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Sub-Bottom Profiler and Side Scan Sonar investigations, with the assistance of hydrochemical and isotopic analysis of Sawa Lake, Al-Muthana Governorate, Southern Iraq

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Abstract - A marine geophysical survey are including Sub Bottom Profilers and Side Scan Sonar integrating with under-water imagery, as well as hydrochemical and isotopic investigations have been carried out for Sawa Lake, one of the unique, shallow and closed water body in Iraq. The results showed that the depth of the Lake is shallow, ranged between 1 m in areas near the edges of the Lake and 2 m in the Lake center. The Recharge site has been detected exactly (this is a first recording (Nov. 2012)), as a hole. It has a longitudinal an axis of 50 m with NW-SE tren, which resembles the trending of the longitudinal axis of the Lake and Abu-Jir fault trending. The maximum width of this hole ranging from 23.0-29.5 m. The hole depth about 20 m, but may be greater then, because the emergence of a high proportion of noise in the geophysical sections. The Lake bottom is homogeneity and does not has any diacritical features. Also, the results showed discontinuous layers on either side of the hole due to the existance a number of caves under the bottom of the Lake extends into several meters with different dimensions and forms. Hydrochemical analysis of the water samples collected from different depths inside the hole by scientific diving with specefic equibments and the result showed that the water is NaCl type, with domination of Mg and Cl over Ca and SO_4. The Stiff diagram, detected that very high TDS arising mainly from sodium and chloride, it is mostly typical marine water. Values of $\delta^{18}O$ and $\delta^{2}H$ in water samples of Sawa Lake, when plotted along the global meteoric water line shows that the three collected water samples from the lake, which have a similar isotopic composition, indicating that all of them are receiving water from the same flow zones, with diffuse recharge type. Also, the isotopic parameter showed that the Sawa lake water suffering from strong evaporation.

Keywords: Sawa Lake, Sub Bottom Profilers, Side Scan Sonar, hydrogeochemical and satble isotope.

Introduction

Iraq has a large number of water systems in the form of streams, rivers, aquifers, marshes and lakes. Generally, these systems, lack of marine geophysical survey and environmental isotop techniques which can identify the rivers or marine sediments and the geomorphic of the sub-bottoms as well as to estimate its recharge sources. The required investigations however become very important because Iraq has a large areas covered by these systems. One of these systems is Sawa Lake, one of the unique, closed water body in Iraq. It deems one of the characteristic feature in the southwestern part of the Al-Muthana Governorate, west of the Euphrates river. It is an important site to put undre consideration due to its scientific, and biodiversity values. Sawa Lake is a strange lake characterizes by the highest salinity among the Iraqi inland waters. It is a mix-mesohaline water body of no inflow and outflow. The Dissolution processes of the gypsum barrier form caveties associated with its coolapse that shear for the increasing of the surface area (Jamil, 1977). Bahgat (1993) concluded that the secondary gypsum is formed as a result of the rise of the deep water with a high of sulfates and calcium. As result of the high temperature and extreme evaporation, layers of gypsum contens was occured. The Lake edges are high and reached a thickness of 5 m.

Several studies have been indicated that the source of the lake water is the deep ground water of marine origin ascending upwards through cracks and joints to be mix with shallower aquifers underneath the Lake; especially the Euphrates, Dammam and Umm Er Radhuma. It reaches the surface and filling the depression with water and then form the lake body (Jamil, 1977; Al-Rawi, 1975; Al-Muqdadi, 2003). On the other hand, Hassan (2007) studied the Physio-chemical characteristic of Sawa Lake water and he concluded that the water of this lake is similar to that water of the Euphrates and differ from the well nearby it or sea waters. The Lake water is mixed with fresh water. It is over saturated with calcite, dolomite, aragonite, gypsum and anhydrite minerals. While, Al-Qurashi (2013) concluded that the Lake water is classified as brackish to saline of alkaline water, while ground water taken from wells vicinity of the lake was slightly-brackish water, however, the chemistry of the Lake differs from the groundwater of wells which is characterized by Mg-chloride, and the wells water are Mg-sulfate.

