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GEOTHERMAL UPDATE REPORT FROM ISRAEL 1999

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Abstract
Since the previous geothermal update report from Israel in 1995, a number of reports and papers concerning geothermal subjects were published. Some 430 deep oil and structural wells were drilled in Israel, Most of these wells are abandoned or not in use. The geothermal information available from the majority of these wells was used in preparation of thermal gradients and isotherm contour maps at different depths. Approximately 100 of the above mentioned wells were examined for possible utilization of low enthalpy geothermal energy. Target horizons, possible yields, water salinity and water temperature were estimated.
A number of the wells were selected for utilization in spas based on different chemical composition and salinity concentrations with varying balneological needs.
These are distributed in a widely spaced network over the country, which also satisfies the legal requirement for spacing between spas.
The use of geothermal water for agriculture was scaled up, mainly in the Dead Sea Rift in the southern part of Israel, for use in greenhouses. Most of this water is pumped from deep water wells.

Introduction
The main geothermal activity in Israel in recent years is in utilization of hot water for fish ponds, spas, and greenhouses (Fig. 1). In spite of the moderated activity, several geothermal studies were made during the 1970's and 80's (Levitte and Olshina, 1978, 1982; Mazor et al., 1980; Eckstein, 1976; Levitte et al., 1978; Rotstein et al., 1977). In recent years some additional studies were carried out: Greitzer and Levitte (1995), Levitte and Greitzer (1996, 1997), Jaffe, et al. (1999). In addition, numerous private consulting studies were carried out for utilization of hot and saline water from abandoned oil wells for spas, some of them in a progressive development stage.
In our previous update in 1995, a review was given on the isotherm and gradient map of Israel. Since then, a study was carried out at the central part of Israel on the geothermal water of the Cenomanian – Turonian aquifer.

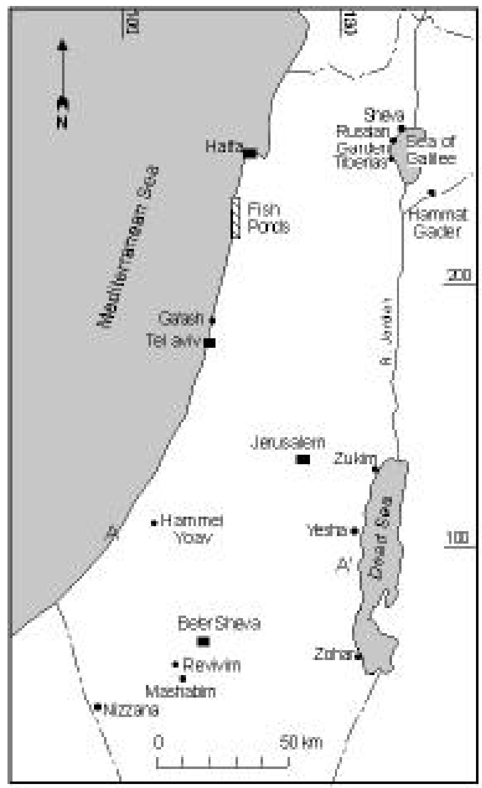

Fig. 1 Location map of Israel

Geothermal water potential of Cenomanian - Turonian aquifer in Central Israel
High temperature water found in deep oil and water wells in Israel, suggested the possibility of using geothermal energy for space, agricultural and recreational heating (Levitte and Olshina, 1985; Greitzer and Levitte, 1995).
Two main aquifers are present in the studied area: a shallow Quaternary Coastal aquifer and a deep-seated Cenomanian - Turonian confined aquifer (Yarkon - Taninim aquifer). The latter is part of the Judea Group, which forms a large basin of low temperature geothermal water (38-42°C), (Fig. 2).

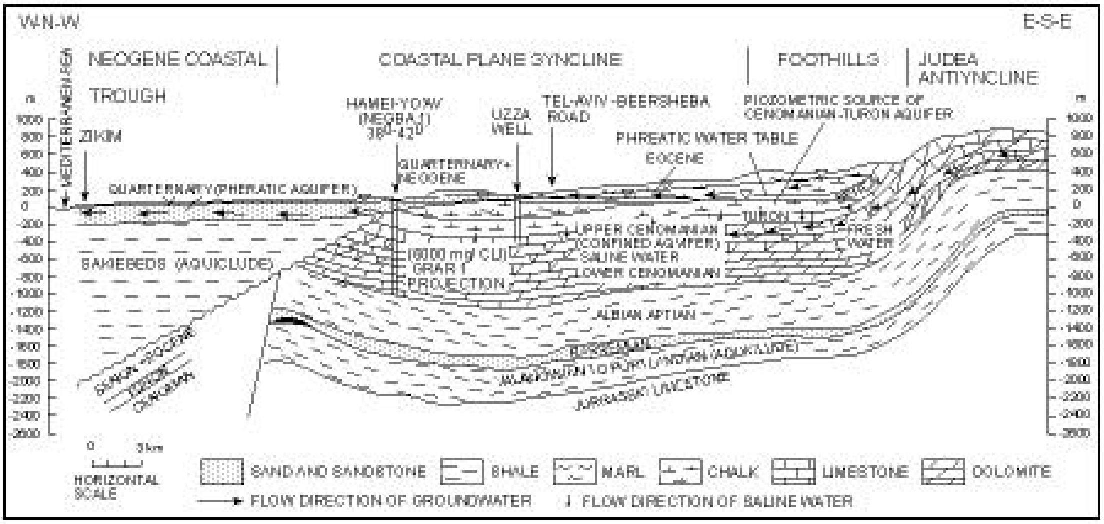

Fig. 2 Schematic geohydrological cross section A-A'
(Modified after Y. Greitzer 1963 and L. Picard 1959)

The geology of the subsurface in central Israel can be schematically divided into three belts (from east to west): (1) The Judea anticline, which slopes westward; (2) the Coastal Plane syncline; (3) the Neogene coastal trough.

