

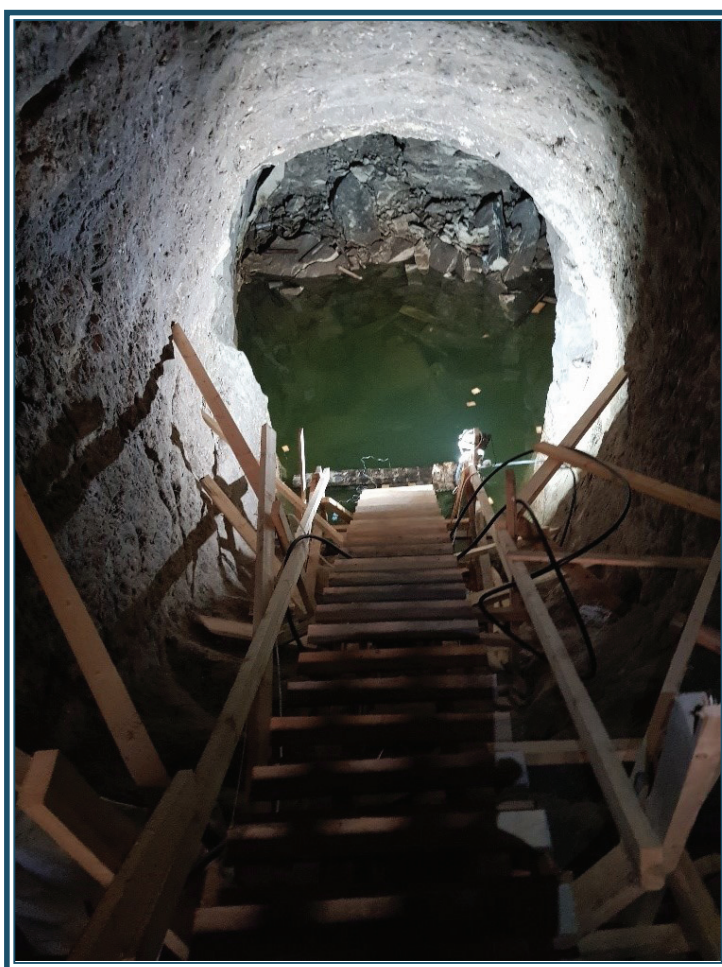


Ministry of Energy
Geological Survey of Israel

The Hydrogeology of Tel Gezer – technical report 2021

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Abstract

Tel-Gezer site was a settlement on Judea Mountains foothills in Israel, existing from the Middle Bronze Age II to the Hellenistic period, and famous for its impressive rock-cut water system. Its 90 m inclined tunnel was excavated into the Eocene semi-permeable chalk aquitard, sloping in 40° angle and reaching at its bottom a water reservoir based on the clayey aquiclude of the Taqiye Formation. The preliminary study (Yechieli et al., 2017) examined the option that there is a small, local aquifer underneath the Tel-Gezer hill, but did not provide a conclusive proof for it. The current study attempted to figure out whether Tel-Gezer reservoir was quarried in a local aquifer, or it is mainly fed by surface water from the tunnel entrance.

A monitoring of reservoir water level was performed, finding that the water level dropped some 12 cm from 04/06/2019 until 11/08/2019. Abrupt sharp rises of the water level during this periods are probably explained by several collapses of big rock blocks. Still, after each collapse, the water level continued to recede naturally as before. The reservoir water $\delta^{18}\text{O}$ - δD values are very close to those of the rainfall during the 2017-2020 showing no proof of evaporation, which is also supported by near-100% humidity in the lowest part of the tunnel. It also shows that the drop of water level is only a result of slow water infiltration through the rock. The nearby En Yarda spring exhibits more positive $\delta^{18}\text{O}$ - δD values, closer to the water of Soreq Cave and coastal aquifer. This data suggests that En Yarda water is more affected by infiltration processes through the rock than the water in Tel-Gezer reservoir. Tel-Gezer reservoir's water chemistry probably supports this conclusion, with concentrations of Ca^{2+} , Sr^{2+} , and HCO_3^- that are lower than those of En Yarda water. Therefore, Tel-Gezer reservoir seems to be mainly fed by the rainwater inflow through the tunnel entrance.

