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Geothermal Energy in Iran

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ABSTRACT

Activities in the field of geothermal energy in Iran are focused on scientific and research aspects, and research part is aimed at reduction of capital required for exploitation of related resources. The second step is to work research results into scientific dimension of this field for practical means, i.e. establishing electricity power plants and direct uses. At the moment, projects assuming 50 MWe of geothermal power plants are underway. Based on the planning in the 4th Socioeconomic and Cultural Development Plan (2005–2010), private sector is expected to have a share of at least 500 MW in renewable energies. However, it is the government's duty to take the first step for investment in geothermal energy. The project of Iran's renewable energy, aims to accelerate the sustainable development of geothermal energy through investment and removal of barriers.

The potential of geothermal development in Iran is large in terms of moderate, low and high temperature. Distribution map of potential areas for geothermal resource in Iran have been drawn which shows 14 suitable regions for geothermal activities. Between these 14 regions, Sabalan region seems to have the most considerable resources and Meshkinshahr field also in this region has priority for installation of a geothermal power plant. Surface and drilling exploration and resource assessment have been ended. According reservoir numerical model and feasibility study, 50 MW power plant for 5 km2 area was proved. Extention of reservoir has been predicted 20 km2 and 250 MW installed capacity was expected from this field. The new exploration and delineation wells are in progress.

1-INTRODUCTION

Due to decomposition of the internal earth's crust elements, huge amount of heat is produced. At the most subterranean layers of the earth, temperature increases so high that stones and soils are melted. If underground flowing water passes in close vicinity, it becomes hot. The Geothermal resources is not same everywhere and these resources mostly exist wherever there is a volcano.

Geothermal energy is classified as direct use (heating) and indirect use (electricity) energy. Direct heat use is one of the oldest, most versatile and also the most common form of utilization of geothermal energy. This method is mostly used in the countries like Island, USA, Hungary, Italy and etc. Another way of using this energy is generation of electricity. Very hot water and vapor is transferred to power plants through pipelines to start rotating and keep on moving turbines. Some of the countries such as New Zealand, Philippines, America, Italy, Japan, Iceland, Turkey, Indonesia, China, etc., have built power plants to generate electricity from geothermal energy. The forecasts of geothermal power were supposed to be at 11025.8 MW[1].

Geothermal energy is fuelled by a resource that is sustainable in economic, social and environmental terms .Geothermal energy has the capacity to provide cost-effective energy to remote communities without the added investment of providing fossil generation. The degree to which such efforts will be successful will be driven in part by the existence of geothermal resources and reliable cost-effective technology. Success will also depend on good policy decisions being made. In many cases compromises are required since options are mutually exclusive. In other cases, carefully considered policy can minimize the conflict between renewable and non-renewable energy.

2-GEOTHERMAL RESOURCES

Interest in the geothermal energy originated in Iran since Mr. James R. McNit [2], a United Nations geothermal expert visited Iran (December 1974). He reported that Iran has very promising prospects for geothermal energy development. Upon Mr. McNitt's recommendations in 1975, a contract between Ministry of Energy (MOE), ENEL (Entes Nazionale per L'Energia Elettrica of Italy) and TB (Tehran Berkeley consulting Engineers of Iran) was signed for geothermal exploration in Northern part of Iran (Azarbaijan & Damavand regions)[3].

Final reports of the regional investigations performed by ENEL for Northern part of Iran were delivered during 1980-1983. According to these reports and investigations of Electric power Research center (EPRC), priorities were given to the Sabalan, Damavand, Khoy-Maku and Sahand regions (fig. 1). Such findings were approved by Dr. Valgardur Stephenson [4] (Inter regional Adviser on Geothermal Energy, United Nations) on his visit to Iran of 1989.

The Meshkinshahr area in Sabalan region has been selected for the first exploration drilling site. The maximum temperature of local thermal springs is 83.5 ^{o}C. The Renewable Energy Organization of Iran (SUNA) as part of Ministry of Energy was done similar investigating in all of Iran during 2000-2002 [5]. the investigations approved 10 more potentially suitable regions for this purpose in other parts of Iran. Fig. 2 shows geothermal prospects of Iran.

