MODEL PROJECT INFORMATION SHEET

ISOTOPE HYDROLOGY AND GEOCHEMISTRY IN GEOTHERMAL FIELDS

EL SALVADOR - ELS/8/005

SUMMARY

El Salvador will be expanding its use of geothermal energy resources for electrical power generation from the current 14% contribution to the national requirement of 22% in the next five years. This requires drilling of about 35 wells in Ahuachapán and Berlín geothermal systems for production of steam and injection of wastewaters. The drilling strategies will be confidently formulated with hydrological conceptual models, which will be generated under this model project by isotopes of oxygen-18, deuterium, iodine-131 and iodine-125 supplemented by geochemical, geological and reservoir engineering data. The Agency will provide direct assistance to CEL for the practical application of isotope techniques in identifying suitable areas for production and injection of wastewaters. This will prevent pollution of the environment, sustain the geothermal and water resources as well as lengthening the economic life of the reservoir.

Project duration: 2 years. Total budget: US $96,000.

INTRODUCTION

El Salvador is the most densely populated country in the Americas, with 254 inhabitants per square kilometre and a population of over five million, which is expected to reach over eight million by the year 2010. Electricity consumption is low (450 kW/h per capita) but is expected to rise significantly with the growth of population and economic recovery. After the peace accord of 1992, El Salvador started a National Reconstruction Plan in which high priority has been given to the expansion of electricity generation. The country currently generates 818 MW(e): 46% from hydroelectric resources, 40% from fossil fuel, which is imported, and 14% from geothermal resources. In addition to hydroelectric energy resources, El Salvador is endowed with abundant

indigenous geothermal energy of sufficiently high temperature for reliable electrical power generation.

Electricity generated from Ahuachapán and Berlín geothermal fields has allowed the country to save about US $9 million per year from reduced oil imports. Ahuachapán has been in operation since 1975 and currently generates 58 MW(e) from 32 production wells. Production in Berlín geothermal field began in 1992 and is currently supplying 5 MW(e) from 10 production wells. The power plants are operating at about 60% of their capacity. The national electricity development plan for 1990-2010 includes an addition of 22% geothermal power from the exploration of new areas and the expansion of existing ones. The plan also intends to augment the capacity factor in the next 15 years to at least 90%. This will require drilling 15 production and injection wells to increase the generation of Ahuachapán to 90 MW(e) within the next five years. Similarly, the production of Berlín geothermal plant will increase to 50 MW(e) by 1997. This will require drilling 18 additional wells. Moreover, in Berlín, two injection wells will be drilled in 1995 to improve the disposal of wastewaters of the existing power plants. Drilling cost per well is about US $2 million.

With a rise in production, the amount of wastewaters will proportionally increase. The volume of wastewaters at Ahuachapán has reached 318 million tonnes during its eight years of operation. These wastewaters have a temperature of about 92°C and contain highly toxic substances which pollute the environment if discharged to the surface waters. Thus, injection wells need to be drilled not only to prevent pollution but also to artificially recharge the reservoir and maintain its pressure.

Exploration activities will also be intensified in San Vicente, Coatepeque and Chipilapa. A total of 135 MW(e) is projected from drilling two to four wells in each area. So far, the Agency has directly supported the development of geothermal energy resources in Ahuachapán and Berlin geothermal fields through projects ELS/8/002 and ELS/8/003. The direct recipient and end user, the Rio Lempa Executive Hydroelectric Commission (CEL) is the public organization responsible for the production, conservation, utilization and development of electricity in El Salvador.

The national plan for geothermal electricity development in El Salvador will involve considerable geoscientific investigations and drilling activities, which are expensive undertakings. This model project supports CEL in the use of nuclear and isotope techniques in these investigations to define drilling strategies for production and injection wells as well as to formulate development and management strategies in the most economic and efficient way. This will have a direct effect on improving geothermal electricity economics and minimizing the environmental impact.

