UPDATEDSTATUSOFTHEGEOTHERMALDEVELOPMENT IN GUATEMALA

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ABSTRACT

Far the last 20 years, the Republic of Guatemala, through the Unidad de Desarrollo Geotérmico (UDG) of the Instituto Nacional de Electrificación -INDE-, the national utility company, has been carrying out continuous geoscientific studies of its territory with the objective of locating and evaluating areas with geothermal resources in order to generate electricity. As result of these studies, 14 areas have been located and defined as geothermal prospects. most of them are sited along the Guatemalan volcanic chain. Of these areas, five have been ranked as first order priority. They are at different levels of development. Zunil I in western Guatemala, is the most extensively studied area. The first geothermal power plant is under construction and planned to be on line by the end of 1995, with a production of 24 MWe. Zunil II, located east of Zunil I, has studies at prefeasability level, Amatitlin, in central Guatemala, (28 km south of Guatemala City) the level of studies is at feasability, San Marcos in the west, Moyuta and Tecuamburro in the east part of Guatemala have studies at prefeasability level.

Also in the area of Zunil I a farm-produce dryer plant has been built through a technical cooperation agreement between INDE and Los Alamos National Laboratory (LANL) and is using steam from slim hole Z-11 to dry fruits and vegetables.

Key Words: Exploration, Development, Zunil, Amatitlan, San Marcos.

INTRODUCTION

Guatemala has an extent of 108,000 km² and a population of about 10 million inhabitants. Most of the actual power supply comes from hydroelectric, and complemented with thermoelectric and gas plants, which implies the importation of hydrocarbons. In the near future. by 1995, the sugar cane factories will use their biomass waste to generate energy and the first geothermal power plant is comitted to December 1995. The energy sources used this year **(1994)** are:

SOURCE	**CAPACITY (MW)**	**ENERGY GWh/yr**	%
Hydro	422.6	1922	63
Thermal & Gas	313.0	1129	37
TOTAL	735.6	3051	100

The development of different options such as geothermal, wind and solar energy has received attention in the past few years due to the variations of the rain regime, the base for the hydropower plants, that has been irregular and created problems in the energy supply during the last 3 years. The energy demand for 1995 is estimated to be 3,288 GWh/yr and will be supplied as follows:

SOURCE	**GWh/yr**	%
Hydro	1982	60
Thermal & Gas	1129	34
Geothermal	178	6

REGIONAL GEODYNAMICS AND GEOLOGY OF GUATEMALA

In Guatemala, the fundamental geotectonic structure is strongly controlled by plate motion. Guatemala is situated between three plates, in the north, the North American Plate, the Caribbean Plate in the central part and the Coco's Plate in the south. This plate is moving north-northeast toward the Caribbean plate and is plunging beneath the landmass (subduction process that has created the volcanic chain) and the Caribbean plate has westward movement respect to the North American Plate, which is evident through the Chixoy-Polochic faults. **(Fig 1)**

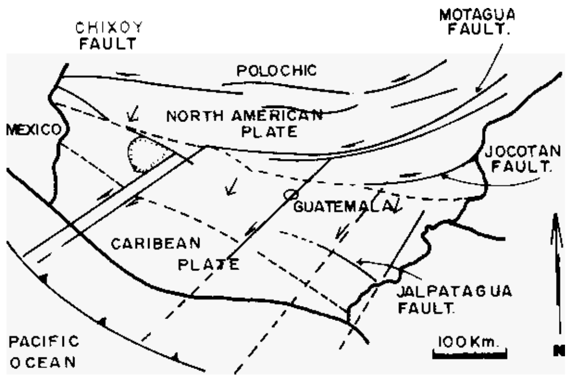
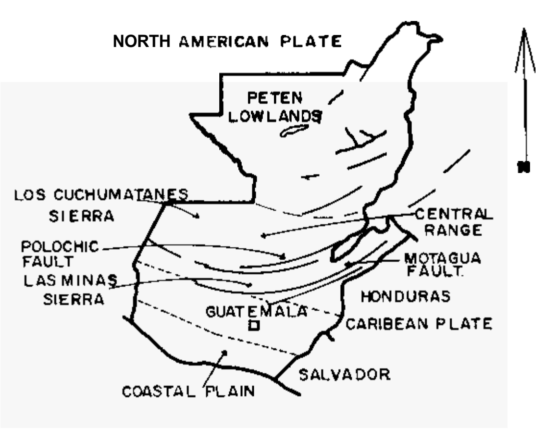