The data is still insufficient to determine the hydraulic properties of the Eocene aquitard rock. In order to reach this goal, we suggest performing a more thorough research as a part of a multidisciplinary (archaeology-hydrology) M.Sc. thesis. This study will include pumping tests in the reservoir during the summer months, as well as monthly chemical and $\delta^{18}\text{O}$ - δD analyses during more than one year in order to study the seasonal changes.

Introduction:

Tel-Gezer site existed since the Middle Bronze Age II (eighteenth–seventeenth centuries BCE) through the Iron Age II (ninth–seventh centuries BCE) and even the Hellenistic period (fourth–second centuries BCE) (Yechieli Y. et al., 2021). The site has a very impressive rock-cut water system (90 m long and 1100 m³ volume), constructed in the Middle Bronze Age II. Its tunnel was excavated into the Eocene semi-permeable chalk aquitard, reaching at its bottom the clayey aquiclude of the Taqiye Formation. The detailed introduction can be found in the preliminary study of Yechieli et al. (2017), which examined the option of a small, local aquifer underneath the Tel-Gezer hill. However, the 2017 study did not supply a conclusive proof for its existence. The current study tried to achieve more information regarding whether Tel-Gezer tunnel penetrate a local aquifer, or it is mainly fed by surface water from the hill's top and the tunnel entrance.

Methods:

The methods used in this study include:

- 1) Monitoring of the water level of Tel-Gezer water reservoir;
- 2) Monitoring of the temperature and humidity at the bottom of Tel-Gezer tunnel;
- 3) Sampling of water every ~3 months for chemical and isotopic analyses for 1 year
- 4) Water stable isotope analyses (oxygen and hydrogen) of Tel-Gezer reservoir and Yarda spring;
- 5) Water chemical analyses for major elements.

Data monitoring in Tel-Gezer reservoir was performed using Campbell Scientific CR800 data logger, with following sensors attached:

- 1) Keller-Druck XW-36 water level sensor (5 mm precision in 10 m range);
- 2) Meter-Group ATMOS-14 sensor of temperature ($\pm 0.25^\circ\text{C}$), humidity ($\pm 2\%$) and atmospheric pressure (± 0.4 kPa);

Observations of En Yarda spring water level were also performed manually.

Water $\delta^{18}\text{O}$ and δD composition was analyzed by Delta V and a Delta Plus mass spectrometers. Chemical composition of most major elements in water was analyzed using Optima 5300V Light Emission Spectrometer. All analyses were performed in Geological Survey of Israel.

Results:

Monitoring of the water level

Monitoring of the water level in the Tel-Gezer reservoir took place from 29th of May 2019 to 11th of August 2019 (Figure 1). The water level increased in the first two days of monitoring (until 31st of May) by 1 cm. This increase stopped at 01.06.2019 and the water level remained relatively stable until 4th of June, and then starting to decrease slowly. Total drop of the reservoir level until 11 of August 2019 was 12 cm. During this period, several collapses of rocks from the tunnel ceiling have occurred, according to the report of the cite workers. Abrupt increases of the water level in the pool, recorded by the water level sensor, could be the results of this rocks' collapse (Fig. 1). The increase in water level took place on 31st of May, 4th of June (twice), 7th of June, 10th of June, 22nd of June (the biggest rock fall), 19th of July, 4th of August and 10th of August 2019.

Between 3rd and 7th of May 2020 most of the water from the pool was pumped out to enable construction works. Before the pumping, the water depth was >1.6 m. About 50 m² of water were pumped out, leading to substantial (>1 m) drop in the pool level (minimal depth after the pumping was ~60 cm). After the pumping stopped, the water level rose by 50-60 cm in the first week (measured by N. Biton from the construction group). Later, the increase in water level gradually slowed down and stopped without reaching the previous level. The amount of rainfall during May 2020 was about 10 mm, most of it (~7 mm) falling between 5th and 6th of May, when the pumping still continued. Such minor rainfall could not cause the observed increase in reservoir water level.

The decrease in the level of the Yarda spring pool was >0.5 m during the same period (until 11/08/2019) and more than 1 m till 23/10/2019.

