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STATUS OF GEOTHERMAL POWER GENERATION IN JAPAN

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SUMMARY
This report describes the geothermal power generation in five years from 1995 through 1999 in Japan. It also mentions the measures by the government for development and the international coordinations. Another report (Sekioka and Yoshii, 2000) deals with the direct geothermal use in this country.

The installed geothermal generation capacity in Japan was 312.3MW as of 1 January 1995 (Yamaguchi *et al*., 1995). Yamagawa, Sumikawa and Yanaizu-Nishiyama geothermal power stations started operation in 1995. Ogiri, Kakkonda II and Takigami joined the line in 1996. A geothermal unit in Hachijojima started operation in March 1999. Thus, as of 1 January 2000, there are nineteen geothermal units at seventeen locations in Japan. The total installed capacity is 546.9MW, which is 0.2% of the power generation facility in Japan. The electricity produced by geothermal energy in fiscal 1998 (April 1998 -- March 1999) is 3,531.6GWh, which is 0.4% of the annual electricity produced during the corresponding period in Japan. Although Oguni is the only definite geothermal construction plan, government surveys prospective fields actively.

In the five years, there was no drastic reform on geothermal power plants. However, solid betterment took place. Two units have equipped hydrogen sulfide (H_2S) abatement system for further environmental protection. Scale prevention systems have been installed for some plants. Operators reexamined the whole system to make the most of the reservoir by minimum modification of the facilities.

Geothermal development involves uncertainty and requires substantial pre-investment; and advanced technology is necessary, especially for survey. Thus government and other institutions provide technical and financial assistance. Geothermal discharges less CO_2 and will be more necessary in the next century. Japan is to apply its knowledge, obtained through domestic development, to contribute to the world.

1. HISTORY OF GEOTHERMAL POWER GENERATION IN JAPAN

The first experimental geothermal power generation in Japan took place in 1925 in Beppu, Oita. Research and development projects proceeded after the interruption during the World War II. Matsukawa Geothermal Power Station, the first full-scale geothermal plant in Japan commenced in 1966. It showed *the Beginning of Geothermal Era* in Japan. This chapter will outline the progress of practical utilization of geothermal power generation in this country since Matsukawa.

<u>First Generation (Mid 1960s -- Mid 1970s)</u>
In these years, there were many unknown realms in survey, resource assessment, facility design and maintenanc. Thus a geothermal power station was also a full-scale demonstration. Otake, Onuma, Onikobe that commenced during the decade since Matsukawa, are in this generation. The output of each plant was added gradually as the condition became clear.

<u>Second Generation (Mid 1970s -- Mid 1980s)</u>
In the next decade, large geothermal power stations (50 MW class) with high efficiency started operations based on the experience of the preceding generation. They are Hatchobaru, Kakkonda (the No.1 unit), and Mori. The two oil crises intensified the demand for alternative energies. Also the progress of technology from survey to operation accelerated the development. The Nationwide Geothermal Primary Survey by GSJ and the Nationwide Geothermal Recourses Exploration Project (later, the Geothermal Development Promotion Survey) by NEDO started during this decade.

<u>Third Generation (Mid 1980s -- present)</u>
As even a small unit became economical enough, thanks to improved survey technology, successful drilling, sophisticated drilling technology, and accurate resource evaluation. Thus the units in this period are smaller (20 -- 30MW) compared to preceding ones. Refined design and improved operation and management are the factors as well.
Thus Yamagawa, Kakkonda (the No.2 unit), and Ogiri commenced their commercial operations. Also in 1996, thirty years since the commencement of Matsukawa, the output of the installed geothermal plants in this country exceeded 500 MW.