Recent studies of the Lake showed that the depth of water decreased with the time, the water depth was 4-5 m before 35 years, while in recent years it ranged between 2-3 m. This have cause decreasing in the circumference of the Lake from 12,258 m in 1990 to 11,388 m in 2012 (Al-Abadi, 2013). The low water level of the lake is as salt because of the reduction of dilution factor and the existence rate of evaporation, in addition to the wide surface area of the lake. Poor rains and the increasing of number of drilled water wells random in the area in last years have caused the low level of the lake (Al-Muqdadi, 2003). Despite of the previous studies that have been conducted on the Lake, but these did not indicated the exact location the site that supply water for the Lake. All the previous studies have not include the marine geophysical surveys such as, a Sub Bottom Profiler (SBP) and Side Scan Sonar (SSS) which give a clear description of the location and dimensions of this site as well as to determine the geomorphology of the Lake bottom. Also, hydrochemical analysis of the previous studies which have been conducted in the region relied on the results of water samples that have been taken from the surface of the Lake only. In this study, a stable isotop technique has been used to detect the water resource of this Lake in addition to conduct hydrochemical analysis of water samples that are taking from different depths.

The climate of the study area is characterized by hot, dry summer, cold winter and a pleasant spring and fall. Approximately 90% of the annual rainfall occur between November and April, most of it in the winter months from December to March. The remaining six months are dry and hot. The climate parameters are derived from the meteorological station in Samawa, during the period (1980-2014), which indicate that the investigated area is characterized by an arid climate. The minimum and maximum temperatures range between (26.8-45.3)°C, the mean annual rainfall is 109 mm, and the highest values of evaporation occur during July (516 mm) with the lowest values occurring in January (91 mm).

Study Area:

Location: Sawa Lake is an elongated closed basin with no tributary of surface water belong to it. The Lake lies between longitudes (44° 59′ 29.01′′ and 45° 01′ 46.61′′) and Latitudes (31° 17′ 43.10′′ and 31° 19′ 49.79′′). The Lake is located about 24 km to the west of Al-Samawa City, and about 4 km to the west of Al-Atshan river, with an area about 4.7 Km^2 (Fig. 1). Also it is characterized by the exestance of several important phenomena such as the Sabkha and sand dune (Al-Shemari, 2006).

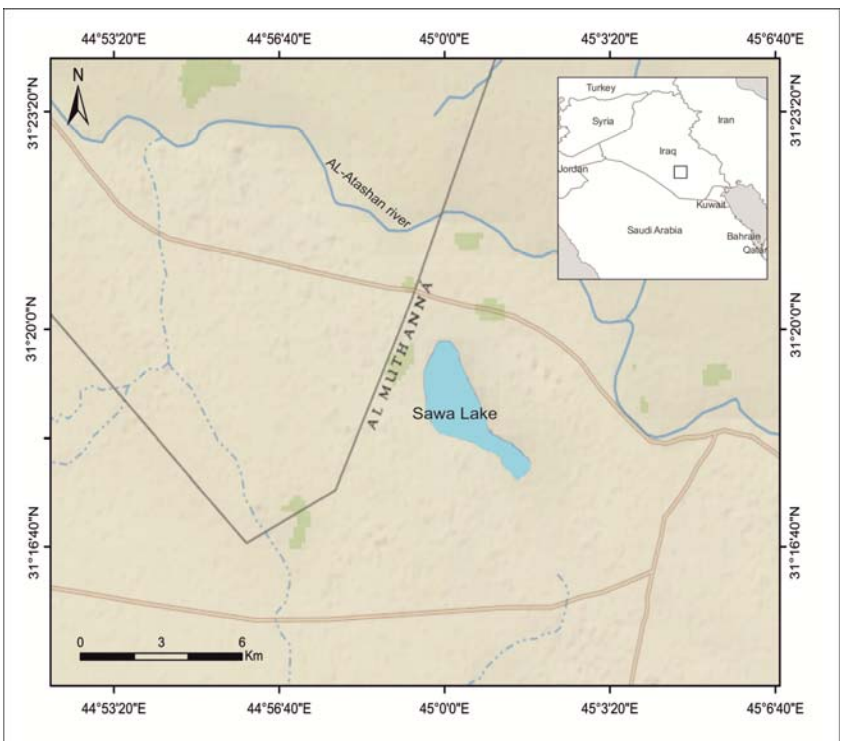

Figure 1. Location map of study area and surrounding.

