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To cite to this article: Arslan VEPAYEV, Ozan DENİZ. (2022). HYDROGEOLOGICAL AND HYDROGEOCHEMICAL INVESTIGATION OF ILICA (BALIKESIR) GEOTHERMAL FIELD. International Journal of Engineering and Innovative Research , 4(1), p:1-9 . DOI: 10.47933/ijeir.892239

DOI: 10.47933/ijeir.892239

To link to this artice: https://dergipark.org.tr/tr/pub/ijeir/archive

International Journal of Engineering and Innovative Research

http://dergipark.gov.tr/ijeir

HYDROGEOLOGICAL AND HYDROGEOCHEMICAL INVESTIGATION OF ILICA (BALIKESIR) GEOTHERMAL FIELD

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DOI: https://doi.org/10.47933/ijeir.892239

(**Received:** 06.03.2021; **Accepted:** 24.04.2021)

ABSTRACT: This study includes the first conceptual modeling studies in Ilıca Geothermal Region of Balıkesir Province. The hydraulic behavior and groundwater properties of the geothermal field were analyzed by conceptual modeling. For this purpose, he used Visual Modflow Flex software used in 3D modeling studies. Physical-chemical parameters and flow velocity from geothermal sources Faults and geological units in the field were mapped to describe the geothermal system. All data were digitized on a scale of 1/25000. Also, geothermal conceptual flow modeling is conceptually defined. The field perimeter is divided into 400 cells by 20 x 20 units. The area of each cell is designed to be 67.85 m x 67.85 m. Approximately 4.6 km^2 has been studied. According to the data obtained, the geothermal aquifer is fed from cracked and hollow sections of marble and schists. The geothermal heater body is thought to be the granite pluton found in the region. Cover rocks of the geothermal system are young sedimentary units. Existing meteoric waters enter the underground through the cracks of the rocks in the region, warm up with a short flow path and are carried to the surface by faults.

Keywords: Geothermal, Ilıca, Conceptual Modelling.

INTRODUCTION

In the study named Groundwater Flow Modeling of Kütahya Plain Shallow Aquifer, sampling was carried out in 2 different periods as dry and rainy seasons. As a result, the groundwater model was formed by evaluating the results of the analyzes made from the samples taken [1]. 3D Modeling of Salt Water Initiative in the Island Aquifer, 3D modeling was performed to control seawater mixture with groundwater on an example island in the Mediterranean region using SEAWAT software [2]. In the study titled Assessment of Hydrogeological Properties of Beyşehir Lake Basin Based on Groundwater Flow Modeling, the characteristics of 8 different basins were evaluated and grid networks and modeling features were proposed for the groundwater modeling of the study area. [3]. In the study of Modeling River-Aquifer Interactions with Visual Modflow, first, by creating a numerical modeling of groundwater, river-aquifer interaction, groundwater distribution and the effects on the flow direction of groundwater were revealed. [4]. In the article titled Time Changing Groundwater Flow Model of Torbalı Region, underground water modeling of Torbalı district of İzmir was created and it was revealed that groundwater was in decline between 2000-2020. [5]. The difference between this study from the above-mentioned studies is a more detailed examination of the hydrogeological and hydrogeochemical properties of Ilıca (Balıkesir) geothermal resources and the creation of topographic 3D maps of groundwater in the Modflow Software.

2. MATERIALS AND METHODS

Conceptual modeling has been done for the first time in Ilıca Geothermal Field. The hydraulic behavior of the geothermal field and groundwater properties were investigated by a numerical modeling study. For this reason, Visual Modflow Flex Pro 6.1 software was used for 3D modeling. Physico-chemical parameters and flow rates were measured from geothermal sources in the study area. In addition, faults and geological units in the field were mapped to define the geothermal system. All data have been digitized on 1/25000 scale in Figure 2. As a result, the flow modeling of the geothermal system is conceptually defined.