FIG I

From the geological point of view, Guatemala is divide into four provinces: a) The Peten lowlands in the north, with sedimentary rocks, b) The Central range, mainly formed by metamorphic racks, c) The Volcanic province and d) The Pacific coastal plain. **(Fig 2)**



FIE 2

GEOTHERMAL RECONNAISSANCE

In 1981 a regional study was carried out and located 14 geothermal areas, most of them located in the Guatemalan Volcanic chain. **(Fig 3)** The results of the geoscientific studies showed four areas as first priority for detailed study: San Marcos, Zunil, Amatitlin and Tecuamburro, with temperatures ranging from 230 to 300 "C (Actual temperatures measured in production wells in Zunil. and exploratory ones in Amatitlan and Tecuamburro, for the San Marcos area, only geothermometry data exists). Second priority areas were Los Achiotes, Moyuta, Totonicapán and Ixtepeque. where the temperatures varied from 130°C (in Moyuta exploratory wells) to 180°C (Ixtepeque geothermometry). In a third category were ranked the areas of Palencia, Retana, Ayarza, Atitlán and Motagua, where the geothermometry was not reliable, but the geology shows favorable conditions and additional studies will be necessary.

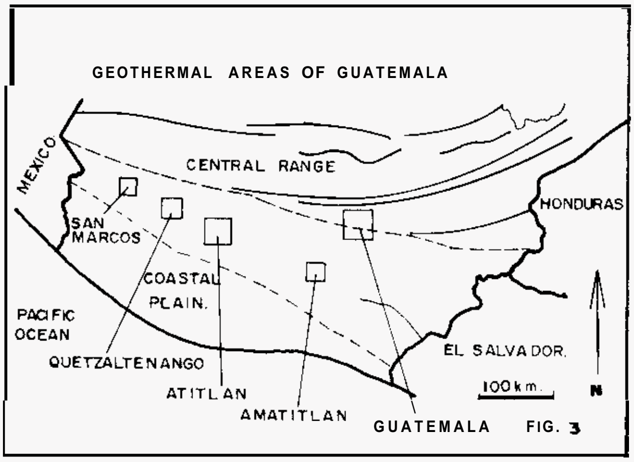


FIG. 3

MOYUTÀ GEOTHERMAL AREA

This area is located in the eastern part of the country and is sited in the Volcanic chain. **(Fig 4)** This was the first studied area for geothermal purposes. The results of the first geoscientific studies (carried between 1972-75), that included the drilling of 12 exploratory wells, determined an anomaly of about 10 km² with a thermal gradient greater than *2.5* °C/10m. These results generated the first geothermal model, and this model was used to site two deep exploratory wells. The first one was drilled to 197 m and the second one to 1,000 m; both wells reached maximum temperatures of 114 "C. At that time. the exploration was suspended.

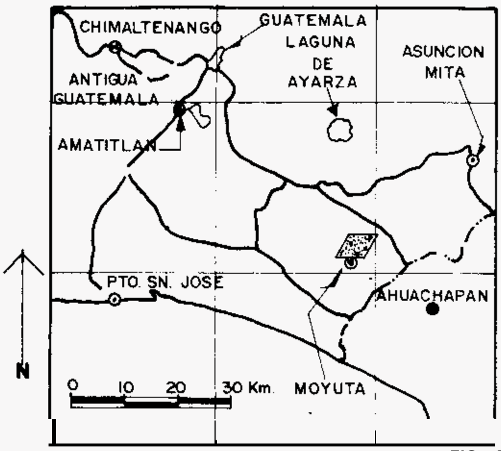


FIG 4

In 1991 a re-evaluation of the Moyuta geothermal area. was conducted by INDE and Los Alamos National Laboratory. Chemical and isotopicdata from four fumarole sites, combined with prefeasability assessments obtained in the 1970's. suggested that there are two subsystems having temperatures of about 210 °C in the north flank of the Moyuta volcanic complex, and 170 °C in the southern flank. **(Fig 5)**