It is a land locked lake with a circumference of 12.26 km maximum length of 5.13 km, maximum width of 1.936 km at the center of it and minimum width about 0.5 km at southeast of it (Al-Abadi, 2013). The area surrounding the Lake has a topographic is ranging about 13-26 m from west to east of the Lake, respectively. The topography of Sawa Lake is slightly different, the western side which rises 1 m in the eastern side (Al-Abadi, 2013). On the other hand, the lake rises 18-16 m above sea level, and it rises about 2-5 m from ground level adjacent to it (Jamil, 1977).

Tectonic and Structural Settings:

The origin of the creation of the Lake is referred to the geological structure effects in the region (Al-Naqash, 1977; Al-Muqdadi, 2003). Tectonically, the studied area is located within the eastern boundary of the south part of the Western Desert (Al-Kadhimi *et al*., 1996). It is represented by a small part of the borderline between the stable shelf (Salman sub zone) and the unstable shelf (Samawa-Nasisrya sub zone). The uplift of the Western Desert Block was formed by fault systems called Abu-Jir Fault. This fault represent a large influence on the hydrological setting of the studied area (Al-Sa'di, 2010), as well as many faults in different directions. One can observe the effect of Abu-Jir Faults through the line of springs and flowing wells distributed along the NW-SE direction. There are three types of the faults (Al-Mubarak and Amin, 1983) as a result of the influence of the structural and tectonic setting in whole area (Fig. 2). The first type of fault is considerd as the oldest (Late Cambrian) one that trends towards NE direction. Deeper sediments were strongly affected by this fault (Ditmar, 1972). The second type is trending NE-SW, and has an age of Late Cambrian-Mesozoic, they are consderd as normal faults. The third type having NW-SE direction is related to Mesozoic-Tertiary age.

Geology of the study area:

The area is covered by recent alluvial and dune sediments that vary in thickness from 1 to 10 m. It is underlain by recent salts deposit (Fig. 2). Geology plays a role and it is considered as an essential factor in determination of the quality of water. According to the reports of GEOSURV (1983), the formation in the study area can be described from oldest to youngest as shown in Table (1).

Quaternary Sediments consist of gypecrete, sabkha, salt sheet, and slope deposits. The aeolian deposit is represented by the sand dunes and sand sheets. Generally, Quaternary sediments are characterized by their inhomogeneous nature, vertically and laterally, especially, within the upper parts of these sediments due to the presence of different layers of silt and clay at a depth that may reach to 20 and 25 m (Jassim and Goff, 2006).

Hydrogeologylogy Setting:

The direction of groundwater flow in west desert (included the study area) is perpendicular on the fault Abu-Jir trend (Fig. 2), hence the groundwater leaks to the surface as springs. At the locations, groundwater meets the low impermeability Quaternary sediments causing springs diffusion along the fault zone which forms a discharge area. It also shows the accordance between the groundwater flow direction and the dissection of some main transverse faults, where groundwater flows from west to east and southeast. In the discharge area, some groundwater issues from large springs aligned along Abu-Jir fault and the

Euphrates boundary fault, while the remaining groundwater is confined below the relatively impermeable layers of the Mesopotamian plain, (Jassim and Goff, 2006). So Sawa Lake is a part of the discharge areas. The main aquifers in study area are:

Dammam Aquifer:

The hydrogeological investigations in the Western and Southern Desert reflected that Dammam Formation contains a huge amount of groundwater (GEOSURV, 1983). This aquifer is part of a complex hydrogeological unit located between different formations and is considered as the main regional groundwater aquifer within the Western and Southern Iraqi Desert, owing to its wide extension and the containing of a huge amounts of groundwater. The electrical conductivity ranges between (3000-4000 μs/cm) and the Total Dissolved Solids (TDS) ranges from (350-8530 ppm).