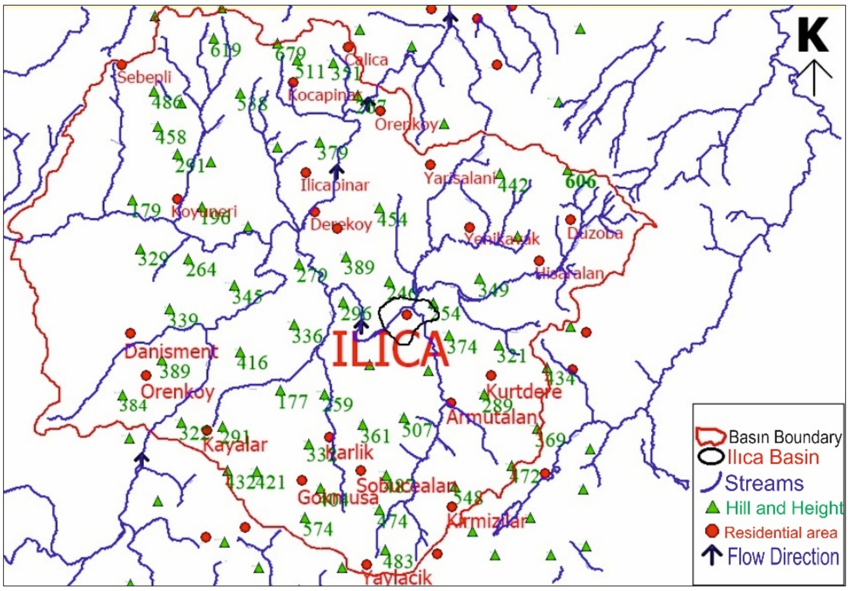

Figure 1. Morphology and hydrological boundaries of the study area.

The study area is located in the Susurluk Basin in the Southern Marmara Region. The study area called Ilıca Basin is located in an area of approximately 427 km^2 in a region close to the northwest border of this basin in Figure 1.

The surface waters of the Ilıca basin, which belongs to the Balya District of Balıkesir, are fed from Ilıca Pond, which is approximately 30 km away from the north of the settlement. Ilıca Pond was established in 1987 and is currently used for irrigation in that region. The water coming from the pond mixes with the Ilıca Stream, cuts the center of the village and flows into Koca Stream. The geothermal resource in the basin comes to the surface spontaneously from the pressurized aquifer.

2.1. Geology of the Study Area

The geology of the study area and its surroundings is taken from this study [6] in simplified form. The geological units in the study area from bottom to top consist of Fındıklı Formation, Altınoluk Marble Member, Oligocene-Miocene Granitoids, Bayramiç Formation, Hallaçlar Volcanite, and Alluvial deposits. Also, as can be seen on the map, it can be said that there are 5 faults in the study area. The reason for the formations is that the region is located between the western end of the North Anatolian Fault and the Horst-Graben systems in the Aegean region.

Due to the movement in the fault zones, the hot underground fluid is leaking from the spaces in between and goes up. The reason for this movement is the tectonic setting mentioned above.