2. SITUATION OF GEOTHERMAL POWER GENERATION IN JAPAN

The installed capacity of geothermal power generation in Japan is 546.9 MW with the generated electricity of 3.532 GWh, which is sixth among the countries. However, it is only a little portion among the electricity sources; as shown in Table 1. Also Table 2 and Fig. 1 shows geothermal power stations in operation as of January 1, 2000. High utilization factor is a topic of these five years and particularly the factor recorded 80.7%, the highest ever, in fiscal 1997 (April 1997 -- March 1998). The achievement may owe to the endeavors of each operation enterprise, based on the knowledge learned through years. This chapter will show the features of each geothermal power station that commenced in the five years. The improvement for the existing geothermal power stations will be described as well. Table 3 shows the geothermal wells drilled in the five years.

2.1 New Geothermal Power Plants in the Last Five Years

** Inside the [] suggests [power generation enterprise/ steam supply enterprise]*.

<u>Yamagawa Power Station</u>
[Kyushu Electric Power Co., Inc./ Japex Geothermal Kyushu Co., Ltd.]
Commenced in March 1995. Output: 30 MW. While most of geothermal power stations in Japan reside at volcanic region, close to one thousand meters above sea level; it is near a coastline at a flat land. As the reservoir temperature is high among the geothermal fields, the turbine inlet pressure (10 kg/cm^2) is high.

<u>Sumikawa Geothermal Power Station</u>
[Tohoku Electric Power Co., Inc./ Mitsubishi Material Corporation]
Commenced in March 1995. Output: 50 MW. The first stage nozzle of the steam turbine equips a cooling device to prevent the drain on the nozzle surface from evaporating, to restrain turbine scale (Amagasa *et al*., 1995). Plural wells are centralized to one base by inclined drilling, to minimize the land to have been changed. As this area has high snowfall,

the warm water from the condenser runs through underground pipelines, to melt the snow around the structures.

Yanaizu-Nishiyama Geothermal Power Station
[Tohoku Electric Power Co., Inc./Okuaizu Geothermal Co., Ltd.]
Commenced in May 1995. Output: 65 MW. While this power station has the largest geothermal unit in Japan, the system was designed as simple as possible to reduce facility costs. Near the power station, the municipal government built greenhouses, which uses warm water from condenser for heating, to demonstrate multi-purpose utilization of geothermal energy.

Kakkonda Geothermal Power Station (the No.2 unit)
[Tohoku Electric Power Co., Inc./Tohoku Geothermal Energy Co., Ltd.]
Commenced in March 1996. Output: 30 MW. The unit uses the reservoir about three thousand meters underground, deeper than that of existing No.1 unit. The system is simplified by omitting stand-by equipments and by appropriating the existing facilities for the No.1 unit. As all the control valves are motor-driven like those in Sumikawa and Yanaizu-Nishiyama, no air compressor is necessary. It also prevents control air tubing from freezing in cold weather. The cooling tower is concentrated-type to help the diffusion of the exhaust fume. Also it can operate at wet/dry modes to prevent the icing on the surrounding trees during winter.

Ogiri Power Station
[Kyushu Electric Power Co., Inc./ Nittetsu Kagoshima Geothermal Co., Ltd.]
Commenced in March 1996. Output: 30 MW. The unit has a module turbine and a common design of the facilities (e.g., cooling tower) with those of Kyushu EPCo.'s existing power stations (i.e., Otake, Hatchobaru, and Yamagawa), to reduce the equipment cost. This plant is the first one within a national park since Mori commenced in 1982.

Takigami Power Station
[Kyushu Electric Power Co., Inc./ Idemitsu Oita Geothermal Co., Ltd.]
Commenced in November 1996. Output: 25 MW. Similar to Ogiri, the power station employs rationalized design based on the experience of the preceding units. The power station locates in Kuju-Aso area where Otake, Hatchobaru, and a couple of private geothermal power stations exist. Also Oguni Point under development is in the region. Thus, the area makes up a most prominent geothermal zone in Japan.

Hachijojima Geothermal Power Station
[Tokyo Electric Power Co., Inc./Tokyo Electric Power Co., Inc.]
Commenced in March 1999. Output: 3.3 MW. This is the first geothermal power station in a small island in Japan. Also it has a vapor-dominant reservoir rare in this country -- Matsukawa is the other one. The geothermal energy is effectively used for various purposes (e.g., space heating for greenhouses) besides power generation. Also the municipal government is actively trying to use other natural energy (e.g., wind force), thus attracting social attention.