Stable isotopes of oxygen and hydrogen in Gezer reservoir and Yarda spring water

An isotopic analysis was performed on water samples from both Tel-Gezer and Yarda spring during the period from March 2019 to May 2020, with the results shown on Fig. 2 and in Table 1. The $\delta^{18}\text{O}$ values of Tel-Gezer pool are between -5.4‰ and -4.8‰, whereas δD values are between -28‰ and -19.6‰. The $\delta^{18}\text{O}$ values of Yarda Spring are somewhat less negative, between -5.1‰ and -4.35‰ and δD values are between -24‰ and -19.0‰. Both water compositions are located between Mediterranean Meteoric Water Line (MMWL) and global Meteoric Water Line (MWL).

Water chemistry

The results of the chemical analysis of major elements in Tel-Gezer reservoir's and En Yarda spring waters are shown in Table 2.

Temperature and humidity inside the Tel-Gezer tunnel

The temperature at the bottom of the tunnel, close to the surface of Tel-Gezer reservoir, slightly increased during the monitoring period, from +16.2°C in 29th of May to +17.8°C on 11th of August 2019. Temperature change was continuous and did not reflect the diurnal changes like in the upper edge of the tunnel near the entrance. The humidity was around 100% ($\pm 8\%$) during this period (Fig. 3), therefore no substantial evaporation was expected.

Discussion:

The aim of this study was to examine whether rainfall recharge plays significant role in feeding of the Tel-Gezer reservoir, and if the Eocene rocks in this site have some storage capacity and hydraulic conductivity that can enable the rock to store and supply substantially more water than the volume of the reservoir itself. The evidence obtained in this study are not conclusive but show the following:

- 1) The sudden increases in water level in the reservoir (Fig. 1) is best explained by collapse of rock blocks that fell into reservoir from the ceiling. It is expected that, immediately after each such collapse, the pool water level will increase by an amount proportional to the volume of the collapsed rocks. After the sharp increase, the water level is expected to quickly drop to previous level in case of high hydraulic conductivity. Instead, the water level continued its general trend of slow decrease, showing that hydraulic conductivity of the surrounding rocks is quite small. On the other hand, the increase in water level in the pool after pumping ($\sim 0.55\text{m}$ in one week) was probably a result of water release from the surrounding aquitard and implies that the hydraulic conductivity is not very small, as indeed expected from an aquitard unit.
- 2) $\delta^{18}\text{O}$ - δD values of reservoir water are very close to the composition of the rainfall above the nearby (distance of $\sim 20\text{ km}$) Soreq Cave during the 2017-18, 2018-19 and 2019-20 seasons (Fig. 2, Table 1). The $\delta^{18}\text{O}$ - δD values of En Yarda are slightly more positive, and closer to $\delta^{18}\text{O}$ - δD values of the dripping water inside the Soreq Cave and coastal aquifers' water (Fig. 2, Table 1). This may indicate that substantial part of the water recharge enters the reservoir directly as a rain water drainage through the tunnel entrance, with relatively little contribution of water infiltrating through the Eocene rock, which would cause more positive isotopic values due to evaporation. The more positive $\delta^{18}\text{O}$ - δD values in En Yarda imply that its water was more affected by infiltration processes through the rock than Tel-Gezer reservoir water.
- 3) The chemistry of water samples in Table 2 shows that Tel-Gezer water has lower concentrations of Ca^{2+} , Sr^{2+} , and HCO_3^- than En Yarda water. This difference may indicate that Tel-Gezer reservoir water spent less time interacting with the carbonate rocks compared to En Yarda. The concentration of most of the dissolved ions in Tel-Gezer water increases from Spring to Autumn 2019, possibly as a result of prolonged interaction with the surrounding rock and other materials found in the tunnel.

The high relative humidity near the reservoir surface (close to 100% Fig. 3) excludes evaporation. The lack of evaporation is also supported by $\delta^{18}\text{O}$ - δD values of reservoir water, which remain constant and close to the ones of the original rainwater. Therefore, the explanation for water level reduction in the reservoir can be slow water infiltration through the cracks in the surrounding rock. Calculation of the exact usable storage capacity of the Eocene aquitard rock in this location requires additional research.