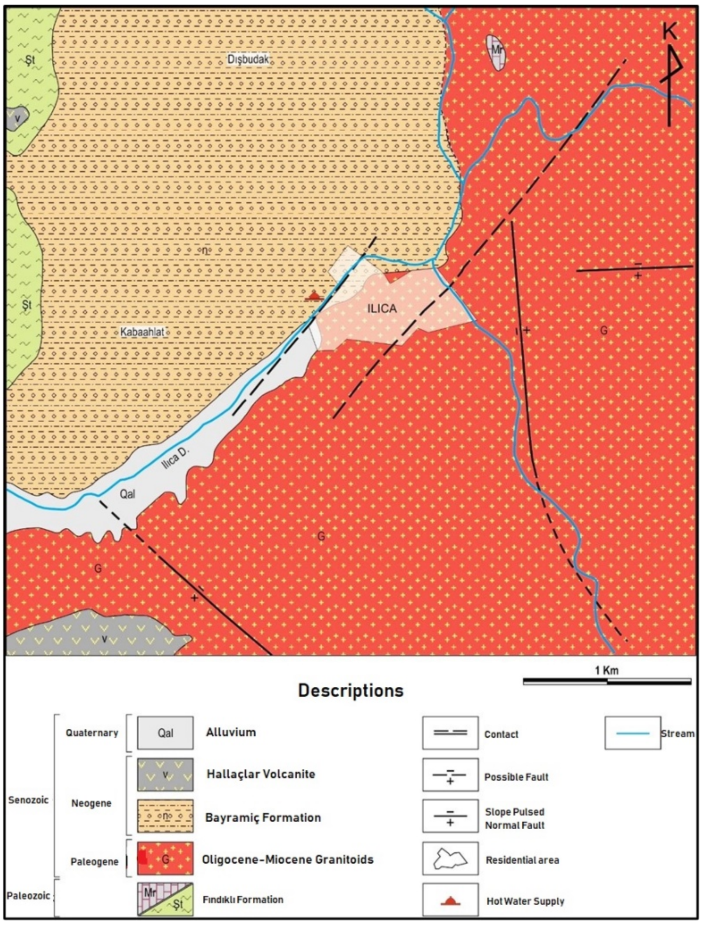

Figure 2. Geology of the study area.

3. HYDROGEOLOGY

3.1. Hydrogeochemistry

In order to examine the chemical and temperature conditions of the geothermal water in the study area and to determine the water-rock relationship and the properties of the source, samples were taken from the places for 2 periods in a year, where the 3-spring water in the field came out and then were sent to the chemical analysis. The analyzes were made in the central laboratory of COMU and the Bureau Veritas laboratory in Canada shown on Table 1.

Table 1. Results of analysis of water samples from Bureau Veritas laboratory for June-November (2020).

Elements	Unit	Lowest Level of Determination	Sample Name				
			HK-1-1	HK-1-2	JK-1-1	JK-1-2	JK-2
			June	November	June	November	November
Ag	PPB	0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Al	PPB	1	7	36	18	37	31
As	PPB	0.5	89.8	87.8	85.8	82.8	88.8
Au	PPB	0.05	<0.05	<0.05	<0.05	<0.05	<0.05
B	PPB	5	2078	2054	2159	1938	1998
Ba	PPB	0.05	40.90	15.99	35.04	14.24	16.57
Be	PPB	0.05	<0.05	<0.05	<0.05	<0.05	<0.05