NUCLEAR TECHNIQUES IN THE DEVELOPMENT AND MANAGEMENT OF GEOTHERMAL RESOURCES

Exploration for geothermal resources requires geological, geochemical and geophysical investigations to produce a conceptual hydrogeochemical model, which is the basis for drilling strategies and development plans in a geothermal area. During the production stage, the reservoir is regularly monitored for physicochemical changes in the

fluids. Of major concern are the quality of the fluids and the contamination by cold water and reinjected wastewaters. In such activities, isotope techniques are indispensable as a tool to confirm the traditional methods.

Stable isotopes like oxygen-18 and deuterium are unaffected by the physical and chemical changes from their source of recharge to the sampling point, and are therefore suitable as tracers of flow. They are also sensitive to changes in temperature, water-rock interaction and physicochemical processes such as steam separation, evaporation, dilution or mixing. These isotopic characteristics are excellent indicators of geochemical phenomena and, together with the chemical parameters, define the hydrology and estimate the subsurface temperatures of the emerging fluids.

Environmental isotopes in geothermal investigations such as oxygen-18, deuterium, and tritium are the main tools to identify the origin of fluids in geothermal systems. They are also valuable for identifying the source of recharge, which is important for modelling the hydrology of the area, assessing the life of the reservoir and zoning areas for watershed protection and management. Furthermore, isotope technology contributes to the understanding of the physicochemical phenomena in the reservoir as a result of exploitation. This includes the monitoring of injected fluids to the production sector, incursion of cooler meteoric waters, formation of acidic waters and generation of a steam layer due to pressure drawdown. These inputs help decision making on operational procedures, development and management strategies.

OBJECTIVES

1. To integrate isotope hydrogeochemical techniques in geoscientific investigations associated with the geothermal electricity development of Ahuachapán and Berlín fields in order to determine drilling strategies for siting production and injection wells and to develop a reservoir engineering model that will support management strategies and operational procedures for optimum utilization of the resources.

2. To enhance local capacity by timely training and technology transfer to improve self-reliance in the use of isotope geochemistry in geothermics and reservoir modelling techniques.

PROJECT IMPLEMENTATION AND MONITORING

The project will be implemented in two years. The activities will focus on the two producing geothermal systems, Ahuachapán and Berlín, although exploration areas like San Vicente, Coatepeque and Chipilapa will also be investigated. The geothermal fluids, injected wastewaters and groundwaters will be characterized by isotopes so that their presence and movement in the system can be monitored. Analysis of stable isotopes, oxygen-18 and deuterium will be undertaken in the Agency Isotope Hydrology Laboratory in Vienna. The water and gas chemistry and the radioactive tracer measurements will be undertaken in the recipient (CEL) laboratory. Injection of the tracers will be conducted by the recipient staff.

In exploration areas, water and steam samples from all hot and cold springs and rivers will be collected and analysed for chemistry, oxygen-18 and deuterium. Approximately 100 samples will be measured each year. The data will be translated to maps to provide an understanding of the movements of fluids and to locate regions of high heat flow. It will constitute the background hydrology of the study areas on which subsequent isotope investigations will be based. Further drilling targets for production and injection wells can be defined. In the exploited fields of Berlín and Ahuachapán, the baseline isotope hydrology of the geothermal system will be re-established with historical isotope and chemical data. New samples from production and injection wells will also be regularly collected and analysed to provide an understanding of the evolution of the fluids as a result of exploitation. This can reflect the effects of steam withdrawal and injection of wastewaters. The results will be utilized to illustrate the evolution of geothermal fluids due to exploitation and serve as an aid in the management of the reservoir.

Tracing with the use of iodine-131 or iodine-125 will be undertaken in producing fields where wells are available for monitoring. About seven experiments are anticipated, five of which will be carried out in 1995. The measurements of about 800 samples will be distributed during the two years of the project. The results will quantify the rate and direction of flow of injected waters and establish interconnection of wells on sectors in the reservoir. The recipient staff, together with the Agency experts, will integrate the isotope, geochemical and reservoir engineering parameters to generate a conceptual understanding of the geothermal systems under exploitation. A reservoir engineering model will also be generated to illustrate quantitatively the pressure and temperature changes as well as heat and fluid flow with time. This will involve extensive computer simulation. The results will support the management strategies for the utilization of the reservoir.