Conclusions:

Tel-Gezer reservoir seems to be mainly fed by the rainwater inflow through the tunnel entrance. This conclusion is supported by proximity of Tel-Gezer water to the rainwater $\delta^{18}\text{O}$ - δD values, compared to En Yarda and other aquifers waters. The increase in water level of the reservoir due to the effect of rock

collapse into it implies that the hydraulic conductivity of the aquitard is relatively small. On the other hand, the increase in water level on the pool after pumping (~0.55m in one week) was probably a result of water release from the surrounding aquitard and implies that the hydraulic conductivity is not very small, as indeed expected from an aquitard unit with some usable capacity.

This capacity could be significant for people who were inhabiting the Tel-Gezer village in the ancient times. There is also a possibility that the soil cover above the tunnel was different in the past, enabling more infiltration of water from the surface through the tunnel ceiling.

In order to determine the amount of water that can be utilized from the surrounding rock of Tel-Gezer reservoir, we suggest to perform a more thorough research that will include the following: pumping tests in the reservoir during the summer months, after the end of the rainy season. Continuous monitoring equipment of water level should be installed during these tests. This monitoring device should be measuring the water level for longer period (more than one year) in order to examine the effect in summer and winter (direct penetration of rain water through the tunnel). A camera that will take continuous pictures may help in tracking rock collapses that may cause sudden level rise. Water samples should also be taken for a period of more than one year to study the seasonal effect. This research can be done as a part of a M.Sc. thesis on multidisciplinary theme that will combine hydrological and archaeological study in this site.

Acknowledgments:

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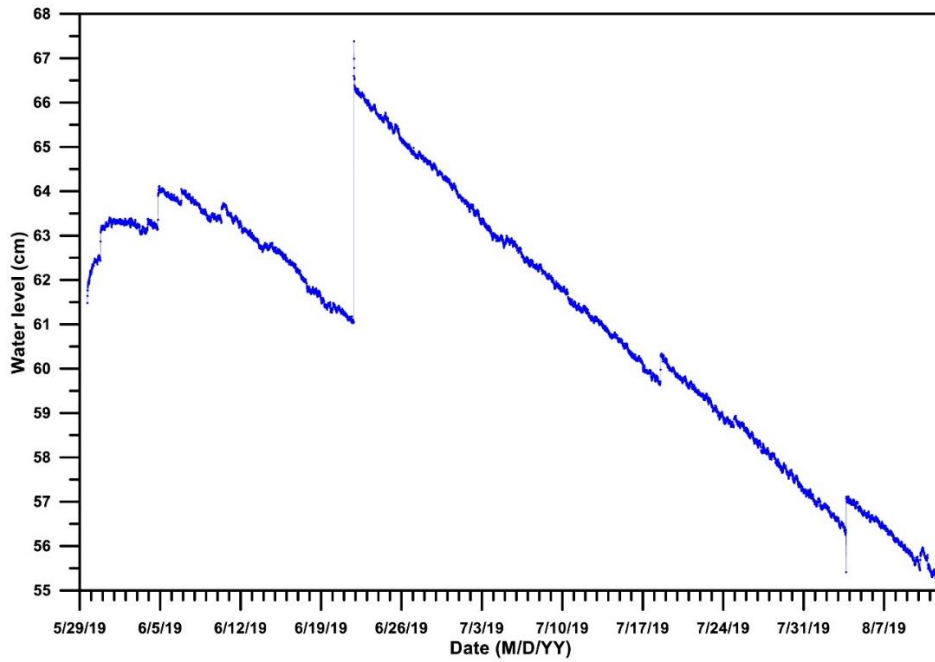


Figure 1: Water level in Tel-Gezer pool in cm (vertical scale) over time of 2.5 months (horizontal scale).

