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GEOTHERMAL ENERGY UPDATE OF NEPAL

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ABSTRACT

Geothermal manifestations occur in more than twenty-eight localities in Nepal, scattered for the most part along the Main Central Thrust and the Main Boundary Fault. Based on preliminary scientific studies conducted in the early 80s over a dozen geothermal localities, attempts to utilize geothermal energy were abandoned since the subsurface temperatures were not economically viable for generating electricity. The subsurface temperatures later measured with other geothermometers were also found to vary between 50° and 120°C. The surface temperature of thermal water in different places ranges between 23° and 73°C.

Great importance has been given to popularizing the use of low temperature water in the media, successfully drawing the attention of the energy planners. as a result, the ninth Plan of nepal (1997-2002) has, for the first time, envisaged the preparation and/or updating of the inventory of geothermal localities as well as conducting a few pilot projects.

While many hot spring localities have been holy places for religious activities, some of them have also served as hospitals for the rural poor for a long time. Amazingly, people from quite distant places visit the Singha Hot Spring in Western Nepal in the belief that hot spring water is a panacea for many diseases. preliminary analysis of geochemical data, including isotopic studies, indicates that there is a large geothermal reservoir in western Nepal. A detailed scientific study of this area could be more rewarding. A relatively high population density and good road access also weigh heavily in favor of the utilization of geothermal resources in this area. Nepal also described its hot spring areas as ideal tourist destinations during its "Visit Nepal 1998" program and gave them great publicity on national television. The hot spring in Myagdi district had already been a very popular place for many foreign tourists undertaking the famous Mount Annapurna circuit.

Although drilling activities for a large-scale utilization of geothermal water are still an onerous task for many localities, there is now a better chance of doing so in some places because of improved roads. His Majesty's Government of Nepal (HMG/N) is placing great emphasis on road construction, linking more thermal locations and this will definitely increase the opportunities of conducting detailed scientific and of utilizing the resource.

1. INTRODUCTION

1.1 General Description of Geothermal Localities

Geothermal manifestations occur in more than twenty-eight localities in Nepal, stretching right across a southeast-northwest elongated region (Fig. 1). Most of these are confined to three distinct tectonic and structural features that characterize the Himalayas in general. The first group is located beyond the Higher Himalayas and north of the main Central Thrust (MCT), which itself is situated between the units of the Lower and Higher Himalayas. It dips northwards and separates into two very different assemblages of rock. Below it are gneiss, schist, phyllite, quartzite, and marble of the Lesser Himalayan Formations. Above it, a sequence of high-grade metamorphic rocks, the Higher Himalayan Crystalline Series, crops out in front of the Higher Himalayas. The second group of thermal springs lies close to the MCT. Along much of the southern edge of the Lower Himalayas, klippen of high-grade rock overlie, in sharp fault contact with the lower-grade rock of the Lesser Himalayas, and mark the southern known limit of the MCT; this is termed the Main Boundary Fault (MBF). A complete profile of all the geothermal localities of Nepal has still to be prepared. A description follows of some of the major thermal springs, according to their geographical regions.

<u>Far Western development region</u>

The thermal springs in the Darchula district occur in three places. The Sina thermal springs occur in crystalline rocks located near the thrust contact between the overlying augen gneiss and the underlying sericitic schist and quartzite. The thrust is displaced by a recent fault on which many springs are aligned. In Sribagar, the hot springs rise from the recent river sediments and are located near the tectonic contact between the autochthonous metasedimentary zone of Baitadi-Bajhang and the crystalline sheet. The tectonic contact is marked by the highly crushed chlorite-sericite-quartz phyllites on the ridge east of Sribagar. The Chamaliya spring issues from the recent terrace deposit and is confined to a metasedimentary autochthonous zone composed of slates and carbonate rocks. The thermal springs in Bajhang district are near the major thrust between the crystalline allochthonous and metasedimentary autochthonous zones. The purple shale and green sandstone with gritty quartzites are highly folded. The major thermal source is located near the thrust zone whereas the minor sources are either near some fault or the contact zone of different lithological units. in Jumla the thermal springs occur mainly in two places. several closely located hot springs can be found on the right bank of Tila Nadi. Gas seepage occurs in some of them in recent deposits of gravel and boulders with sandy-silty clay. Mini-folds and micro-faults can be observed along the Tila Nadi valley indicating the neotectonic activity. Two seepages occur at the fracture joints in the calcareous gneiss and marble. in Dhanchauri area the spring issues from the light-grey platey dolomite and is characterized by a thick tuffaceous deposit consisting of carbonate and silica. three major hot springs are located here.