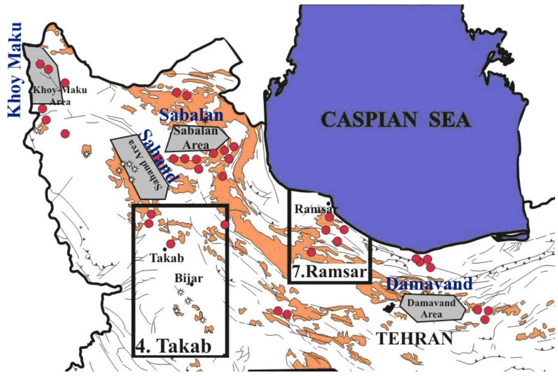
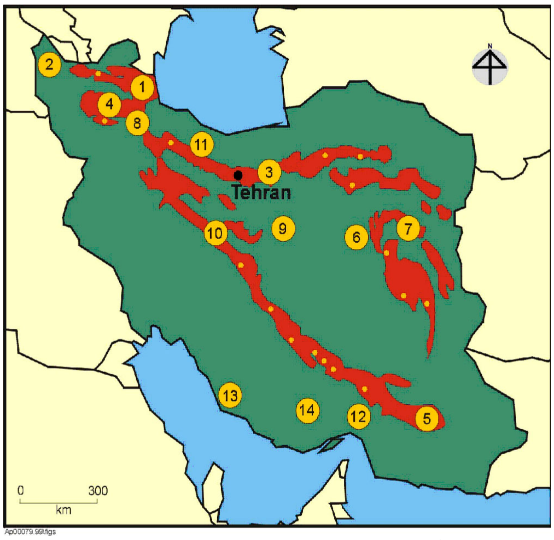


Fig.1 – The Regions identified by ENEL



1-Sabalan 2-Kuoy Maku 3-Damavand 4-Sahand 5- Taftan6-Tabas 7-Ferdos 8- Takab 9- Khour biabanak 10-Mahalat 11- Ramsar 12-Minab 13- Kazeroon 14-Lar-Bastak

Fig 2.-Distribution Map of Potential Areas for Geothermal Resourcesal

Since Iran is a developing country with an increasing rate of electricity of consumption, in order to secure the supply of electrical energy, estimated at a growth rate of 3000 MW/year, in future renewable energy in general and geothermal energy in particular should play an important role to help the sustainable development of the country. In the long-term, geothermal energy will remain a viable option to furnish clean, reliable power in Iran. Geothermal development offers a viable energy alternation to fossil fuel, though environmental and social impacts of geothermal development must be carefully a properly managed. With the experience of Meshkinshahr we can write our scenario for the future and define new projects for developing a geothermal industry in Iran.

3- THE SABALAN GEOTHERMAL FIELD

The Sabalan geothermal prospect lies on the western slopes of Mt. Sabalan. The prospect site is located at about 20 km south of the City of Meshginshaar in the Province of Ardebil, North West of Iran. The area is located between 38° 12' 52" and 38° 20' 00" North and 47° 40' 30" and 47° 49' 10" East. The Mt Sabalan geothermal field is located in the Moil Valley on the north-western flank of Mt Sabalan, in the Ardebil Province of NW Iran. The resource area has been previously identified by geoscientific studies as an approximately quadrangular shaped area that covers approximately 75 km^2.

Many hot springs found in the larger prospect area are believed to be connected to Mt. Sabalan volcanism which consist of young trachyandesitic lavas infilling a 14 km diameter caldera.

The prospect area is located within the Moil Valley which exposes Quaternary Terrace deposits (known as Dizu formation), altered Pliocene volcanics and unaltered Pleistocene trachydacite rocks (Ar-Ar dated at 0.9 Ma) (Bogie et al., 2000 [**6**]).

Structurally, three main directions of faulting have been recorded: NE, NW and N-S.

Northern slopes of Sabalan hosts many hot springs (seven in the Mouil Valley near Meshkinshahr, one further west at Yel Sou, and three aligned along a major NE trending structure near Ghotur-Suii). The temperatures of these thermal springs range from 21°C to 82°C. Chemically they fall into different types including neutral, Cl-SO4 and acid SO4 (Bogie et al., 2000). Giggenbach[7] (1992) analyzed the hot springs waters and found relatively low Na-K-Mg temperatures of about 150°C.

Mt. Sabalan lies on the South Caspian plate, which underthrusts the Eurasian plate to the north. It is in turn underthrust by the Iranian plate, which produces compression in a northwest direction. This is complicated by a dextral rotational movement caused by northward underthrusting of the nearby Arabian plate beneath the Iranian plate. There is no Benioff-Wadati zone to indicate any present day subduction (McKenzie [8], 1972).

Mt. Sabalan is a Quaternary volcanic complex that rises to a height of 4811 m, some 3800 m above the Ahar Chai valley to the north. Volcanism within the Sabalan caldera has formed three major volcanic peaks which rise to elevations of around 4700 m.