Bi	PPB	0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Br	PPB	5	259	240	304	246	234
Ca	PPM	0.05	16.48	16.6	16.10	16.2	15.72
Cd	PPB	0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Ce	PPB	0.01	<0.01	0.02	<0.01	0.02	0.01
Cl	PPM	1	65	68	67	68	70
Co	PPB	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Cr	PPB	0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Cs	PPB	0.01	61.63	58.8	61.52	57.22	58.29
Cu	PPB	0.1	2.4	0.9	1.0	0.8	0.9
Dy	PPB	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Er	PPB	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Eu	PPB	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fe	PPB	10	<10	<10	<10	<10	<10
Ga	PPB	0.05	1.40	1.63	1.70	1.6	1.38
Gd	PPB	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Ge	PPB	0.05	7.81	7.93	8.56	7.79	7.63
Hf	PPB	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Hg	PPB	0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Ho	PPB	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
In	PPB	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
K	PPM	0.05	4.30	3.91	4.34	3.88	3.74
La	PPB	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Li	PPB	0.1	503.3	457.4	517.4	439.2	435.2
Lu	PPB	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Mg	PPM	0.05	0.07	0.07	<0.05	0.06	0.07
Mn	PPB	0.05	12.09	9.6	6.27	9.26	5.18
Mo	PPB	0.1	97.3	95	99.9	87.1	87.2
Na	PPM	0.05	268.67	256.38	271.59	254.77	254.68
Nb	PPB	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nd	PPB	0.01	<0.01	0.01	<0.01	0.01	<0.01
Ni	PPB	0.2	<0.2	<0.2	<0.2	<0.2	<0.2
P	PPB	10	<10	<10	<10	<10	<10
Pb	PPB	0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Pd	PPB	0.01	<0.01	0.02	<0.01	0.03	0.05
Pr	PPB	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Pt	PPB	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Rb	PPB	0.01	41.01	41.81	42.00	41.51	42.05
Re	PPB	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Rh	PPB	0.01	<0.01	0.01	0.01	0.01	0.01
Ru	PPB	0.05	<0.05	<0.05	<0.05	<0.05	<0.05
S	PPM	1	122	119	121	119	114
Sb	PPB	0.05	1.34	0.98	1.27	1.09	1.23
Sc	PPB	1	<1	<1	<1	<1	<1
Se	PPB	0.5	0.9	0.9	0.8	0.9	0.9
Si	PPB	40	29639	28489	28095	27938	27997
Sm	PPB	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Sn	PPB	0.05	0.98	0.06	0.79	0.07	0.22
Sr	PPB	0.01	450.98	454.41	455.59	425.84	413.54
Ta	PPB	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Tb	PPB	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Te	PPB	0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Th	PPB	0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Ti	PPB	10	<10	<10	<10	<10	<10
Tl	PPB	0.01	0.10	0.08	0.08	0.06	0.08
Tm	PPB	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
U	PPB	0.02	0.14	0.24	0.03	<0.02	0.15
V	PPB	0.2	0.5	0.7	0.4	0.5	0.7
W	PPB	0.02	486.68	462.96	487.16	443.98	469.5
Y	PPB	0.01	<0.01	0.01	<0.01	<0.01	<0.01
Yb	PPB	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zn	PPB	0.5	9.3	6.2	4.2	6.8	4.5
Zr	PPB	0.02	0.07	<0.02	<0.02	<0.02	<0.02

3.2. Major Anion-Cation Analysis and Evaluation of Results

Major anion-cation analyzes of the geothermal spring waters taken from the study area were made in the Bureau Veritas Laboratory in Canada in accordance with ASTM and TSE standards. The pH, T, and EC parameters were measured in-situ. Ca and Mg analyzes were made by ICP-MS, Na and K analysis by flame photometry method, SO_4 analysis by gravimetric method, Cl, HCO3, and CO_3 analyze by titrimetric method, and the results obtained are given in Table 4. Analysis results were evaluated using AquaChem.

Table 2. Major anion-cation chemical analysis results of water samples.

Elements	HK-1-1	HK-1-2	JK-1-1	JK-1-2	JK-2
Na (ppm)	268.67	256.38	271.59	254.77	254.68
K (ppm)	4.30	3.91	4.34	3.88	3.74
Ca (ppm)	16.48	16.6	16.1	16.2	15.72
Mg (ppm)	0.07	0.07	<0.05	0.06	0.07
Cl (ppm)	65	68	67	68	70
SO_4 (ppm)	280	290	280	280	270
HCO_3 (ppm)	232	182	232	190	197
CO_3 (ppm)	0.00	0.00	0.00	0.00	0.00
pH	8.45	8.30	8.38	8.10	7.97
T (℃)	58.2	48.3	58.0	58.5	58.2
EC (µS/cm)	1132	1195	1148	1196	1188

3.3. Geothermometry

One of the most important geochemical tools in the research and development of geothermal spring waters is chemical geothermometry. In observations during use and production, these geothermometers are calculated to see the response of the chamber to production. It is also used to estimate subsurface temperatures during exploitation. Chemical geothermometers are divided into 2 groups as silica and cation geothermometers and in this study was used silica geothermometer calculation [7].