2.2 Major Facility Modifications

In the last five years, there was no drastic reform, such as a turbine rotor rebuilding. However, deliberate works supported the utmost use of the resource and the facilities.

Turbine Scale Prevention at Uenotai
In January 1995, Tohoku EPCo, the operator, installed a water injection system at main steam inlet of the turbine. Akita Geothermal Energy Co., the steam supplier, set a mist separator in the steam system. The equipments reduce the concentration of silica, to prevent turbine scale effectively. (Mimura *et al*., 1988)

Output Increase of Uenotai
The operation of Uenotai revealed that the reservoir has extra capacity. The operators planned to produce more steam by using the stand-by wells. In February 1997, they increased the rating output from 27.5MW to 28.8MW, within the design allowance of the facilities.

Modification of Hatchobaru No.1 Steam Turbine
In May 1998, Kyushu EPCo, the operator, made a modification to lower the rating inlet pressure of the steam turbine, as the counter-measure for chronic decline of wells. The result is an increase of blowing volume of production wells and prolongation of their lives. It contributed to the recovery of electric output and saved the cost for supplemental wells.

Hydrogen Sulfide Abatement System for Yanaizu-Nishiyama
The amount of hydrogen sulfide (H_2S) diffused from Yanaizu-Nishiyama plant has been well below the environmental standards. However, Tohoku EPCo., the operator, installed H_2S eliminating device in 1998 for better environmental preservation. In Japan the apparatus is the first for a geothermal power station.

2.3 Geothermal Power Station Under Construction

Now Oguni is the only construction point in Japan. Electric Power Development Co., the developer, is paying sufficient care to protect the scene and environment, as the point is within a natural park. Although there is no definite construction plan after Oguni, the government and private sectors are surveying promising locations (see Chapter 3).

2.4 Deregulation of Electricity and Geothermal Power

The government is planning to reduce medium and long-term electricity cost by deregulation, as a part of structural reform of the national economy. Geothermal energy, like nuclear and hydraulic power, will be out of the competitive bid. However, as the costs of other energies go down, there would be higher pressure for more efficient development and utilization of geotherm.

3. MEASURES FOR SUPPORTING GEOTHERMAL DEVELOPMENT

The potential of geothermal resources for power generation in the country is estimated as about 2,500 MW. However, the installed geothermal power generation is merely around 500 MW, as mentioned in the last section. A factor hindering the development is that advanced technology is necessary for the survey, which implies uncertainty. Also, a development takes a long period and requires substantial pre-investment. Therefore, even an ambitious enterprise cannot always start a project. Furthermore most of the geothermal resources immediately available for power generation have been already developed. Thus the technical break-through to develop unused geothermal resources is crucial.

3.1 Support for Geothermal Development by the Government

The ANRE establishes the national policy for supply of energy, and is playing a core role in development and utilization of geothermal, such as providing subsidy. Table 4 shows the investments for geothermal development by MITI.
On the other hand, the NEDO is playing a central role to support actual geothermal development. The NEDO, organized in 1980, is a special juridical person under the MITI to develop and introduce new energies, besides the research and development of industrial technology. Thus the introduction and promotion of geothermal energy as an alternative for petroleum, has been its major task. The organization is also making international cooperation relating to geothermal engineering (see Chapter4).