The climate in the area is relatively dry, especially during the summer months. The site is exposed to severe winter weather, including very high wind speeds of up to 180 km/hr. Winter temperatures over the past 4 years have been measured as low as -30°C.

Table -1 Summary Weather Data, NW Sabalan

Item	Parameter	Moil Village Station (Year 2000)	Well Site B Weather Station (Year 2001-2002)
Temperature	Annual Average	3.8 °C	3.6 °C
	Annual Maximum	30 °C	29 °C
	Annual minimum	-18 °C	-30 °C
Humidity	Average annual value	60%	52%
Precipitation	Average annual value	196mm	306mm

The area is identified as a seismically active location. The National Building Code published by the Building and

Housing Research Centre for Iran, includes a seismic macrozonation hazard map for Iran. The Design Basis Earthquake (DBE) (return period 75 year) for a site location around Mt Sabalan is identified with a peak ground acceleration of 0.35g. The MCE (Maximum Credible Earthquake) (return period 2475 year) for a site location around Mt Sabalan is identified with a peak ground acceleration of 0.45g.

3-FIRST STAGE OF EXPLORATION

On the basis of the results of the MT survey (as shown in Fig. 3) and the presence of hot springs with significant Cl concentrations a three well exploration program was undertaken.

The topography of the valley limits the location of drill pads to interconnected terraces requiring that two of the wells to be directionally drilled to access and extensively test the resistively anomaly at depth.

The location of the project with a detailed map of the drilled area is given in Fig 3. The 3 deep exploration wells that have been drilled are coded NWS-1, NWS-3 and NWS-4 and these have been drilled on well pads A, C and B respectively. The wells vary in depth from 2265m to 3197m MD. Well NWS-1 was drilled vertically while NWS-3 and NWS-4 are deviated wells with throws of 1503 and 818 m respectively. Casing tally was shown in fig. 4.

Additionally, two shallow injection wells have been drilled to 600m depth. The basic well completion data are summarized in Table 2.

Table2 – summary of the the exploration wells

Well	TD	Prodn	Casing	Prodn	Liner
		Size (in)	Depth (mMD)	Size (in)	Depth (mMD)
NWS-1	3197	9-5/8	1586	7	3197
NWS-3	3166	13-3/8	1589	9-5/8	3160
NWS-4	2255	9-5/8”	1166	7	2255
NWS-2R	638	13-3/8	360	9-5/8, 5	638
NWS-5R	538	20	139	9-5/8	482