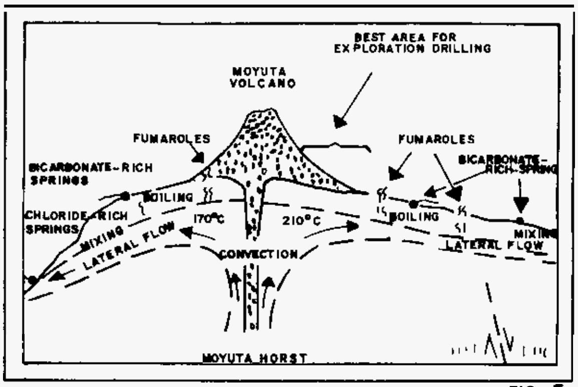


FIG. 5

From this new model we can say that the general characteristics of the Moyuta model are similar to many geothermal systems associated with Quaternary andesitic volcanoes. With this **re**-evaluation, the drilling targets differs from those proposed before, and the best areas for exploration drilling are between the **axis** of the volcanic complex and the fumaroles flanking this complex. We would select sites along fault and fracture zones on the north side of Moyuta to intercept the hotter of the two subsystems.

ZUNIL I GEOTHERMAL FIELD

This field **is** located at 2W km west from Guatemala City. **(Fig 6)** The geoscientific studies carried out from 1988 to 1990, (the studies included neotectonics, gravity and SEV interprelation, fluid inclusions and mercury soil surveys) demonstrated the existance of open and active faults within the granitic basement, that are acting as upflow conduits for the geothermal fluids. These faults would be the main drilling targets in order to get better geothermal production than the field already had with the previous ZCQ wells (Caicedo & Palma 1990).

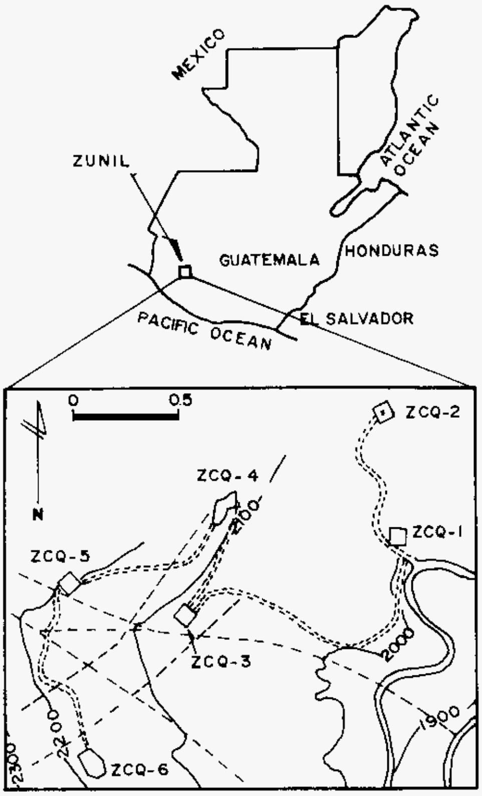


FIG 6

With the interpretation of open faults in the granitic basement, the drilling targets were located and the development drilling program was established. This program was intended to reach the main upflow zones of the field. These zones correspond to major fractures and faults of the granitic basement and are mainly concentrated in the west part of the field. The development drilling started in December 1990 and was finished in July 1992. Three directional wells were drilled (named ZD wells). The three of them intersected the fracture zones in the basement. The depth of the wells range from 1,516 m to 2230 m. The total production of the field, *according* with **the** performed production *tests is* ***645.6*** *T/h* of mixture, at a separation pressure of 10.5 bar, 239.59 T/h of steam and 406.41 T/h of brine. **(Fig 7)**

Well	Qt	Qv	Qb
ZCQ-3	32.40	9.72	23.00
ZCQ-4	30.28	30.28	-----
ZCQ-5	25.04	25.04	-----
ZCQ-6	42.50	7.65	34.85
ZD-1	290.36	90.17	200.21
ZD-2	192.30	72.09	125.35
ZD-3	32.72	4.64	23.00
TOTAL	***645.60***	**239.59**	**406.41**

With this production and in accordance with the reservoir engineering studies, it has been defined that a 24 MWe geothermal power plant can be operated during a plant lifetime of 25 years.