Western development region

Rior thermal spring is located at the south of the siwalik formation (a northern chain of hills reaching a height of some 1500 m) and the immediate vicinity is covered by soil. The Mayangdi spring issues from the base of a cliff of poorly cemented Quaternary conglomerates. An extensive fault passes through it, and carbonaceous schist and siltstones are exposed on both sides of the fault. There are four springs in this locality. The rock in the area surrounding Surai Khola thermal spring is sandstone, siltstone and clay, belonging to the middle Siwalik. There are two discharge points in this area. The springs in Jomsom area are grouped at the foot of a berm about 100 m high on the bank of the Kali Gandaki River. Five springs are located here. Several other geothermal springs can be discerned in the western region. the prominent ones are bhurung tatopani, dokhola, singha Tatopani (myagdi district), chhumrung and dhadkharka (parbat district), dhee (Mustang district), chame and la To Manang (Manang district), bhulbhule khar (Lamjung district) and khar Pani (Kaski district). -

Central development region

The Chilime thermal spring issues on the top of a cliff and has one discharge point. the surrounding bedrock consists of quartz, biotite sandstone, graphitic argillaceous schist and siliceous limestone. Likewise, two springs issue at Syabru Besi. Hot water issues at several points in the Kodari area. The surrounding bedrock is of quartz biotite sandstone overlain by slightly graphitic argillaceous schist and underlain by siliceous limestone.

Eastern development region

Only one thermal spring at Hatiya (Sankhuwasabha district) has been identified so far in eastern Nepal. Geochemical studies of this area are, however, lacking.

1.2 Heat Source

Since heat flow in Nepal falls within the global mean range (60 – 80 mW/m^2) and most thermal springs are located very close to the MCT or MBF, the heat acting on the spring water is likely to be of tectonic origin. The MCT is a major tectonic boundary, occuring along most of the length of the Himalayan chain, and it seems likely that while slip was occuring in the Everest region it was also occuring in the Annapurna – Manaslu region in Western Nepal. Secondly, in the migmitized zone the leucogranitic melts from which the granite was derived vary from being intensively sheared by the MCT deformation to cutting across the fabrics of that formation, indicating that melt was present in the MCT zone during, and at a late stage of, its major movement. There are no known geologically recent magmatic intrusive and/or volcanic rocks in the Nepal Himalayas.

2. DATA ON THERMAL SPRINGS AND FINDINGS

Some new geothermal localities have been identified in different parts of Nepal over the past four years and attempts have been made to update the geochemical data of some springs and establish new geochemical data for some of them. Data for flow rate, pH, major cations and anions, dissolved solids, silica, and surface temperatures are available for some of the locations. geothermal temperatures, ionic balances and discharge enthalpy were calculated from the available data using the Program WATCH. The updated chemical data of the thermal springs are given in Table 1. The maximum surface temperature recorded was 73°C in Sribagar, followed by 71°C in Bhurung Tatopani. Temperatures above 40° C were recorded for six other springs. Table 2 lists the results of the chemical analyses for some thermal springs.

Evaluation of Na-K and K-Mg equilibrium temperatures of the thermal springs shows that the springs waters are all shifted, to varying degrees, towards the magnesium corner. This points to extensive interaction of the spring water with rock at comparatively low temperatures.