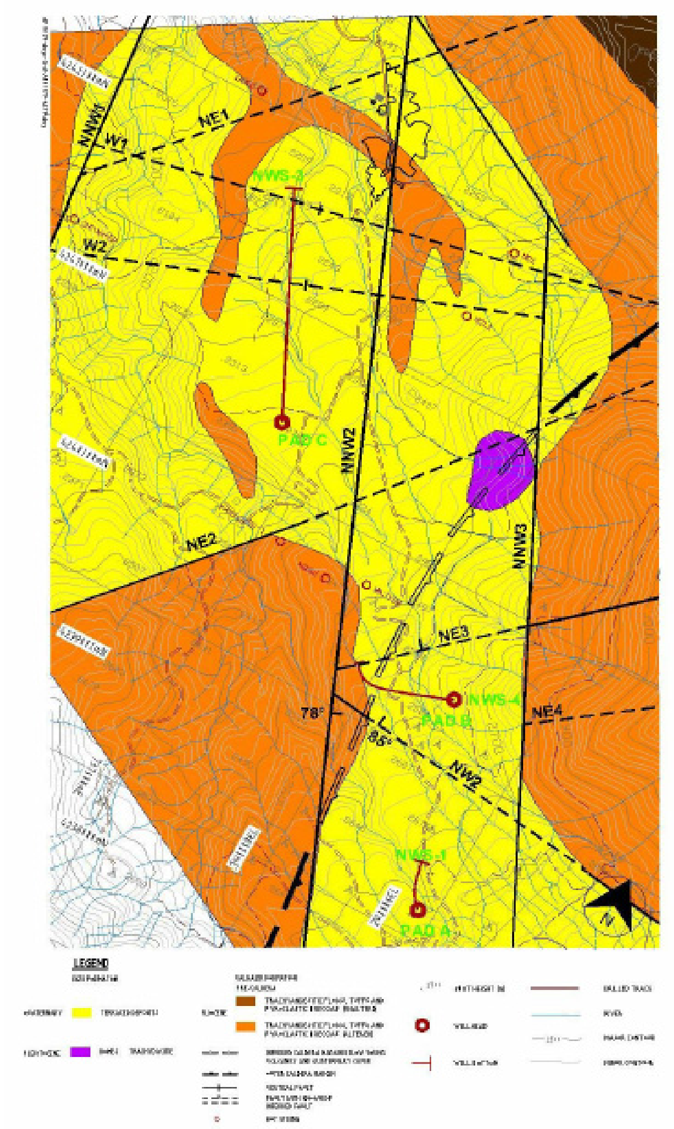


Fig.3 the exploration wells

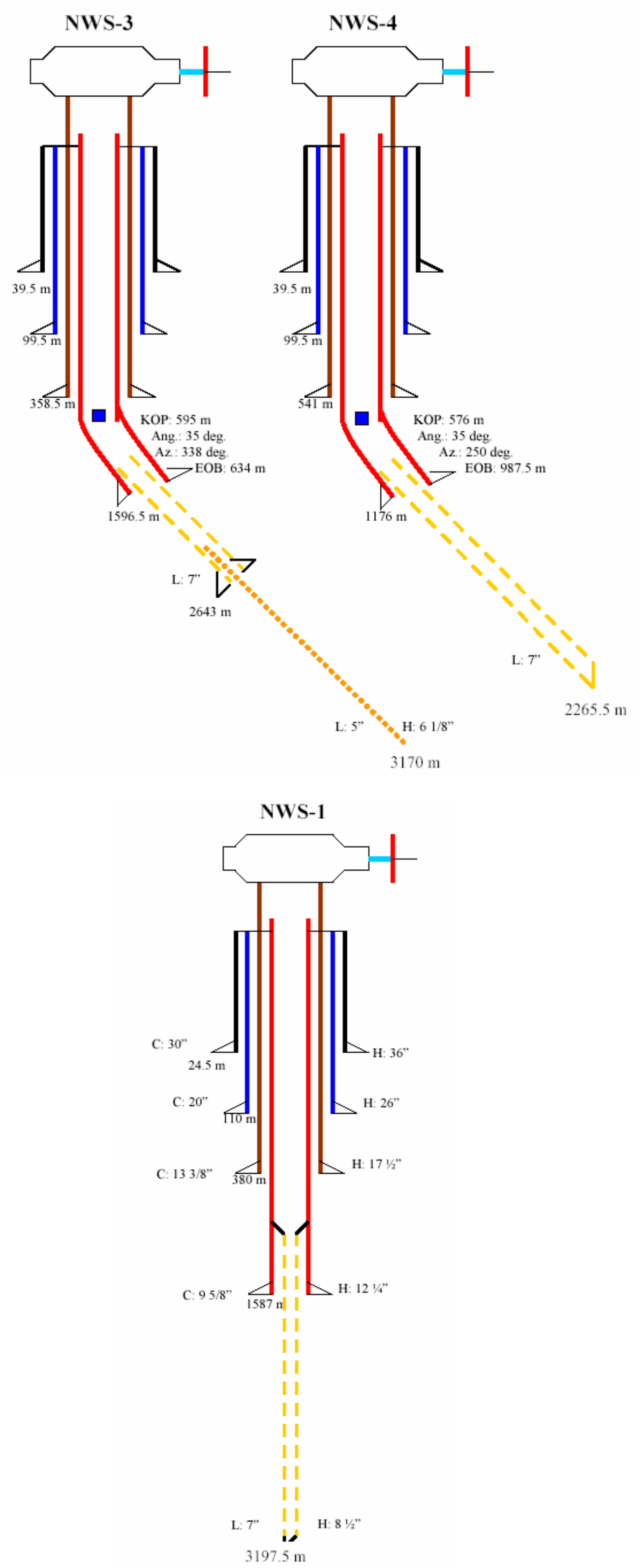


Fig 4. depth and casing configuration for NWS1 ,3,4

By plotting the well temperature profiles together on Fig. 5 it is possible to make a number of observations regarding the nature of the geothermal resource based on changes in temperature with depth as following:

1-The temperatures are all below the BPD curve, indicating that the reservoir in this area of the field does not contain a two-phase mixture of steam and water. 2----

2-Temperatures behind the casing of NWS-1 at an elevation of about 1900 masl are close to BPD conditions, indicating possible proximity to two-phase fluid.

3-From +1500 masl to between +600 – 200 masl a slight temperature inversion is evident.