Survey for Promotion of Geothermal Development

The NEDO is to make leading survey with the subsidy from ANRE, for promising areas with potential geothermal resources throughout the country. The objective of the survey, which comprises three stages: A, B, and C, is to evaluate the possibility of geothermal power generation.
Survey of fifty-two areas has been initiated since the beginning of the program in 1980 by the end of fiscal 1998 (i.e., March 1999), as shown in Fig. 2. In fiscal 1999 surveys take place in the following six areas:

- Survey A (three years): Survey mainly to detect and confirm a presence of underground high temperature, for areas of 100 -- 300km^2.
  - Kumbetsu-dake (Hokkaido) and Kuwanosawa (Honshu) are the places in this category.
- Survey B (three years): Survey mainly to detect and confirm geothermal reservoir, for areas of 50 -- 70 km^2.
  - Three areas: Musa-dake (Hokkaido), Tsujino-dake (Kyushu), Kumaishi (Hokkaido) are being surveyed.
- Survey C (four years): Survey for areas of 5 -- 10 km^2 to estimate the amount of geothermal resources.
  - Akinomiya (Honshu) is the only location at this stage.

Kyushu Electric Power Co., Inc., a private enterprise, is conducting a survey at Kirishima, Kagoshima Prefecture, Kyushu. In June 1999, production test showed the presence of geothermal resource. The firm is planning to search and estimate the reservoir.

Subsidy and Guarantee of Liabilities

As a support for the pre-investment necessary for geothermal development, the ANRE provides 50% of the expenses of survey wells (repayment upon success). The agency also subsidies 20% of the costs of the wells for production or injection and the generation facilities. The NEDO has a program to guarantee the liabilities for the survey and development for geothermal power generation.

Technical Development for Further Geothermal Usage

As a part of the New Sunshine Project, the NEDO is promoting technical developments in survey, drilling, and exploitation of geothermal resources. Also it conducts long-range projects to develop unused geothermal resources.

- For better understanding of the underground structure and for more accurate reservoir evaluation.
  - Development of Exploration methods using Seismic Wave
  - Development of Technology for Reservoir Mass and Heat Flow Characterization
- For the utilization of unused geothermal resources
  - Deep-Seated Geothermal Resources Survey
  - Development of Drilling and Production Technology for Deep Seated Geothermal Resources
  - Development of the Technologies for Hot Dry Rock Power Generation System
  - Development of a Geothermal Binary Cycle Power Plant using Hot Water
- For more efficient development and utilization of geothermal energy.
  - Development of MWD (Measurement While Drilling) System for Geothermal Wells

3.2 Research and Development by the Government

The AIST belongs to the MITI and is in charge of science and technology. Among the fifteen research organizations under AIST, GSJ and NIRE have closest relation to geothermal development.

Geological Survey Japan (GSJ)

The GSJ is making research and development for survey and development of energy and resources with the latest technology of geophysics and geochemistry. It is planning reasonable and safe utilization of the national land as well.
For geothermal development, the GSJ is conducting the data analysis, model building, and technology evaluation. It also prepares the nationwide geothermal resource map and researches the technologies for survey and evaluation of geothermal resources. Especially in the geothermal portion of the Sunshine Project (presently New Sunshine Project), which was initiated in 1974, it is making research and development in close cooperation with the NEDO.

National Institute for Resource and Environment (NIRE)

The object of the NIRE is doing the research on development and rational use of fossil fuel and resources. It is making researches on geothermal, also total global resources and the environmental problems.
The NIRE has constructed a demonstration of the "Gaia Snow-Melting System," which takes out lower temperature geothermal to melt snow.
The NIRE also is doing research on "MWD," which intends to estimate the situation at the bottom of wells such as hardness of the rock and wear of the bit. The system analyzes the information of bit load, torque, and propulsion ratio at the time of well drilling.
Besides those researches, the NIRE is conducting research tasks related to the New Sunshine Project.

At Tohoku National Industrial Research Institute, Mechanical Engineering Laboratory, and National Institute of Materials and Chemical Research, institutions under the AIST, conducting associated researches on geotherm such as material, method of measuring and logging.

3.3 Supports by Other Organizations

Other organizations in private sector and research organizations are providing supports for the development and utilization of geotherm.

The New Energy Foundation (NEF)

In 1980, after the two petroleum crises, the energy industry in Japan invested to establish the NEF. It is promoting the introduction of new energy, regional energy, and unused energy. It also provides suggestions on the development and use of new energies to government and other organizations.