The implementation of project activities will be monitored by annual progress reports prepared by the recipient organizations and submitted to the Agency. The reports will show the degree of implementation, the important results, the problems encountered, and actions needed for further progress. This report will be discussed at an annual meeting attended by representatives from the Agency and other organizations and individuals concerned. Upon completion of the project, a seminar will be held for final evaluation of project activities, including discussion of the main results and assessment of the impact and the project's contribution to sustainable development. Monitoring meetings can be organized and co-ordinated within regional Agency geothermal project meetings. A model project final report will be prepared by the Agency on the basis of the seminar papers.

NATIONAL COMMITMENT

The Government is committed to an electricity development plan, emphasizing geothermal electricity as an indigenous resource, which CEL is implementing. The Government has taken a loan of US $25 million from the International Development Bank (IDB) to finance the feasibility studies of San Vicente and the third phase development of Berlín. In addition, a loan of US $180 million is in a final stage of negotiation to finance the integrated programme for Ahuachapán and development of the condenser at Berlín. In both, CEL provides 10% as counterpart financing.

The infrastructures, facilities in the field and in the laboratory have been set up at CEL and made available for this project. These include suitably equipped and fully operational petrology, geophysical, geochemical and radioisotope laboratories. Well qualified scientific and engineering staff are operating the geothermal fields. The importance of scientific inputs of isotope applications to the management and utilization of the resources is recognized.

THE AGENCY'S INPUT

The Agency has the experience and capability to assist the counterpart in the application of nuclear techniques to El Salvador's electricity geothermal development. This input will facilitate the confident formulation of strategies for the development of the reservoir, specifically in the siting of wells and their utilization and in prioritizing areas for exploitation.

A total of 3/15 m/m expert assistance will be provided to integrate the isotope, reservoir engineering and geochemical data in order to generate a conceptual understanding of Berlín and Ahuachapán geothermal systems. The expert for isotope hydrology and geochemistry will assist CEL to interpret the data, understand the gross hydrological flow of fluids and establish the interconnection of wells or sectors in the reservoir. A total of six m/m are allocated for fellowships: four in isotope hydrology and two in reservoir engineering. This will develop the local capability in preparation for independent work on isotope technology in geothermics.

IMPACT

Enhancing the efficient use of indigenous geothermal resources and increasing electricity generation from non-carbon-emitting resources will increase energy self-sufficiency in El Salvador and contribute to sustainable development.

The integration of nuclear and isotope techniques in geothermics is crucial in determining the proper siting of 35 production and reinjection wells in the Ahuachapán and Berlín fields, which cost about US $70 million. Large losses and considerable delays resulting from improper siting will be avoided. Increasing the number of production wells is the basis for increasing electricity generation and improving plant capacity factors to meet the targets of the electricity development plan. Reinjection of millions of tonnes of hot and toxic waters will have an immediate beneficial effect on the protection of the environment. The development of a reservoir engineering model based on the understanding of geothermal systems will, in the long term, optimize the management of the resources, lengthen the life of the reservoir and make it renewable.

FINANCES

The budget allocation for the project is US $96,000, distributed as follows:

Year	Experts		Equipment	Fellowships		Scientific Visits		Grp trg.	Sub-contr.	Misc. Comp.	Total
	M/D	US $	US $	M/D	US $	M/D	US $	US $	US $	US $	US $
1995	1/0	11,400	17,000	4/0	13,200	0/0	0	0	10,000	0	51,600
1996	2/15	30,000	5,000	0/0	0	0/0	0	0	10,000	0	45,000
Total	3/15	41,400	22,000	4/0	13,200	0/0	0	0	20,000	0	96,600

Source of funding: TACF