INDE with its new policy of inviting private investors to participate in the energy generation through natural resources, has signed an energy purchase agreement with ORMAT, to exploit the geothermal resource of Zunil I. The power plant is comitted by the end of 1995 with a net output of 24 MWe.

ZUNIL II GEOTHERMAL AREA

The Zunil **II** area **is** located 2 km east of Zunil I. **(Fig 8)** In this zone, the prefeasability studies were finished in 1992. The studies consisted in geological, geophysical and geochemical surveys and wvered an area of 16 km^2. Three slimholes were drilled with depths ranging from 370 to 757 m. The well Z-21A, the deepest of them, reached a production cone from 690 m to total depth. The flow test results indicated that the well can produce 35 t/h of *dry* steam. The production of this well comes from a steam cap, the main reservoir was not reached.

From the assessment done in the prefeasability study, it is estimated that the Zunil II area is a promising area and could produce enough steam to generate 40 - 50 MW. However, this production can not be tested until the exploration and development drilling **is** completed.

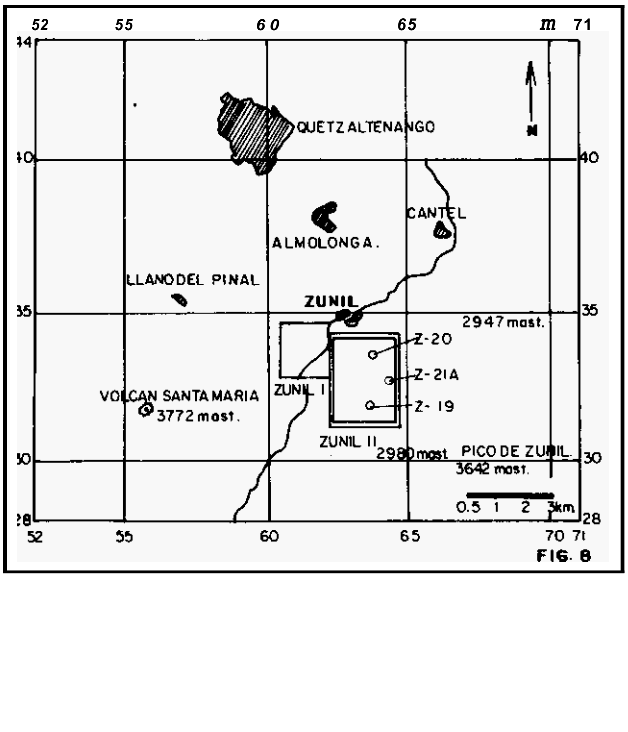


FIG. 8

AMATITLAN GEOTHERMAL FIELD

This field is located 28 km south of Guatemala City. In this field, exploration started in 1980 (Caicedo & Palma, 1990). In 1991 prefeasability studies were finished and indicated a zone of about 16 km^2 in the southern part of the field **as** the most promising area, where the main upflow wne is located. **In** this part were located 4 **sites for deep exploration drilling. (Fig 9) Exploration drilling** started in late 1992 and was finished in October 1993. Four wells were drilled, named AMF wells (1-4). These wells range from 1500 to 2058 m deep, with temperature values from 230 to 300°C. the production zones in the tour wells are located at about 1,110 m depth to bottom hole and the host rocks of the reservoir is a thick pile of fractured andesitic lavas. The results of the exploration drilling are encouraging and have confirmed the existance of a commercial geothermal reservoir and suitable to generate electricity. The test flow of the well AMF-1 was performed during July 1994 and showed a stable production of about 5 MW for this well (at a separation pressure of 8.5 bara). Eventhough the production test of the four exploratory wells has not been finished, we can estimate that this field could easily produce energy to generate in the order of 25 to 30 MWe.