3.3.1. Silica Geothermometer

Silica geothermometer, which is the most widely known among geothermometers, is used to estimate the aquifer temperature and the reservoir temperature of the geothermal source. The fact that many rocks on the earth contain silicate minerals within themselves is an indication of the widespread use of silica geothermometers.

Silica geothermometer calculation has been made for the geothermal spring water points in the study area and the formulas used are given in Table 3, and the calculation results with the formulas are given in Table 4.

The results of the silica geothermometer calculations of the hot water points in the study area are below 250 ℃, which is suitable for the reservoir fluid temperatures. Calculation results are not written in columns 5 and 6 of all samples and column 4 of JK-1-1, JK-2 samples since lower temperatures are obtained from the measured temperatures on the surface. Considering these calculations in general, the obtained reservoir temperatures are between 62 and 113 ℃ for HK-

1-1 welding, between 60 and 111 °C for HK-1-2 welding, between 60 and 110 °C when looking at JK-1-1 source, For JK-1-2 and JK-2 samples, it varies between 81 and 110 shows in Table 4.

Table 3. The formulas of the silica geothermometer used in the study.

Silica Geothermometer	Source	Meaning Range°C	Sequence number in the table
t°C=[1309/(5,19-logSiO_2)]-273 (SiO_2, no steam loss)	Fournier (1977) [8]	25-250	1
t°C=[1522/(5,75-logSiO_2)]-273 (SiO_2, Maximum steam loss at 100)	Fournier (1977)	25-250	2
t°C=[1032/(4,69-logSiO_2)]-273 (Chalcedony)	Fournier (1977)	0-250	3
t°C=[1000/(4,78-logSiO_2)]-273 (α-Cristobalite)	Fournier (1977)		4
t°C=[781/(4,51-logSiO_2)]-273 (Opal)	Fournier (1991)	25-250	5
t°C=[731/(4,52-logSiO_2)]-273 (Amorphous silica)	Fournier (1977)	25-250	6
(t<250°C and SiO_2 concentration is mg / Kg			

Table 4. Reservoir fluid temperatures.

Sample	Geothermometer equation (formulas are given in Table 3 according to the order number)						
No	**T (°C)**	**1**	**2**	**3**	**4**	**5**	**6**
HK-1-1	58.5	113	112	85	62	*	*
HK-1-2	58.0	111	110	82	60	*	*
JK-1-1	57.1	110	110	81	60	*	*
JK-1-2	59.8	110	109	81	*	*	*
JK-2	59.7	110	110	81	*	*	*

*: The geothermometer value was not used because it is equal or lower than the surface temperature.

4. RESULTS AND DISCUSSIONS

Groundwater data measured in the field were used to model the surface flow of groundwater exiting from the granite-granodiorite unit in the study area. There is no previous water budget calculation in the field. The field perimeter is divided into 400 cells with 20 x 20 units. Each cell is designed to be 67.85 m x 67.85 m. The area of the study field approximately 4.6 km^2. The height of each cell is limited by the topographic surface and the zone up to sea level (0 m) is defined as a single cell in the vertical area in Figure 3. Kx and Ky values were accepted as 1E-6 m/s, Kz value as $1E^{-7}$ m/s, porosity as 0.2. There are no flow and measurement data for groundwater and surface waters in the region. Therefore, theoretical values were used to calibrate. The hydraulic conductivity value of cracked granite was calibrated as 1×10^{-6} m / s.

Below is the 3D image of the study area mapped according to groundwater and digital topographic data modeled in Modflow Flex Pro 6.01 in Figure 4. Before creating Field Modeling, the Define Unstructured Q-Grid Method was chosen from 4 different celling methods in Modflow software.