Central Research Institute for Electric Power Industry (CRIEPI)
In 1951 electric power companies in Japan invested to establish the CRIEPI, as a consolidated research organization. The institute covers the problems of long-term and global resources, environment, and social issues; also the problems that the electric power enterprises are facing.
It has been conducting the researches of key technologies of hot dry rock power generation.

Geothermal Research Society of Japan (GRSJ)
The GRSJ, established in 1978, is an academic association comprising mainly university people and researchers in geothermal enterprises. The GRSJ is holding scientific seminars, lecture meetings and publication of the theses on geothermics such as analysis, modeling, and theorization.

Japan Geothermal Energy Association (JGEA)
The JGEA, established in 1960, is an society in the private sector. The main members are the organizations related to geotherm such as electric power companies, developers, consultants, and manufacturers. The engineers in the businesses are individual members. The JGEA is holding lecture meetings, seminars, inspection tours, and general education activities to the public. It publishes information journals, reports, and statistics.
Table 5 shows the numbers of the members of above-mentioned two organizations.

4. INTERNATIONAL COORDINATION

Japan is making international technical exchange and cooperation programs related to geothermal energy development.

Participation in IEA Projects
The energy technology development department of the IEA is making an international joint research project on energies with little carbon dioxide discharge. The regenerative energy section under said project is going to carry out the tasks of worldwide information exchange on geothermal development technology. Among the tasks, Japan is participating in "influence of geothermal development over environment," "hot dry rock," and "deep-seated geothermal resources." The NEDO is working as an implementation organization for the latter two tasks. The GSJ, the NIRE, and the Tohoku National Industrial Research Institute are rendering cooperation with the NEDO.
The NEDO participates in the CADDET, an IEA joint project with the OECD. The project is to exchange the latest technical information made on energy saving and new energy in the world. The NEDO is also participating in GreenTie, another joint project of the IEA and the OECD, to exchange technical information for reducing greenhouse effect gas.

Cooperation in Research on Survey of Small Scale Geotherm in Remote Solitary Islands
The NEDO and the GSJ are making geothermal survey with the Volcanology Survey of Indonesia and the Perusahaan Listrik Negara for solitary island area in East Indonesia (e.g., Flores Island). This project was initiated in the fiscal 1997 and is to be completed in March 2002. (International Geothermal Association, 1999)

International Group Training Course
The UNESCO, the JICA and Kyushu University have held International Group Training Courses in Geothermal Energy. The objective is to provide comprehensive knowledge from survey to the operation of a power station through studies and field trips over several months. Since 1970 the courses have continued every year to date, upgraded to advanced courses since 1990. (Fukuda, 1994)
The aggregate number of the participants to these courses reached 351, at the end of fiscal 1998. They are from mainly developing countries in Asia, Middle and South America and Eastern Europe. They are working as geothermal specialists in their home countries after finishing the courses.

Support for Developing Countries
Japan is supporting the geothermal utilization in the developing countries in Southeastern Asia and the Pacific Rim of the South America, etc. The aid range from surveying geothermal resource, constructing geothermal power stations, to renewing existing geothermal power plants.
Also the JICA is transferring geothermal technology. As geotherm persists for a long period, it is not necessary to import fuel in future. Thus application of geothermal energy is beneficial for the self-reliance of developing countries.

5. CONCLUSION

Japan, which has little natural resources, should develop geothermal resources more. It will be necessary to build a new scheme of development with the conservation of nature and the cooperative arrangement with local communities, to develop the geothermal resources within natural parks.
The geothermal is excellent clean energy with very little CO_2 discharge, a cause of global warming.
In COP3 in 1998 in Kyoto, Japan, the participants recognized international coordination such as joint implementations and clean development mechanism as the means to reduce CO_2 discharge. While Japan is investigating possibility of the projects with various parts of the world, geothermal development in Russia and Asian countries is in the scope.
Japan is expected to apply its advanced technologies in development and utilization of geotherm, learned through domestic development, in other countries. It is not only to achieve the target of reduction of CO_2 discharge but also to play a role in the international society.