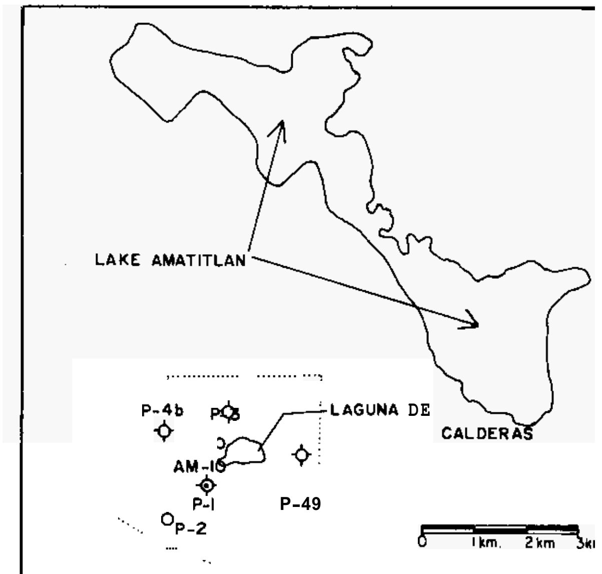


FIG 9

TECUAMBURRO GEOTHERMAL AREA

The Tecuamburro area is located 60 km southeast of Guatemala City. **(Fig 10)** In this region INDE carried out geoscientific studies with the technical assistance of the Los **Alamos** National laboratory, and sponsored the drilling **of** a slimhole that reached 806 m depth in a volcanic secuence of andesitic lavas and pyroclastic deposits, and that found a bottomhole temperature of 235°C. From the geochemical point of view (gas and fluid geothermometryj the temperature of the reservoir has been estimated to reach 300°C.

SAN MARCOS GEOTHERMAL AREA

This zone is located **250** km west of Guatemala City. **(Fig 11)** **In** this region, INDE with the technical and financial assistance of the European Community (Proyecto Geoterguaj. is wnducting the geoscientific studies at prefeasability level. This studies include: geovulcanology, geophysics, geochemistry, environmental assessment and economics of the future development.

The first results indicate the existance of a high temperature reservoir (gas and fluid geothermometry) with an estimated temperature of about 250°C. Exploratory drilling has been programed to start in November 1994, and a detailed geophysical survey (gravity and magnetics) to define the structure **of** the area will be performed during 1995.