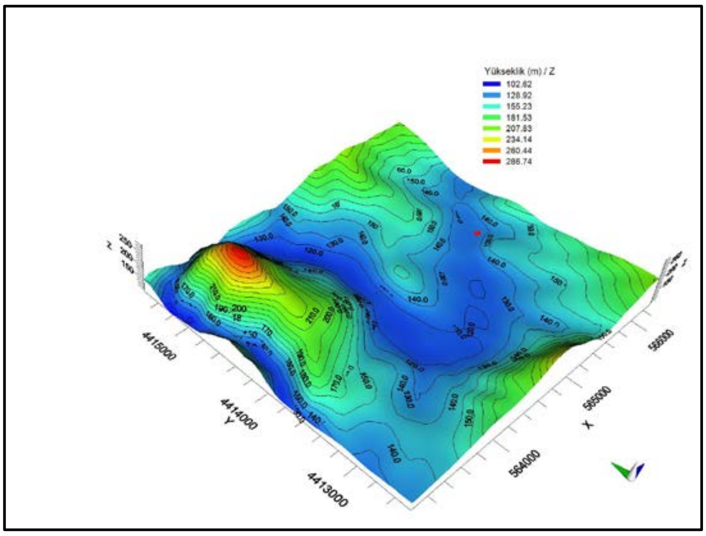

Figure 3. Topographic map of the study area created in Modflow program.

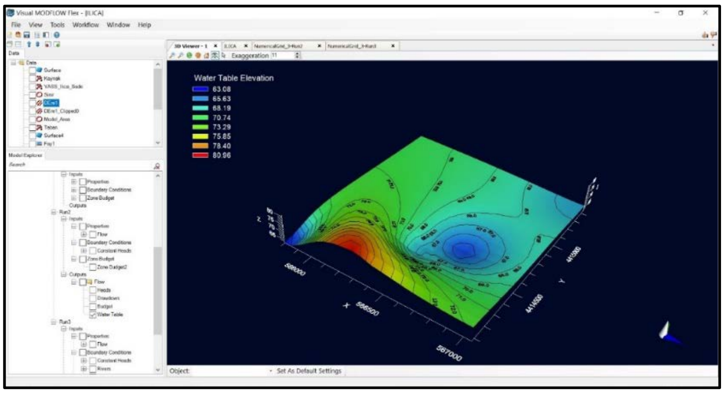

Figure 4. 3D view of groundwater level map of the study area prepared in Modflow program.

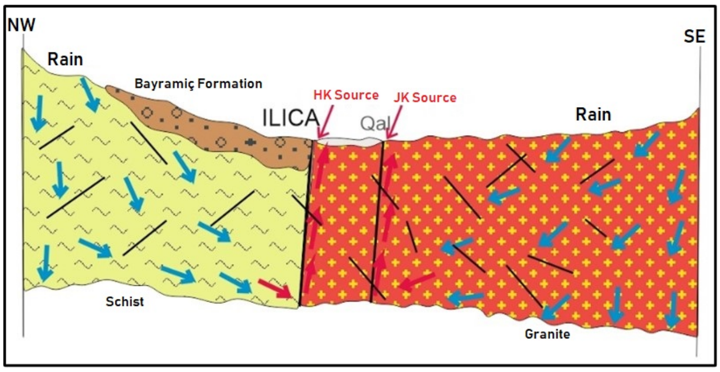

Figure 5. Schematic conceptual hydrogeological model of the Ilıca geothermal field.

The precipitation water entering underground from the dominant hills around the Ilıca hot water spring flows down through the cracks of the granites or granites, heats up along the flow path to the depths and rises upward from the Ilıca fault in Figure 5. Sediments belonging to the Neogene aged Bayramiç formation located in the west of the fault form the cover rock of the system. The reservoir rock of the system is Oligocene-Miocene Granitoids.

5. CONCLUSIONS

As a result of tectonic activity in the region, fracture-crack zones are formed in geological units. Geothermal spring waters reach the surface by seeping from hollow geological structures like this. It is believed that the source of the Ilıca Thermal spring is the granitoids of the Oligocene-Miocene age or the marble slates below it. The temperature of the water that comes to the surface of its own volition varies between 55 and 60 degrees.