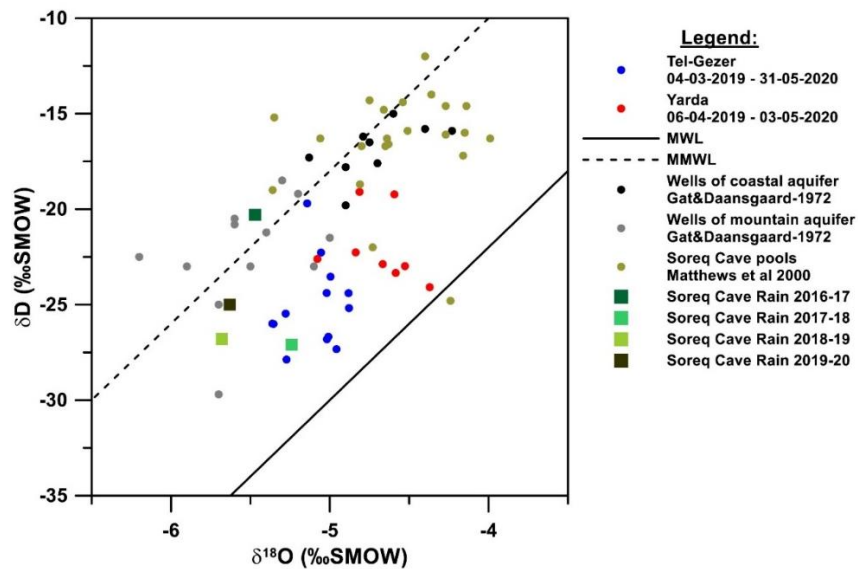


Figure 2: Oxygen and Hydrogen isotopic values of Tel-Gezer reservoir and of Yarda spring water during the period from March 2019 to May 2020, compared to MWL, MMWL, coastal aquifer water, mountain aquifer water (Gat and Dansgaard, 1972), Soreq Cave pools water isotopic values (Matthews et al., 2000) and the rain above the Soreq Cave during the 2016-2020 four seasons (Ayalon et al, unpublished).

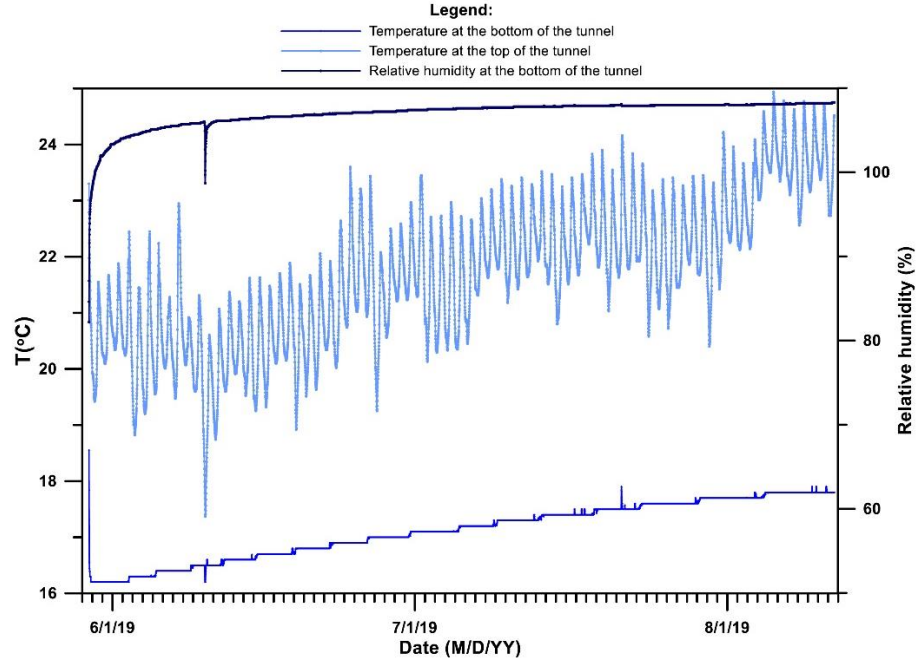


Figure 3: Temperature and relative humidity in Tel-Gezer tunnel from 29th of May to 11th of August 2019. Relative humidity in the bottom of the tunnel is shown by the upper graph. Temperature at the top of the tunnel is shown by the middle graph and the temperature in the bottom of the tunnel near the reservoir is shown by the bottom graph.

