluids.

The significant impacts from the 10 MWe geothermal project, the civil conflict and its effect on the communities were the key issues to consider for the project planning process. Environmental staff made great efforts during the construction phase to balance the needs of the project against those of the village people. Most of the social problems are due to unforeseen action causing stress and conflicts on both parts.

An awareness and accident prevention measures programme developed for 9 schools allowed the promotion of understanding, acceptance and appreciation of the geothermal company and was the key to an informal public consulting process for the condensing power project.

The collection of data on natural resources, history and customs of the Berlín geothermal field surroundings are promising for tourism development of the zone.

6.2 Recommendations

Due to the steep topography of the geothermal field and the communities located downhill of the operation, the significant impacts are more serious than in other conditions. Therefore, the geothermal company should establish a contingency plan during the condensing power station operation.

The geothermal resource in El Salvador is considered an important national heritage. Therefore, it is a topic that should be included into the government education plans through the Science, Health and Environmental basic teaching books.

Geothermal development is responsible for the transformation from an agriculture-based livelihood to one that is partially industrially based. This disruption of the communities causes a cultural conflict and it is therefore necessary to involve the geothermal company in community life. The geothermal company could be the leader of programmes to promote the quality of life in the communities where it operates.

Payment for land constituted is a major concern of the affected landowners during geothermal development. Good compensatory political measures as regards payment for land will be required in the future.

Geophysical and chemical investigations for geothermal purposes could be used to obtain baseline data for the recovery of the San Simón river project which will be developed shortly as an initiative of the Alegría, Berlín and Mercedes Umaña municipalities´ NGO´s and communal leaders.

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