4-Below +200 masl in NWS-1 and +600 masl in NWS-3 temperatures increase with depth.

5-The hottest temperature has been measured in NWS-1, suggesting that it is located closest to a deep upflow located in a generally southern direction.

6-The estimated stable temperature data have been used to construct temperature contour maps at various elevations (+2200 masl, +2000 masl, +1500 masl, +1000 masl, +500 masl) where data was available from the 3 deep wells. A cross-section generated by Winlink software is shown in Fig. 6.

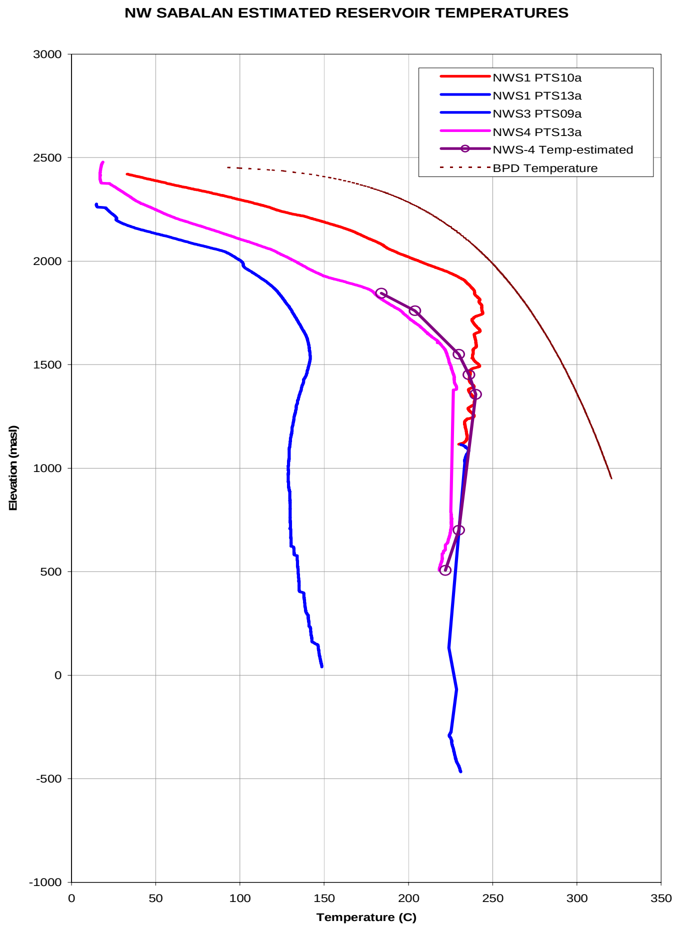


Fig. 5 Well temperature profile

The injection tests were conducted by injecting water at various flow rates and measuring the corresponding downhole pressure changes in the vicinity of the major permeable zone.

The slope of the resulting plot of injection flow rate versus pressure is referred to as the injectivity index and provides a comparative measure of the overall permeability encountered by the well. The data can also be used to estimate reservoir flow capacity (transmissivity). The results from the tests are summarised in Table 3

Table 3 Injectivity Index and Transmissivity for wells

Well	Date	Injectivity Index (l/s-Mpa)	Transmissivity (d-m)
NWS-1	1 Jun 03	7.3	5
NWS-2R	25 Jun 03	-	-
NWS-3	27 Nov 03	8	low?
NWS-4	27 Mar 04	16	2
NWS-5R	2 May 04	30	-

Based on the material and interpretations presented here hydrogeological model has been developed for the NW Sabalan resource as shown in Figure 6. Also geological section has been shown in Figure 7.