Sample	Date	$\delta^{18}\text{O}$	δD	$d\text{-excess}$	Comments
Gezer-31-4/3/19	04/03/2019	-5.01	-26.7	13.4	
Gezer-32-12/3/19	12/03/2019	-4.88	-24.4	14.7	
Gezer-33-2/4/19	02/04/2019	-5.36	-26.0	16.9	
Gezer-1-29/5/19	29/05/2019	-5.27	-27.9	14.3	
Gezer-2-29/5/19	29/05/2019	-5.35	-26.0	16.8	
Gezer-1-21/7/19	21/07/2019	-5.06	-22.3	18.2	
Gezer-2-21/7/19	21/07/2019	-5.14	-19.7	21.4	
Gezer-1-23/10/19	23/10/2019	-4.96	-27.3	12.3	
Gezer-2-23/10/19	23/10/2019	-5.02	-24.4	15.8	
Gezer-1-3/5/20	03/05/2020	-5.28	-25.5	16.8	
Gezer-2-3/5/20	03/05/2020	-5.00	-23.5	16.4	
Gezer-27/5/20	27/05/2020	-4.88	-25.2	13.9	
Gezer-31-31/5/20	31/05/2020	-5.02	-26.8	13.3	
Yarda-20-6/4/19	06/04/2019	-3.60	-24.3	4.5	Probable post-sampling evaporation
Yarda-29/5/19	29/05/2019	-4.59	-23.3	13.3	
Yarda-1-29/5/19	29/05/2019	-4.53	-23.0	13.2	
Yarda-1-21/7/19	21/07/2019	-4.59	-19.2	17.5	
Yarda-2-21/7/19	21/07/2019	-4.81	-19.1	19.4	
Yarda-1-23/10/19	23/10/2019	-5.08	-22.6	18.0	
Yarda-2-23/10/19	23/10/2019	-4.84	-22.3	16.4	
Yarda-1-3/5/20	03/05/2020	-4.37	-24.1	10.9	
Yarda-2-3/5/20	03/05/2020	-4.67	-22.9	14.5	

Table 1: Oxygen and hydrogen stable isotope composition of Tel-Gezer and Ein-Yarda waters.

Sample	Date	SiO ₂	Na+	K+	Ca++	Mg++	Sr++	Cl-	Br-	NO ₃ -	SO ₄ --	HCO ₃ -	TDS #	Cat	An+NO ₃	An-NO ₃	R.E.+NO ₃	R.E.-NO ₃		Na/Cl
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	equi	valence	valence	%	%	pH	eqv. Ratio
yy gezer-31	04.03.2019	24	50	89	45	13	0.3	78		82	103	119	543	7.8	7.6	6.29	1.01	10.51		0.99
yy-gezer-33	02.04.2019	30	57	102	49	15	0.4	86		79	135	146	625	8.8	8.9	7.63	-0.72	6.99		1.02
gezer-1	29.05.2019	30	63	107	53	18	0.43	96		108	122	168	680	9.6	9.7	8.01	-0.76	9.06	7.4	1.01
gezer-2	29.05.2019	32	72	114	56	19	0.47	99		109	133	180	723	10.4	10.3	8.52	0.55	9.90	7.4	1.11
gezer-3	29.05.2019	32	67	111	54	19	0.46	100		109	131	176	710	10.0	10.2	8.42	-0.87	8.59	7.4	1.03
gezer-4	21.07.2019	33	71	123	56	20	0.49	107		120	139	183	759	10.7	10.8	8.90	-0.62	9.19	7.6	1.03
gezer-5	21.07.2019	33	71	121	55	20	0.49	106		120	138	182	754	10.6	10.8	8.86	-0.97	8.88	7.6	1.02
gezer-6	23.10.2019	36	77	132	57	22	0.53	116		127	155	183	812	11.4	11.6	9.51	-0.83	8.90	7.5	1.02
yarda-20	06.04.2019	52	50	12	141	19	0.9	136	0.8	57	27	342	664	11.1	10.9	10.01	0.77	5.15		0.57
yarda-1	29.05.2019	46	51	12	137	17	0.85	141		77	23	326	666	10.8	11.1	9.81	-1.29	4.66	7.0	0.56
yarda-2	29.05.2019	46	51	12	137	17	0.85	142		79	23	328	669	10.8	11.1	9.86	-1.63	4.44	7.0	0.56
yarda-3	29.05.2019	46	51	13	138	17	0.85	142		81	22	326	671	10.8	11.1	9.81	-1.25	5.00	6.9	0.56
yarda-4	21.07.2019	46	49	12	125	16	0.78	123		71	20	321	620	10.0	10.3	9.14	-1.43	4.47	7.0	0.62
yarda-5	21.07.2019	46	48	12	126	16	0.78	122		70	20	319	618	10.0	10.2	9.10	-1.27	4.57	7.0	0.60
yarda-6	23.10.2019	46	43	10	120	14	0.73	102		57	17	324	569	9.3	9.5	8.55	-1.02	4.08	7.1	0.64