The types of thermal waters available in Nepal have also been confirmed from detailed chemical studies. The plots of log Q/K versus temperature curves for thermal waters of various locations indicate that the spring waters of Jomsom, Sadhu Khola, Bhurung Tatopani, Chilime, Sribagar, Dhanchaur and Tila Nadi are in equilibrium and all the other springs waters are unsaturated with the most common hydrothermal alteration minerals. The Cl - SO_4 - HCO_4 diagram indicates that the spring waters from Bhurung Tatopani and Sadhu Khola are chloride waters (relatively mature), and those of Jomsom, Dhanchauri-Luma, Mayangdi, Surai Khola and Chilime are representative of the waters with high CO_2 reactivity.

A combination of isotopic studies (o^{18}/O^{16} and D ratios of water samples from 36 hot springs in western nepal and tritium activity) and the other chemical analyses indicates that a large geothermal reservoir exists in western Nepal.

3. GEOTHERMAL AS AN ALTERNATIVE ENERGY RESOURCE IN NEPAL

Nepal's energy sector is still dominated by only a few resources. The bulk of the country's energy requirements is met by traditional resources such as wood fuel, agricultural waste and animal dung. Commercial energy, mainly comprising petroleum products, coal, and electricity, contribute about 5 % of the total energy supply. This situation puts constant pressure on the already depleted forestry resources. Efforts have been made in the past to harness some alternative sources of energy; biogas, for example, is becoming a significant and economic substitute for wood at present, owing to heavy investments in the development and promotion of this resource. However, the population in the northern colder and hilly regions are deprived of this energy because the technology is not successful in these climatic conditions.

A few solar power plants have been installed in some districts. However, satisfactory results have not been achieved because of high installation costs and the problems associated with maintenance and repairs. Wind energy is not used to any practical extent in Nepal even though some places have been considered feasible. The quantity of power that can be generated is still unknown. So far, two wind turbines with a total capacity of 20 kW_e have been installed in Mustang but with extremely limited success.

Although the success of sustainable development in Nepal lies in exploiting its abundant hydropower for energy, the Mega-project approach is time-consuming and relies heavily on foreign loans and assistance. His Majesty's Government of Nepal (HMG/N) has recently emphasized the need to set up mini-hydroelectric plants (100 kW_e or less). Recently, it has been able to attract a few private entities in this venture under the rural electrification program but there is a long way to go before this program will be fully realized.

The Perspective Energy Plan document (1992/93) identified geothermal as one of the alternative energy resources that need to be tested and proved viable in Nepal. However, no programs have been drawn up so far.

4. IMPEDIMENTS AND PROSPECTS

Two factors have led to the total lack of exploitation of geothermal energy in Nepal: the lack of knowledge on the application of low-temperature waters in economically feasible activities and poor road networks. The execution of large geothermal projects for direct applications involves the drilling of wells, which entails the operation of drilling rigs. The location of the geothermal springs, mostly in the remote and steep Himalayan terrain, acts as a natural constraint to their development because of the lack of a good road network. This was one of the major impediments in the past to finding approval for this resource. However, significant progress has been made in constructing roads in the hilly and mountainous regions over the years, providing good access to some geothermal localities (e.g. in Kodari, Syabru Besi). The Chilime geothermal area can be accessed by road with little effort. HMG/N is currently committed to constructing North-South highways in the Western and Far-Western region of Nepal. Some projects have already been initiated and are expected to be completed within a few years. The projects involving geothermal localities include Baglung-Beni-Jomsom sub-Highway and Karnali Highway (Surkhet-Jumla portion). HMG is to initiate a Chameliya Hydroelectricity Project quite soon, linking Chameliya and also opening an access road to the Sribagar and Sina - Tatopani geothermal localities in Darchula district. Evidently, development of geothermal energy is becoming an increasingly more viable propsect as far as road infrastructure is concerned.