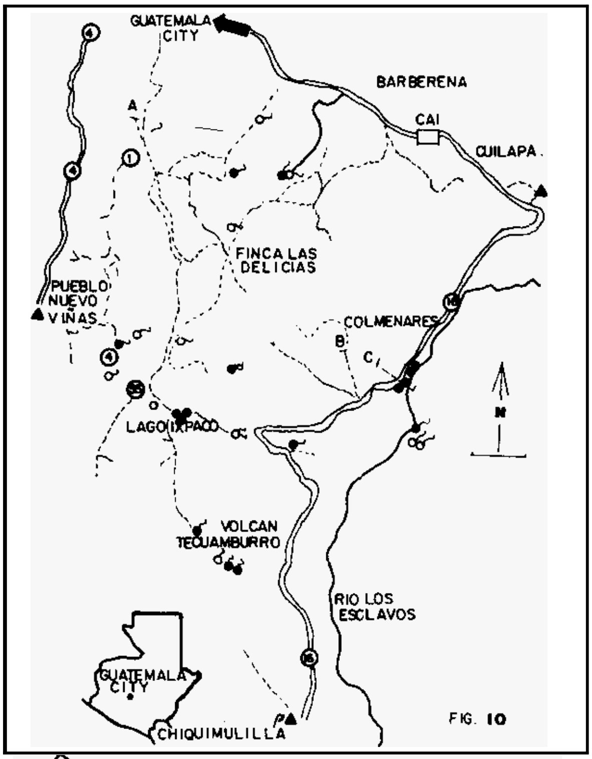


FIG. 10

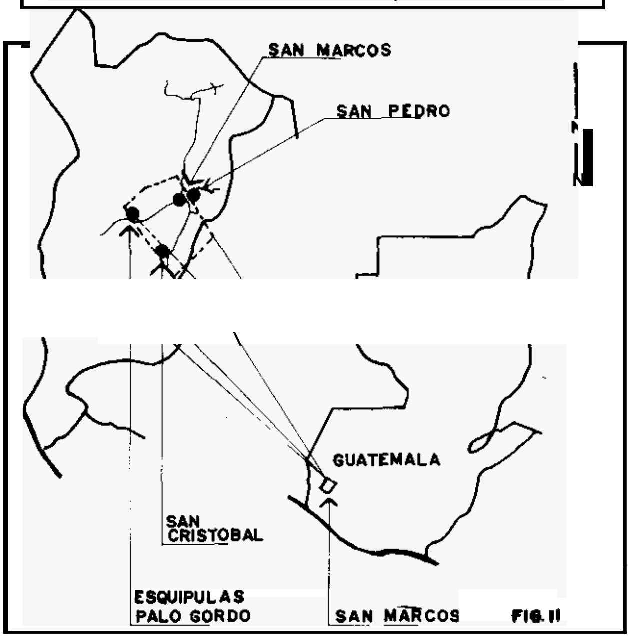


FIG. 11

CONCLUSIONS

Although Guatemala has several geothermal resources, it does not have any geothermal power plant operating at present time. This is because the National Plan only used hydro resources to supply energy for a long time.

The growing energy demand and the dramatic changes in the rain regime occurred during 1991 and 1992, showed the vulnerability of the system. Due to this, the Energy sector started to look for alternative energy **sources,** and especially those from natural resources, in wich the geothermal has an important role.

The first geothermal power plant is scheduled for December 1995 at the Zunil I field with a net output of **24** MWe and the second one in the year 2,000 with an expected capacity of at least 30 MW.

The development of the other areas will continue with the aim of having about 100 MW by 2005.

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TABLE **1.** PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	Geothermal		Fossil Fuels		Hydro		Nuclear		Total	
	Capacity, MW	Gross Prod. GWh/yr	Capacity, MW	Gross Prod. GWh/yr	Capacity, MW	Gross Prod. GWh/yr	Capacity, MW	Gross Prod. GWh/yr	Capacity, MW	Gross Prod. GWh/yr
In operation in January 1995	-	-	313	1129	422.6	1922	-	-	735.6	3050
Under construction in January 1995	24	178	-	-	10	60	-	-	34	238
Funds committed, but not yet under construction in January 1995	70	521	100	570	143	814	-	-	313	1905
Total project use by 2000	94	699	413	1699	575.6	2796			1082.6	5193

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT IN DECEMBER **1994**

1) I = Industrial process heat
C = Air Conditioning
A = Agricultural drying
F = Fish and other animal farming
D = Space Heating
B = Bathing and swimming
G = Greenhouses
O = Other (please especify by footnote)

2) Enthalpy information is given only if there is steam or two-phase flow.

3) Energy use (TJ/yr) = Annual average water flow rate (Kg/s) **x** [Inlet Temp.(°C) - Outlet Temp.(°C)] x 0.1319

Locality	Type 1)	Maximum Utilization					Annual Utilization		
		Flow Rate Kg/s	Temperature (°C)		Enthalpy 2) (kJ/Kg)		Average Flow Rate Kg/s	Energy Use 3) TJ/yr	Load Factor
			Inlet	Outlet	Inlet	Outlet			
Zunil	A	1	230	90			I	18.47	
Zunil	A	1	60	20			1	5.28	
Amatitlán	I	nd	nd	nd			nd		
Amatitlán	B	10	60	15			10	59.36	

TABLE 4. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES

1) Inst. thermal power (MW_t) = Max. water flow rate (kgs/s) x [Inlet Temp.(°C) - Outlet Temp.(°C)] x 0.004184

2) Energy use (TJ/yr) = Annual average water flow rate (Kg/s) x [Inlet Temp.(°C) - Outlet Temp.(°C)] x 0.1319