The geological units in the study area from bottom to top consists of Fındıklı Formation, Altınoluk Marble Member, Oligocene-Miocene Granitoids, Bayramiç Formation, Hallaçlar Volcanite and Alluvial deposits. Alluvial deposits are the most productive aquifer among the geological units of the study area.

The temperatures of the fluid have been estimated using the geothermometer equations of the geothermal system in the Ilıca region. The results of the silica geothermometer calculations of the hot water points in the study area are found to be below 250 ℃, which is suitable for the reservoir fluid temperatures. Considering these calculations in general, the obtained chamber temperatures are between 62 and 113 ℃ for HK-1-1 welding, between 60 and 111 ℃ for HK-1-2 welding, between 60 and 110 ℃ when looking at JK-1-1 source, For the JK-1-2 and JK-2 samples, it changes between 81 and 110 ℃.

In addition, modeling studies of the geothermal system in Turkey has not been passed yet from a conceptual level, the measured-calculated size modeling studies (except areas in the direct production of electricity).

The information discovered by this study, has a high potential to contribute to the people living in the region Ilıca and to Turkey's economy. Because many properties of the water are determined by modeling the hot fluid, the possibilities of using the geothermal resource have also been determined.

The information obtained from this study shows that the geothermal potential of the site has a higher reservoir temperature than its current use and can therefore be used for geothermal applications at higher temperatures (if the resource is developed). For this reason, the trends of the faults should be determined with geophysical and structural geology-tectonic studies in the field, and it should be evaluated whether it is possible to increase the temperature and flow in order to benefit more from the field by conducting research drilling / drillings at appropriate locations. If high temperature and flow rate can be achieved; If high temperature and flow rate can be obtained; In this region, there is a suitable geography for activities such as house heating, geothermal greenhouse, fish farm.

ACKNOWLEDGEMENTS

I would like to pay my special regards to ESAN-Eczacıbaşı Endüstriyel Hammaddeler San. ve Tic. A.Ş. and Deniz Jeotermal Enerji ve Yeraltı Suları Araştırma companies for their scientific and financial support for this research paper. This research summarizes master's thesis named: Conceptual Modelling of Ilica, Balikesir (Turkey) Geothermal Field.

REFERENCES

[1] Berhe, B, A (2016). *Groundwater Flow Modeling of Kütahya Plain Shallow Aquifer*. Doctoral dissertation. Ankara University, Institute of Science (38-144).

[2] Kilit, M (2011). *3D Modeling of Saltwater Initiative in Island Aquifer*. 7th Coastal Engineering Symposium p-329.

[3] Soyaslan, İ, Hepdeniz, K (2018). *Evaluation of Hydrogeological Properties of Beyşehir Lake Basin Based on Groundwater Flow Modeling*. MAKÜ FEBED. ISSN Online: 1309-2243. DOI: 10.29048 / makufebed.358206.

[4] Boyraz, U and others (2018). *Modeling River-Aquifer Interactions with Visual Modflow*. Water Foundation. Water resources (8-13).

[5] Aksoy, A. Ö and others (2011). *Time Changing Groundwater Flow Model of Torbalı Region*. İMO Technical Journal, 2011 5509-5522, Article 355.

[6] Pehlivan, Ş and others (2007). *Map of Turkey Jeloji No: 96 Balikesir - Sheet of I19*. MTA 1/100000 m. Geological Studies Department Ankara.

[7] D'Amore, F, Arnorsson, S (2000). Geothermometry. In S. Arnorsson, (Ed.), *Isotopic and chemical techniques in geothermal exploration*, *development*, and use (152-199). Vienna: International Atomic Energy Agency.

[8] Fournier, R. O (1977). *Chemical geothermometers and mixing models for geothermal systems*. Geothermics, 5, 41-50.