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TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICTY

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (specifiy)		Total	
	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr
In operation in January 2000	520	3,600	131,980	474,700	43,820	98,100	44,920	329,600	1 (wind power)	1,900	221,240	907,900
Under construction in January 2000	0		16,851		6,971		3,305		0		27,127	N/A
Funds committed, but not yet under construction in January 2000	20		17,757		4,856		9,974		0		32,607	N/A
Total projected use by 2005	540	3,900	153,430	578,800	46,110	97,000	45,740	320,500	1		245,820	1,000,200

TABLE 2. UTILIZATION OF GEOTHERMAL ENERGY FOR ELECTRIC POWER GENERATION AS OF 1 JANUARY 2000

1) N = Not operating (temporary), R = Retired. Otherwise leave blank if presently operating.

2) 1F = Single Flash; 2F = Double Flash; 3F = Triple Flash; D = Dry Steam; B = Binary (Rankine Cycle); H = Hybrid; O = Other (please specify)

3) Data for fiscal 1998 (1 April 1998 - 31 March 1999)

Locality (prefecture)	Power Plant Name	Year Com-missioned	No. of Units	Sta-tus[1)]	Type of Unit[2)]	Unit Rating MWe	Total Installed Capacity MWe	Annual Energy Produced 1999[3)] GWh/yr	Total under Constr. or Planned MWe
Hokkaido	Mori	1982.11.26	1		2F	50.0	50.0	188.489	
Akita	Sumikawa	1995. 3. 2	1		1F	50.0	50.0	361.651	
Iwate	Kakkonda	1978. 5.26	2		1F	50.0	80.0	199.508	
		1996. 3. 1			1F	30.0		201.724	
Akita	Uenotai	1994. 3. 4	1		1F	28.8	28.8	237.743	
Miyagi	Onikobe	1975. 3.19	1		1F	25.0	25.0	101.208	
Fukushima	Yanaizu-Nishiyama	1995. 5.25	1		1F	65.0	65.0	426.846	
Oita	Otake	1967. 8.12	1		1F	13.0	13.0	104.908	
Oita	Hatchobaru	1977. 6.24	2		2F	55.0	110.0	381.994	
		1990. 6.22			2F	55.0		469.825	
Kagoshima	Yamagawa	1975. 3. 1	1		1F	30.0	30.0	146.006	
Kagoshima	Ogiri	1976. 3. 1	1		1F	30.0	30.0	262.570	
Oita	Takigami	1976.11. 1	1		1F	25.0	25.0	217.086	
Akita	Onuma	1974. 6.17	1		1F	10.0	10.0	63.135	
Iwate	Matsukawa	1966.10. 8	1		D	23.5	23.5	157.362	
Oita	Suginoi	1981. 3. 6	1		1F	3.0	3.0	10.671	
Kagoshima	Kirishima Kokusai Hotel	1984. 2.23	1		1F	0.1	0.1	0.674	
Kumamoto	Takenoyu	1991.10.19	1	N	D	0.2	0.2	0.000	
Tokyo	Hachijojima	1999. 3.25	1		D	3.3	3.3	0.231	
Kumamoto	Oguni	2000.4	1	N/A	1F	20.0			20.0
Total			20			566.9	546.9	3531.631	20.0