Until now, the use of hot spring waters in Nepal has been largely confined to bathing and laundering. However, some hot spring locations have been used as holy places and some localities have also served as free hospitals for the rural poor for a long time. Amazingly, people from quite distant places visit the Singha Hot Spring in Western Nepal, in the belief that its hot spring water is a panacea for many diseases. People suffering from skin diseases, gastroenteritis, leprosy and stomach pains have tremendous benefits. The number of visitors is increasing at an alarming rate. Detailed scientific studies of this area could be really rewarding for the local people as well as for those involved in the medical profession.

Many of the thermal springs of Nepal are located in the northern colder parts where there is no hydroelectricity .and other sources of alternative energy are as yet untapped. Exploitation of geothermal energy in these areas might produce several economically productive activities. Chemical results indicate that the subsurface temperatures of geothermal locations in Darchula, Jumla, Bhurung Tatopani, Sadhu Khola, Mayangdi and Chilime are in the range 85 to 115°C. These waters could, for example, be used for space-heating, in greenhouses, for drying stock-fish, agricultural products and cement blocks, etc. Likewise, the range of subsurface temperatures available in different places could permit a number of direct utilizations; for instance, double crops could be achieved in the northern parts through soil heating, greenhouse farming in the high mountains, domestic use, balneology and some rural industry, fish farming, space heating, air conditioning, animal husbandry, etc.

Geothermal energy can be utilized for the promotion of the tourist industry in various parts of nepal. Every year thousands of foreign tourists trek the chhumrung- Bhurung Tatopani-Jomsom area in the famous annapurna Circuit, and Syabru Besi. A hot water supply to hotels and the construction of swimming pools would provide added comfort and help to lengthen their stay.

5. PRESENT EFFORTS FOR DEVELOPMENT

One of the major reasons for the under-exploitation of geothermal energy in Nepal is a lack of knowledge among the energy planners and the general public about the possible direct uses of low temperature waters such as can be found in Nepal. Over the past four years a great deal of effort has been expended in publicizing the importance of direct geothermal uses in magazines and on national television. This has helped ordinary people to understand the potential of this resource.

The Ninth Plan (1997 – 2002) has, for the first time, included geothermal energy among the alternative resources to be considered. It aims to collect and/or update information on the geothermal resources of Nepal. The plan also aims to carry out some pilot projects in the feasible geothermal locations. A modest budget has been allocated for this project but so far nothing has happened because of the low priority accorded to it. HMG/N has however recently created the Alternative Energy Promotion Center, which is currently focussing on the biogas projects but has included geothermal energy among the potential resources.

Plans are under way to analyze geothermal gases found in various parts of Nepal as part of a joint foreign collaborative project. The project is expected to provide substantial first-hand information on many thermal springs of Nepal. The Ninth Plan also aims to encourage the private sector to arrange attractive visits to the hot spring areas.

HMG/N is preparing a Renewable Energy Perspective Plan of Nepal in which geothermal energy will be considered a potential resource. Geothermal is therefore expected to gain further importance in the energy development scenario of Nepal in the future. The recently established Center for Energy Studies of Tribhuvan University will shortly add geothermal energy to its curriculum at the graduate level as part of a course on renewable energy engineering, besides organizing short courses in the subject for planners, administrators, journalists and technical personnel in different fields.