Table 2: Water chemistry in Ein-Yarda spring and Tel-Gezer reservoir.

תקציר

תל-גזר היה יישוב קדום בשפלת יהודה שהתקיים מתקופת הברונזה התיכונה II ועד לתקופה ההלניסטית ומפורסם במפעל המים המרשים שלו. הנקבה של מפעל המים באורך של כ-90 מטרים היורדת מטה בזווית של כ-40 מעלות, נחצבה בתוך סלע קירטון אקוויטארדי מתקופת האיאוקן. היא מסתיימת במאגר היושב על סלע חרסיתי אקוויקלודי מתצורת תקיה. המחקר הקודם (Yechieli et al., 2017) בדק אפשרות שהמאגר יושב בתוך אקוויפר מקומי קטן הממוקם בתוך תל-גזר, אך לא סיפק הוכחה ברורה לכך. המחקר הנוכחי ניסה שוב לבדוק האם המאגר של תל-גזר נחצב בתוך אקוויפר מקומי, או שהוא ניזון בעיקר במי נגר מפתח הנקבה.

ניטור מפלס המים במאגר הראה כי מפלס המים ירד בסך 12 ס"מ מ-29.05.2019 עד ל-11.08.2019. מספר התמוטטויות של גושי סלע גדולים כנראה גרמו ל"קפיצות" פתאומיות במפלס המים במהלך תקופה זו. לאחר כל קפיצת המפלס אחרי ההתמוטטות, מפלס המים המשיך בירידה הדרגתית מנקודה אליה עלה לאחר ההתמוטטות. הדבר מראה על מוליכות הידראולית נמוכה יחסית של סלעי האקוויטארד. ערכי ה- $\delta^{18}\text{O}$ - δD של מי המאגר קרובים מאוד להרכב הגשמים בשנים 2017-2020 ולא מראים סימני התאיידות, מה שנתמך על ידי לחות יחסית של כ-100% באוויר בתחתית הנקבה. מכאן שירידת המפלס נובעת אך ורק מחלחול המים. מי מעין עין ירדה, הממוקם ליד תל-גזר, מראים ערכי $\delta^{18}\text{O}$ - δD חיוביים יותר, המתקרבים לאלו של מי מערת שורק ומי אקוויפר החוף. מכאן שמי עין ירדה הושפעו יותר מתהליכי חלחול דרך הסלע מאשר המים במאגר תל-גזר. הרכבם הכימי של מי מאגר תל-גזר תומך במסקנה זו כאשר מראה ריכוזי Ca^{2+} , Sr^{2+} ו- HCO_3^- נמוכים יותר ממי עין ירדה. לכן נראה כי מאגר תל-גזר ניזון בעיקר מכניסת מי הגשמים דרך פתח הנקבה.

הנתונים שהתקבלו במחקר זה עדיין אינם מספיקים כדי לכמת את התכונות ההידראוליות של סלעי האקוויטארד מגיל איאוקן, בהם חצוב המאגר. לצורך השגת מטרה זו אנחנו מציעים לבצע מחקר יסודי יותר כחלק ממחקר לתואר מוסמך בינתחומי (ארכיאולוגיה – הידרולוגיה). מחקר זה יכלול מבחני שאיבה מהמאגר במהלך הקיץ, כמו גם אנליזות חודשיות של הרכב כימי ואיזוטופי ($\delta^{18}\text{O}$ - δD) של מי המאגר במשך יותר משנה לצורך החקר של שינויים עונתיים.



משרד האנרגיה
המכון הגיאולוגי הישראלי

הידרוגיאולוגיה של תל-גזר – דו"ח טכני 2021

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