	Installed Thermal Power 1) MW_t	Energy Use 2) TJ/yr
Bathing and swimming	2.05	64.64
Agricultural drying	0.59	18.47

TABLE 9 ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES (Restricted to personnel with a University degree)

(1) Goverment
(2) Public Utilities
(3) Universities
(4) Paid Foreing Consultants
(5) Contributed Through Foreing Aid Programs
(6) Private Industry

Year	Professional Man Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
1990	10			4	1	
1991	10			5	1	
1992	9			5	-	
1993	8			3	1	
1994	10			3	1	1

TABLE 6 INFORMATION ABOUT GEOTHERMAL LOCALITIES

1) Main type of reservoir rock

2) Total dissolved solids (TDS) in water before flashing. Put v for vapor dominated.

3) N = Identified geothermal locality, but no assessment information available.
R = Regional assessment
P = Pre-feasability studies
F = Feasability studies (Reservoir evaluation and Engineering studies)
U = Commercial Utilization

LOCATION	LOCATION TO NEAREST 0.5 DEGREE		RESERVOIR		STATUS 3) JANUARY 1995	RESERVOIR TEMP. (°C)	
	LATITUDE	LONGITUDE	ROCK 1)	DISSOLVED SOLIDS 2)		ESTIMATED	MEASURED
Zunil I	14°46'	91°30'30"	Granodiorite	2000	F - U	> 270°C	295°C
Zunil II	14°45'	91°29'	Granodiorite	1800	P	> 220°C	245°C
Amatitlán	14°25'	91°35'	Volcanics	5000	F	240°C	300°C
Tecuamburro	14°10'	91°21'	Volcanics	--	P	240°C	240°C
Moyuta	14°02'	91°05'	Volcanics	900	P	> 200°C	--
San Marcos	14°56'	91°46'	Granodiorite	--	P	> 240°C	--
Ipala	14°30'	89°39'	Volcanics	--	R	---	--

TABLE 7 WELLS DRILLED FOR ELECTRICAL AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY I, 1990 TO DECEMBER 31, 1994
(Do not include thermal gradient wells les than 100 **m** deep)

1) Type **of** purpose **of** well

T = Thermal gradient **of** other scientific purpose
P = Production
C = Combined electrical and direct use
E = Exploration
I = Injection

2) Total **flow** rate at given wellhead pressure

Locality	Year Drilled	Well Number	Type of[1] Well	Total Depth m	Max. Temp. °C	Fluid Enthalpy kJ/kg	Well output[2] Flow Rate kg/s	WHP bar
Amatitlán	1990	AM-10	TIE	900	240°C			
Amatitlán	1990	AM-IO	TIE	700	180°C			
Amatitlán	1992	AMF-1	E	1581	290°C	1215	47.50	10.5
Amatitlán	1993	AMF-2	E	1502	300°C	1672	24.70	7.0
Amatitlán	1993	.AMF-3	E	1500	250°C			
AmatitIan	1993	AMF-4	E	2058	250°C			
Amatitlán	1993	AMR-I	I	I20				
Amatitlán	1993	AMR-2	I	120				
Amatitlán	1993	AMR-3	I	150				
Amatitlán	1994	AMR-4	I	150				
Zunil I	1991	ZD-1	P	1516	297°C	1360	80.65	10.5
Zunil I	1991	ZD-2	P	1789	294°C	1299	53.33	10.5
Zunil I	1992	ZD-3	P	2230	290°C	1299	10.08	10.5
Zunil I	1992	ZCQ1-R	I	1500	250°C			
Zunil II	1990	Z-20	TIE	385	240°C			
Zunil II	1992	z-21	E	751	240°C			

TABLE 10 TOTAL INVESTMENTS IN GEOTHERMAL IN (1994) US$

Period	Research & Development Incl. Surf. Exp. & Exp. Drilling Million US$	Field Development Incl. Prod. Drilling & Surf. Equipment Million US$	Utilization		Funding Type	
			Direct Million US$	Electrical Million US$	Private %	Public %
1975-1984	11.19			11.19		100
1985-1994	13.80	12.85		26.65		100