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Figure 1: Location of thermal springs in Nepal

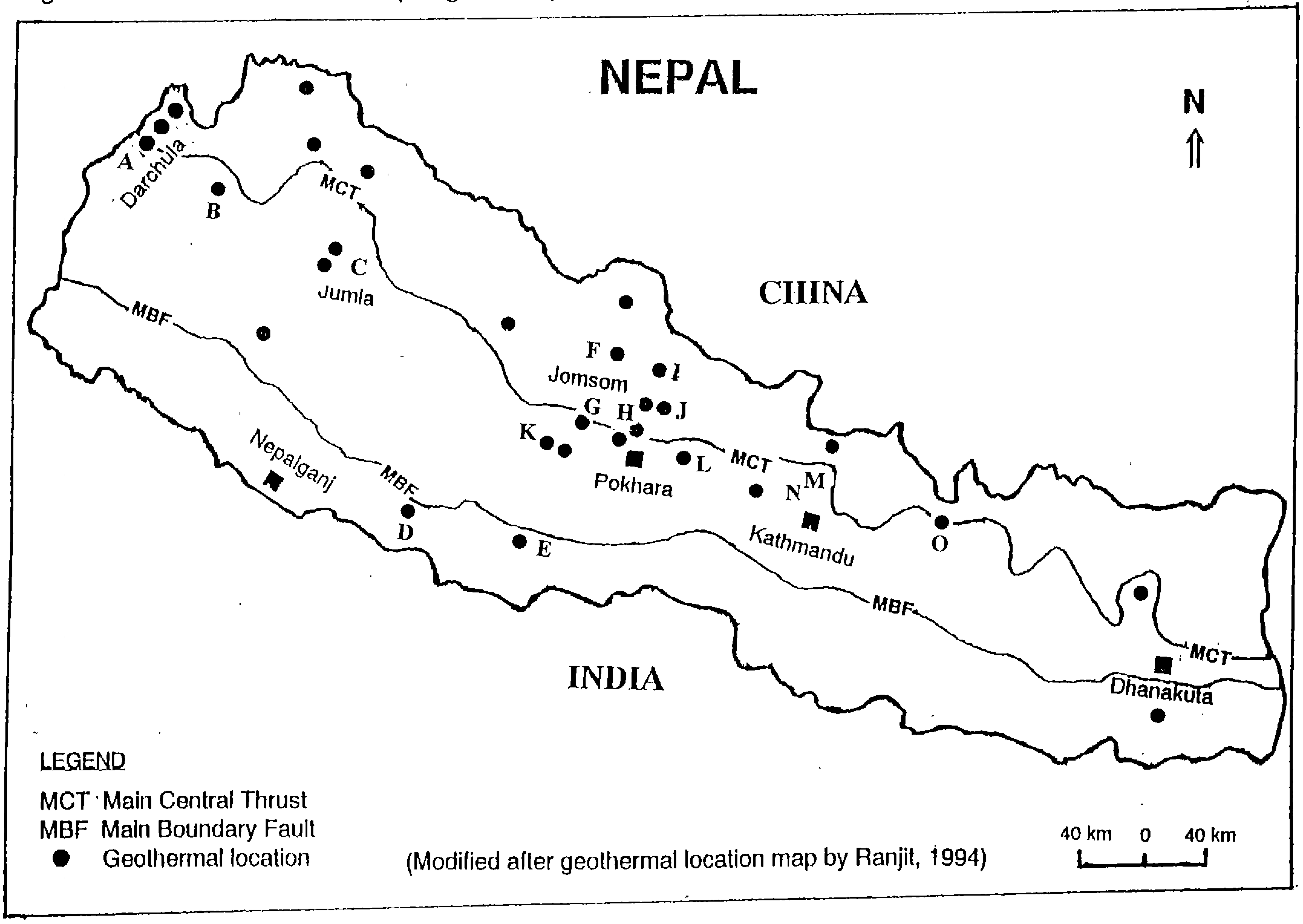

Table 1. Information about geothermal localities and temperature in nepal

Locality	Symbol	Location		Flow rate (l/s)	Surface temp. (°C)	Geothermometer temp. (°C)			Ionic balance diff. (%)	Discharge enthalpy (kJ/kg)
		Lat. (E)	Long. (N)			SiO_2	Chalce-dony	Na/K		
Darchula	A									
Sribagar		80.6°	29.9°	0.85	57-73	86.2				361
Sina-Tatopani		80.7°	29.9°	0.76	waro					
Chamaliya		80.6°	29.7°	0.25	warm	37.6				158
Bajhang-Tapoban	B	81.2°	29.6°	0.2	warm	55.1				126
Jumla	C									
Dhanchauri- Luma		82.3°	29.3°	0.6	24	106.9		88.2		448
Tilanadi		82.1°	29.2°		36-42	110.6			-34.26	464
Rior	D	82.7°	27.9°	1.5	33		54.2	52.3		227
Surai Khola	E	83.3°	27.8°		37		50.1	100.4	4.8	210
Jomsom	F	83.7°	29.8°	0.2- 5	21	50.3			1.61	211
BhurungTatopani	G	83.7°	28.5°	1.8	71	115.4			-0.19	484
Sadhu Khola	H	84.2°	28.4°	1.39	69	109.8		115.3	4.52	460
Kharpani	I	84.1°	28.4°	0.4	48					
Mayangdi	J	83.5°	28.4°	2	40	89.8			-21.03	376
Singha Tatopani	K	83.3°	28.2°	5	46-55					
Bhulbhule Khar	L	84.2°	28.2°	1.05	34					
Chilime	M	85.3°	28.3°	0.83	48	98.8				386
Syabru Besi	N	85.2°	28.1°	0.3	34	86.5	55			
Kodari	O	83.9°	27.9°	5	42	96.5				17

Table 2. Results of chemical analyses of some thermal springs in Nepal (in mg/kg)

Location	**pH**	**Na**	**K**	**Mg**	**Ca**	**Cl**	**SO_4**	**HCO_3**	**SiO_2**	**B**	**TDS**
Bhurung Tatopani	7	365	90	30	102	555	217	387.5	67.6	13	1841
Jomsom	8	60	5.6	54	113	96	249	302	14.3	2.4	889