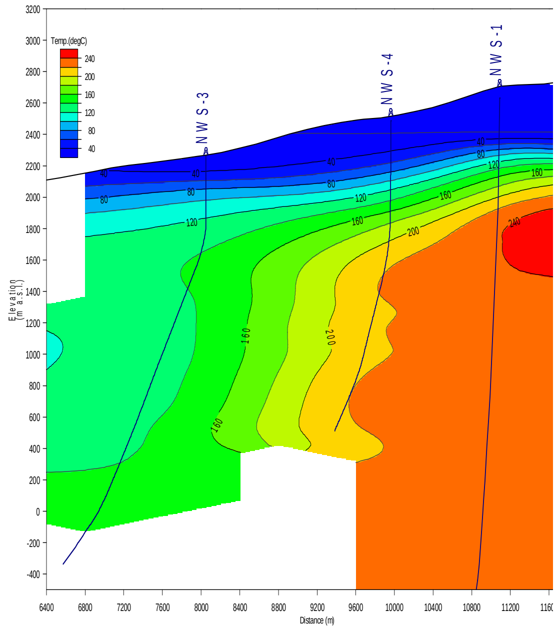


Figure 5

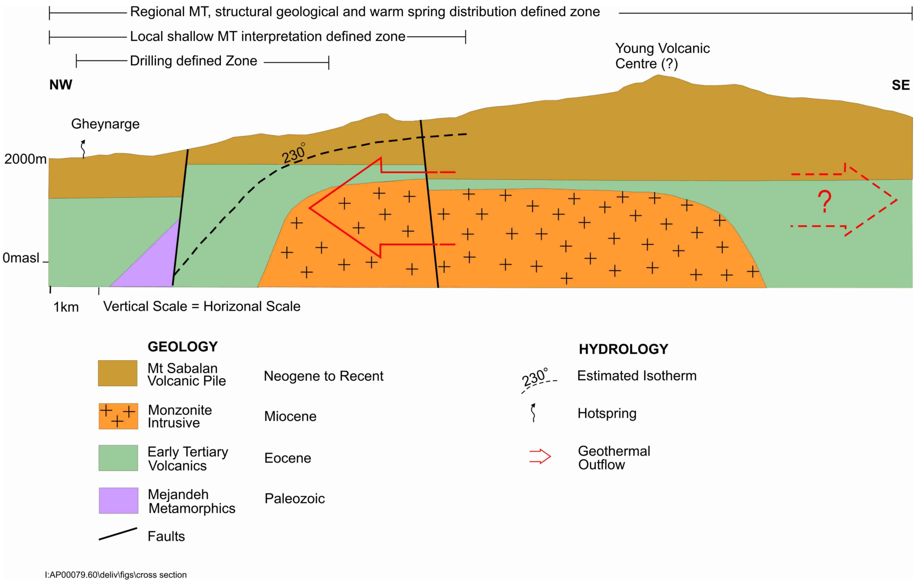


Fig 6. hydrogeological model for NW sabalan resource

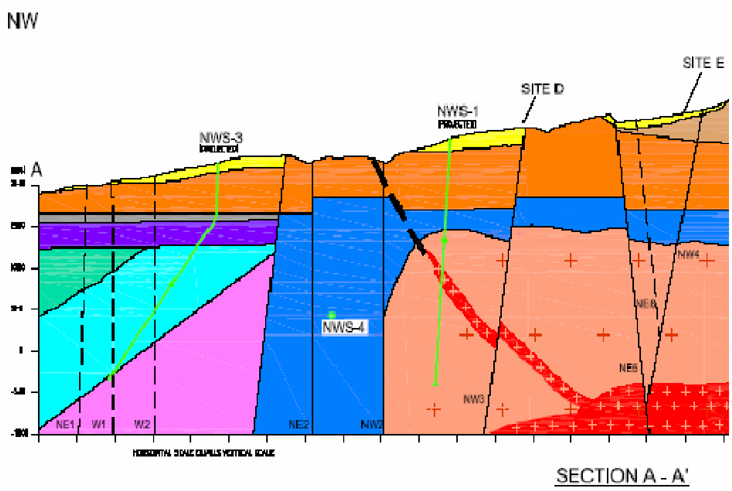


Fig 7. geological section from resource

The resource potential of the NW Sabalan area has been estimated using the Monte Carlo 'stored heat' approach, where probability distributions for some of the resource parameters are defined. The resulting estimated electrical power potential was also compared with comparable geothermal fields using analogy.

The basic principle of the method is to estimate the heat stored within a defined reservoir volume, above a defined base temperature. This includes both the heat stored in the rock and the heat stored in the reservoir fluid. The reservoir volume is usually taken as the defined resource area multiplied by the resource depth, which is normally based on the drilled depth plus some additional storage volume that is assumed to exist below the drilled depth.