The Cenomanian - Turonian aquifer consists mainly of limestones and dolostones, confined by overlying Senonian - Eocene chalk, marls and clay. To the west, the "Saqie clays" unconformably overlie the Cenomanian - Turonian formations.

The recharge area of this aquifer is exposed on the Judea Anticline and the ground water is stored within a basin located in the Coastal Plain Syncline (Greitzer, 1963).

The volume of the aquifer in the Coastal Plain Syncline is relatively large in relation to it's recharge area. This large reservoir is blocked from all sides, except to the north, where it discharges into the distant Yarkon and Taninim springs.

To the east, the aquifer is bounded by the recharge area and flow direction. To the west toward the Mediterranean coast, it is bounded by the impermeable "Saqie clays". To the south, the boundary is the water divide together with impervious chalk and marl formations.

Since the quantity of the recharge is relatively small in comparison to the huge volume of the blocked reservoir, the groundwater in most of the basin is nearly stagnant, partly moving northward on a very gentle gradient (1°/30 km).

The low mobility and lack of flushing provides ample time for heating by the normal geothermal gradient. For the same reason, the salinity of the groundwater is relatively high (2000-6000 mg/l Cl).

At present, only one well (Negba - 1), is utilizing geothermal water at a temperature of about 42°C in central Israel at the Hamei Yoav Spa . This well is a structural oil well abandoned at a 1916 m which was perforated at a depth of only a few hundred meters within the limestones and dolostones of the Cenomanian - Turonian aquifer.

Thermal waters for health and recreation

Two different sources supply thermal water for health and recreation: (a) water emanating from springs and (b) water pumped from wells.

(a). No new data has been added about thermal springs in Israel since our report in 1995. It is worth mentioning that temperatures observed in springs along the Jordan - Dead Sea Rift range between 26°C and 62°C (Fig. 1).

(b). Many deep boreholes in Israel encountered thermal water. In addition to Negba - 1 with a water temperature of 42°C which was utilized by Hammey Yoav Spa (Fig. 1), Ga'ash abandoned oil well north of Tel Aviv is in preparation now for recreational use.

Agricultural utilization of geothermal water

Agricultural uses of geothermal water in Israel are divided into two branches: (a) greenhouses, and (b) fish farming.

(a). Greenhouses.

The geothermal water here is used for both space and ground heating, using brackish water (1000–1400 ppm Cl at a temperature of 35–42°C). The hot water is supplied by the Nizzana - Mash'abbe Sade well field, located in the northern Negev. These wells tap the Yarkon - Taninim aquifer at a depth reaching 750 m and yield about 200 m^3/h. These hot waters are exploited by Kibutz Revivim and Moshav Nitsanei Sinai.

Another source of geothermal water in the southern part of Israel is the huge Nubian Sandstone aquifer. The Paran deep well (which is the deepest water well in Israel, 1536 m) located 80 km south of the Dead Sea, draws water from this aquifer at 60°C with a yield of 140 m^3/h and 600 mg/l Cl. Another well field was developed in the Paran area exploiting the Cenomanian – Turonian limestone and dolomite aquifer. The wells are 200–500 m deep and their temperatrure is about 30–33°C. This water is used for heating greenhouses.

(b). Fish farming.
Geothermal water for fish farming is used in two regions; in northern Israel adjacent to the Jordan Valley at Hammat Gader Springs (27°C), and along the Mediterranean coast about 70 km north of Tel – Aviv, utilizing warm brackish water (26°C). The water is supplied by shallow wells of about 30 m depth, penetrating the sandstone Pleistocenie aquifer and draw water from the interface zone between sea and fresh water. Recently the same type of wells were drilled in the southern coastal plain for supplying warm water to fish ponds.

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TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 1999

[1] I = Industrial process heat
C = Air conditioning (cooling)
A = Agricultural drying (grain, fruit, vegetables)
F = Fish and animal farming
S = Snow melting
H = Space heating & district heating (other than heat pumps)
B = Bathing and swimming (including balneology)
G = Greenhouse and soil heating
O = Other (please specify by footnote)

[2] Enthalpy information is given only if there is steam or two-phase flow

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

[4] Energy use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] 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

[5] Capacity factor = [Annual energy use (TJ/yr) x 0.03171]/Capacity (MWt).
Note: the capacity factor must be less than or equal to 1.00 and is usually less, since projects do not operate at 100% of capacity all year.

Locality	Type[1]	Maximum Utilization					Capacity[3]	Annual Utilization		
		Flow Rate (kg/s)	Temperature (°C)		Enthalpy[2] (kJ/kg)		(MWt)	Ave. Flow (kg/s)	Energy[4] (TJ/yr)	Capacity Factor[5]
			Inlet	Outlet	Inlet	Outlet				
Hamat Gader	F	300	27	22			300	198		
Mediteranean Coast	F	800	26	20			800	633		
Tiberias	B	20	42	30			20	32		
Hamat Gader 1	B	200	42	32			200	260		
Hamat Gader 2	B	140	42	32			140	185		
Hamey Zohar	B	7	30	26			7	4		
Hamey Yesha	B	10	41	30			10	14		
Hamey Yoav	B	50	42	32			25	33		
Mashabbe Sade	G	50	42	24			25	59		
Paran - Nubian	G	60	60	24			30	142		
Paran C-T	G	100	30	22			75	79		
Nizzana	G	50	38	24			40	74		
TOTAL		1787					1672	1654		

Note: please report all numbers to three significant figures.