Jumla											
Tila Nadi	7.3	56	0	1.2	6	45	130	0	60	0	353
Dhanchauri-Luma	7	49	1.3	0.2	6.1	82	104	217	56	0	803
Mayangdi	8	460	49	17	2	351	68	430	43	0.3	1340
Rior	9	310	4	3	4	14	70	7.9	37.5	6	788
Surai Khola	9	123	3.9	28	18	3.2	70	370	38.5	trace	510
Darchula											
Sribagar	7	100	11	8.5	n.d.	34.2	18.5	n.d.	35	0	516
Chamliya	7	n.d.	n.d.	n.d.	n.d.	39.6	10.7	n.d.	10	n.d.	1320
Tapoban-Bajhang	6	n.d.	22	10	n.d.	50.1	25.9	n.d.	16	0	444
Sadhu Khola	7	300	12	0.6	10	286	197	78	60	0	954
Chilime	7	7.35	8.1	20.8	25.8	10	6	180	47.1	0	166
Syabru Besi (SB)											
SB1	8	73	44	84	38	66	94	848	59.7	n.a.	620
SB2	7.5	7.2	12.5	90.5	75.9	12	121.4	760	35.3	n.a.	1300
Kodari	7.3	147	29.7	20.5	53.5	31.5	85.6	412.5	44.3	1.36	n.a.

Table 3. Present and planned production of electricity in Nepal

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (Solar)		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			60.27		256.20				0.13		316.60	
Under construction in January 2000					293.66				0.17		293.83	
Funds committed, but not yet under construction in January 2000					65.00						65.00	
Total projected use by 2005			60.27		614.86				0.30		675.43	

B = Bathing and swimming (including balneology)

Capacity (MWt) = Max. flow rate (kg/s)[inlet temp. (^oC) - outlet temp. (^oC)] x 0.004184 ($MW = 10^6$ W)
or = Max. flow rate (kg/s)[inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

Energy use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (^oC) - outlet temp. (^oC)] x 0.1319 ($TJ = 10^{12}$ J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.03154