The potential geothermal resource area at NW Sabalan was subdivided into five areas because of differing temperatures and levels of uncertainty. Each area has the same three levels. The areas are shown in Figure 8

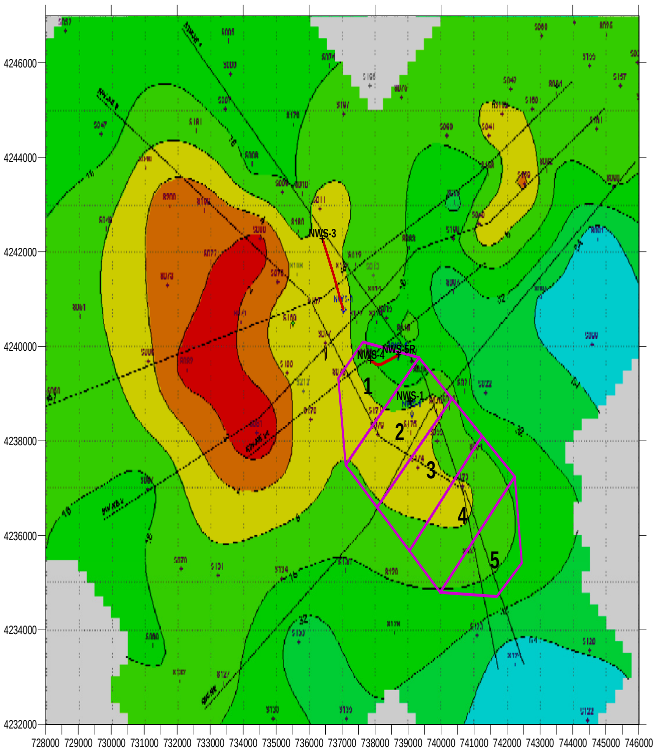


Fig. 8 Areas Used for Stored Heat Calculations

Area 1 is associated with NWS-4 (Pad B) and Area 2 with NWS-1 (Pad A). Areas 3, 4 and 5 are assumed to have progressively higher temperatures towards the postulated source of the outflow. Each area was thus assigned different temperatures. The formation porosity was assumed to be lower for the 2 deeper levels and was assumed to be the same for the same levels in each area.

The Monte Carlo analysis was undertaken for the area as a whole to give the probability distribution for the whole area. Results from the individual areas were used to guide the selection of average properties for the whole area. Three layers were also used for the whole area analysis.

The areas and mean values of estimated power potential for each of the five individual areas are summarized in Table 4.

Table 4 Summary of Stored Heat Values for Each Block

	Block 1	Block 2	Block 3	Block 4	Block 5	Total
Area (km_2)	**3.2**	**4.2**	**4.2**	**4.3**	**3.1**	**19**
Mean MWe	**23**	**41**	**45**	**52**	**45**	**206**

The calculated parameters indicate that the potential capacity of the NW Sabalan resource has a mean value of 209 MWe, with a 90% probability of being greater than 125 MWe and a 50% probability of being greater than 205 MWe. The average calculated energy density for the whole area is 11 MW/km².

After completion First Stage of Exploration The SKM proposed the following steps for Second stage.

1. An ongoing delineation drilling program be undertaken at Pads D and E. The results from the delineation program would determine the most suitable size for the Stage of development.

2. Well pads B and C need to be allocated for reinjection use only and not for production wells. This is to ensure that sufficient injection capacity is preserved in the geothermal outflow at well pads A and B to accommodate future waste brine flows from production wells on Pads A, D and E of up to 100MWe capacity

4-SECOND STAGE OF EXPLORATION

This first well in second stage (nws5) is drilled directionally to North-East.to a Td of 1900m. the well profile is shown in figure 9. the direction of wells is shown in figure 10.

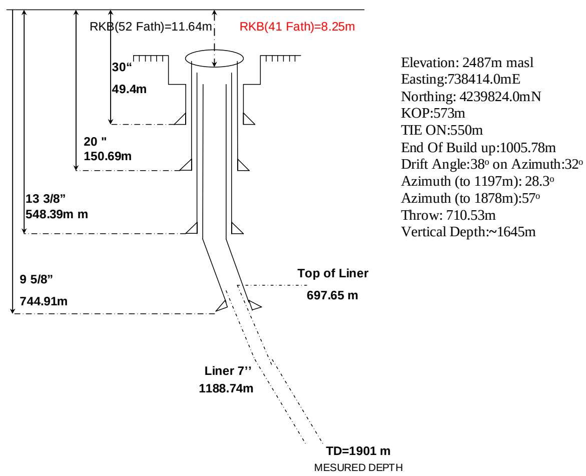


Fig. 9 the well profile of NWS5 on site B

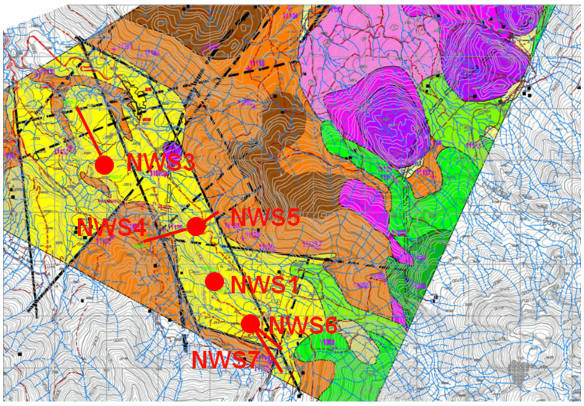


Fig 10 the direction of wells

For designing well nws6 on site D, FEDCO company was selected for analysis the magneto-telluric sounding from 50 stations conducted by SKM in 1998 and EDC in 2007. the location of these stations is shown in figure 11.