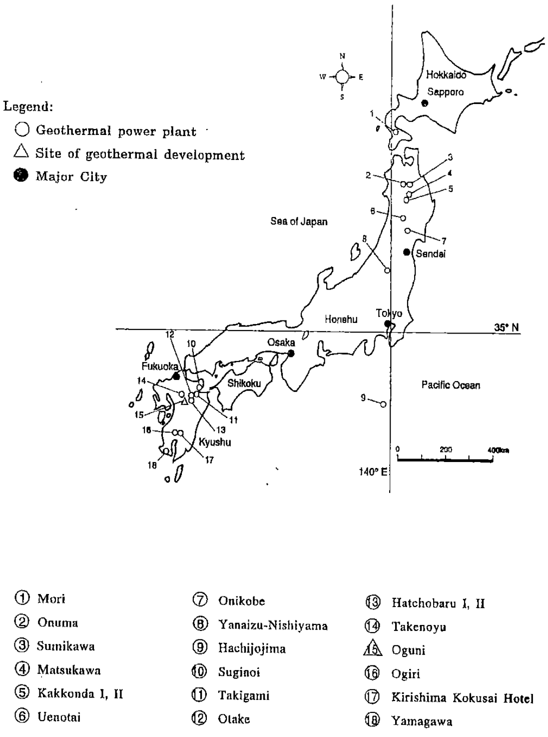

FIG. 1. GEOTHERMAL POWER STATIONS IN JAPAN

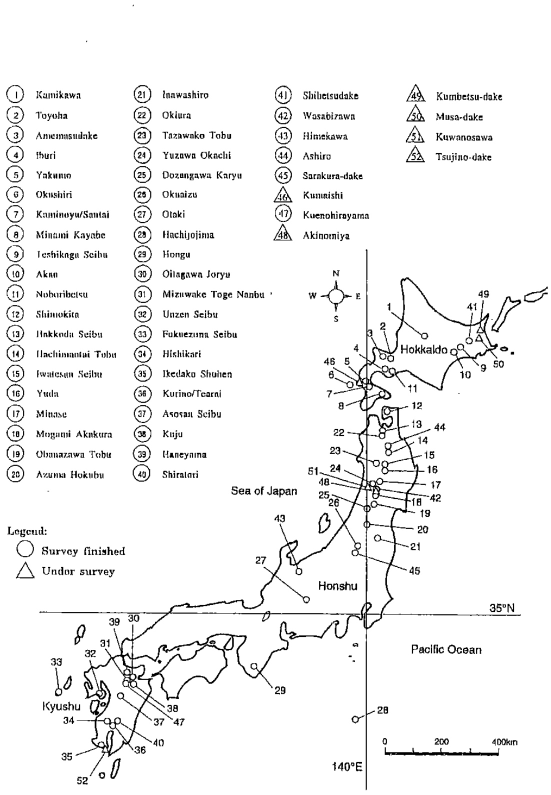

FIG. 2. AREAS SURVEYED BY NEDO

TABLE 3. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 1995 TO DECEMBER 31, 1999

[1)]Include thermal gradient wells, but not ones less than 100 m deep

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Com-bined	Other (specify)	
Exploration[1)]	(all)	52.8				52.8
Production	>150°C	26.9				26.9
	150-100°C	0				0
	<100°C	0				0
Injection	(all)	16.3				16.3
Total		96				96

TABLE 4. TOTAL INVESTMENTS IN GEOTHERMAL IN (1999) US$

Period	Research & Development (by AIST) Million US$	Field Development Including Production (by ANRE) Million US$	Total (by MITI) Million US$
1985-1989	493.7	233.6	727.3
1990-1994	198.9	433.9	632.8
1995-1999	345.4	121.6	467.1

A I ST = Agency of Industrial Science and Technology
ANRE = Agency of Natural Resources and Energy
Note: JPY is converted to US$ at US$1=JPY120

TABLE 5. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL

(1) Member of JGEA (individual)
(2) Member of JGEA (corporate)
(3) Member of GRSJ (individual)
(4) Member of GRSJ (corporate)

Year	Professional Person-Years of Effort			
	(1)	(2)	(3)	(4)
1995	470	110	821	117
1996	448	108	810	115
1997	445	109	804	113
1998	430	108	787	111
1999	408	101	771	107
Total	2,201	536	3,993	563

JGEA = Japan Geothermal Energy Association
GRSJ = Geothermal Research Society of Japan