Capacity factor = [Annual energy use (TJ/yr) x 0.03171]/Capacity (MWt) * Estimated

Locality	Type	Maximum Utilization					Capacity	Annual Utilization		
		Flow Rate (kg/s)	Temperature (^oC) Inlet	Temperature (^oC) Outlet*	Enthalpy (kJ/kg) Inlet	Enthalpy (kJ/kg) Outlet	(MWt)	Ave. Flow* (kg/s)	Energy (TJ/yr)	Capacity Factor
Singha Tatopani	B	5.0	41	30			0.230	4.1	5.949	0.820
Bhurung Tatopani	B	1.8	42	30			0.090	1.3	2.058	0.725
Kodari	B	5.0	42	32			0.209	3.5	4.617	0.700
Mayangdi	B	2.0	40	31			0.075	1.5	1.781	0.750
Bhulbhule Khar	B	1.0	34	28			0.025	0.7	0.554	0.700
Sadhu Khola	B	1.4	41	34			0.041	1.0	0.923	0.714
Chilime	B	0.8	40	36			0.013	0.6	0.317	0.750
Sribagar	B	0.8	40	32			0.027	0.6	0.633	0.750
Chameliya	B	0.2	32	25			0.006	0.1	0.092	0.500
Tapoban	B	0.2	37	30			0.006	0.1	0.092	0.500
Dhanchauri	B	0.6	24	23			0.003	0.4	0.053	0.666
Tilanadi	B	0.7	42	35			0.021	0.4	0.369	0.571
Rior	B	1.5	33	25			0.050	1.0	1.055	0.666
Surai Khola	B	1.0	37	30			0.029	0.5	0.462	0.500
Jomsom	B	0.8	21	20			0.003	0.5	0.066	0.625
Kharpani	B	0.4	42	32			0.017	0.3	0.396	0.750
Syabru Besi	B	0.3	34	30			0.005	0.2	0.106	0.666
Others*	B	10.0	40	35			0.209	4.0	2.638	0.400
TOTAL							1.059		22.16	0.663

Table 5. Summary table of eothermal direct heat uses in Nep al at 31 December 1999

1) Installed Capacity (MWt) = Max. flow rate (kg/s) x [inlet temp. (^{o}C) - outlet temp. (^{o}C)] x 0.004184
or = Max. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalphy (kJ/kg)] x 0.001

2) Annual Energy Use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (^{o}C) - outlet temp. (^{o}C)] x (TJ = 10^{12} J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg) x 0.03154

3) Capacity Factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171

Use	Installed Capacity[1)] (MWt)	Annual Energy Use[2)] (TJ/yr = 10^{12} J/yr)	Capacity Factor[3)]
Space Heating			
Air Conditioning (Cooling)			
Greenhouse Heating			
Fish and Animal Farming			
Agricultural Drying			
Industrial Process Heat			
Snow Melting			
Bathing and Swimming	1.06	22.16	0.66
Other Uses (specify)			
Subtotal	1.06	22.16	0.66
Geothermal Heat Pumps			
TOTAL	1.06	22.16	0.66

Table 6. Allocation of professional personnel to geothermal activities in Nepal
(Restricted to personnel with a University degree)

(1) Government
(2) Public Utilities
(3) Universities
(4) Paid Foreign Consultants
(5) Contributed through Foreign Aid programs
(6) Private Industry

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
1995			1			
1996			2			
1997			2			
1998			1			
1999			2			
Total						

Table 7. Total investment in geothermal in (1999) US$

Period	Research & Development Incl. Surface Explor. & Exploration Drilling	Field Development Including Production Drilling & Surface Equipment	Utilization		Funding Type	
			Direct*	Electrical	Private	Public
	Million US$	Million US$	Million US$	Million US$	%	%
1985-1989			0.006		100	
1990-1994			0.007		100	
1995-1999			0.007		100	

* Estimated