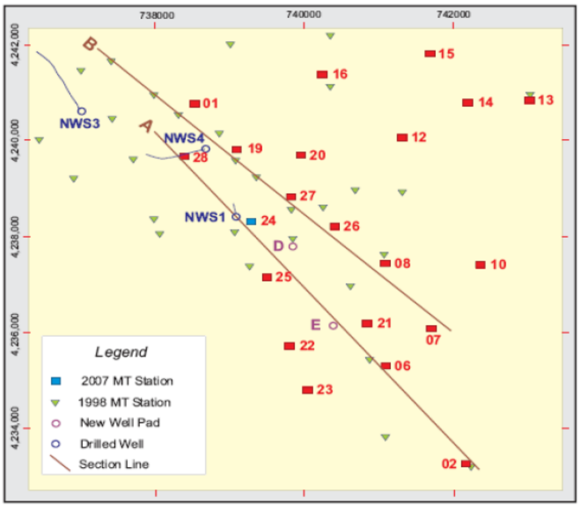


Fig 11 location map of MT station lined used in delineation of the Sabalan geothermal resource

Based on the result of MT and informations available to Fedco, an uptodate hydrlo electrical model of the north west sabalan obtained (shawn in fig 12)

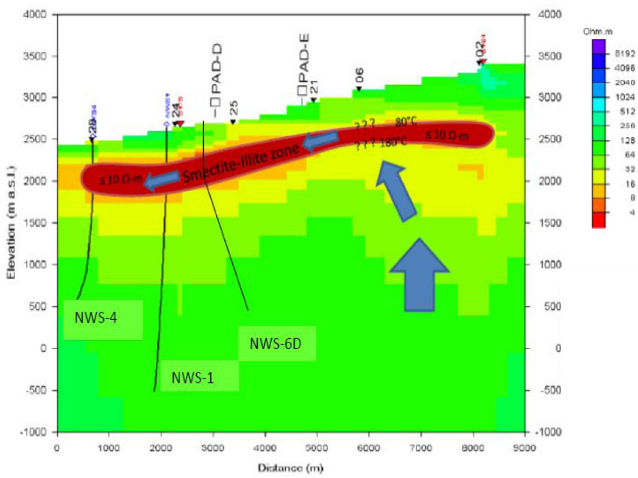


Fig. 12 postulated hydro-electrical model of the North West Sabalan geothermal field

According MT results the FEDCO desined the well NWS6. This well was drilled directionally to south-East ,Td is 2374m. the profile of well is shown in fig 13. the direction of well nws6 is shown in fig 10.

Well nws7 is drilling on site D now. The direction of this well and its profile was designed by FEDCO as shown in Fig 10. After Drilling Nws7 we continue or drilling on site E. after drilling of site E, exploration was complete and here is enough information for designing of production wells.

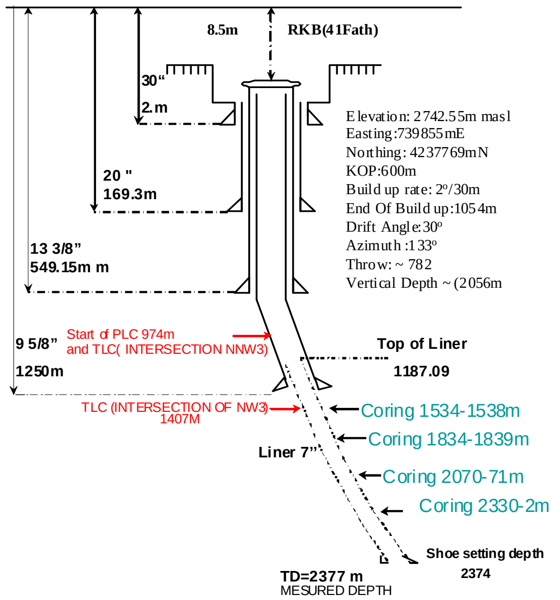


Fig. 13 the well profile of NWS6 on site D

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