Euphrates Aquifer:

Euphrates Formation is composed mainly of limestone, with impermeable clay and marl (Al-Jiburi and Al-Basrawi, 2007). Near the surface the limestone's are weathered, fractured and karstified, and have enhanced permeability. Karstification is usually restricted to the 10m thick basal conglomerate unit of the Formation. The unit consists entirely of carbonate pebble and cobbles, which are prone to solution and due to their high original primary porosity it forms a very effective aquifer. The electric conductivity ranges from (5000-7000 μs/cm) and the total dissolved solids ranges from (1966-64853 ppm), with predominance of chloride water type. This aquifer is not considered as a main and important one, due to its bad water quality in most cases and its limited extension.

Materials and Methods

Sub Bottom Profiler (SBP) and Side Scan Sonar (SSS) Survey:

Underwater acoustics have for many years been a fundamental tool for oceanography and marine geology because of the ability of these methods to determine physical properties of the seafloor, and to identify geological acoustic reflectors below the seafloor (McQuillin *et al.*, 1984). A subsurface mapping system is used to obtain information about the sediments beneath the surface of the rivers, lakes, and sea bottoms. High-resolution mapping, Side Scan Sonar (SSS) and Sub Bottom Profiler (SBP) of seabed morphology became as essential tools for geophysical investigations, and therefore, these two techniques have been used in this study. The SBP an acoustic investigation technique that canmaps the sub-bottom by attaching the probe to a boat and dragging it through the water. With this technique one can, depending on the desired accuracy-varying from a few meters to several tens of meters in depth, map the sub-bottom and trace obstacles both in or on top of it. The SBP uses acoustic waves that are sent into the sub-bottom by means of a transducer. The acoustic signal reflects upon material transitions in the ground, that are registered by a receiver. By carrying out a sequence of measurements along a measuring line, detailed information concerning the composition of the sub-bottom and the internally present disturbances can be obtained. The SBP survey had been carried out in Nov., 2012 using the Strata Box™ marine geophysical Instrument (produced by SyQuest Inc, USA).

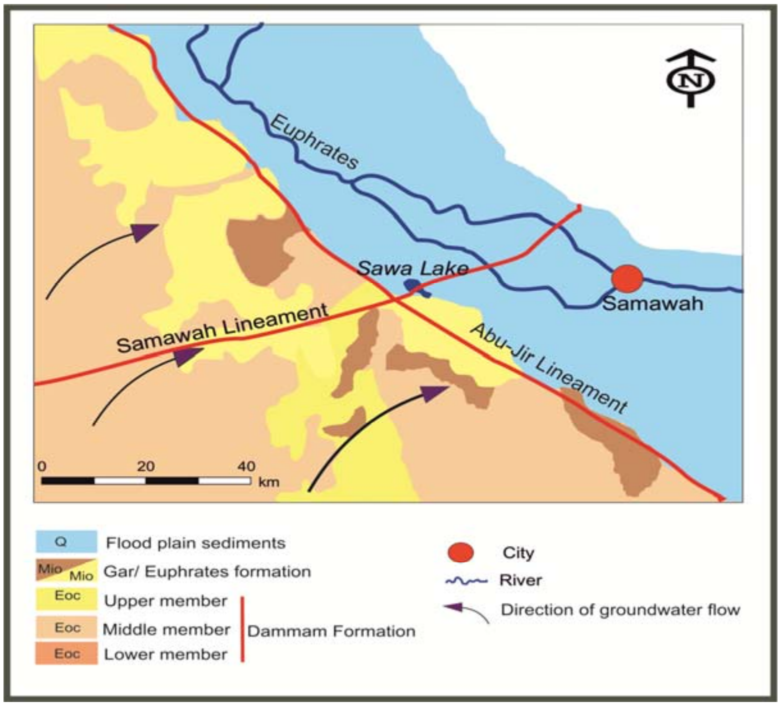

Figure 2. The geological map and simplified tectonic of the study area and surroundings (Modifid from Sissakian, 2000; Awadh *et al.*, 2013).

Table. 1. The formation in the study area from oldest to youngest

Formation	**Age**	**Composition and Thickness**	**Environment**
Rus	(E. Eocene)	Anhydrite alternating with marl, shale and limestone, dolomitize (Buday, 1980). The thick of formation of 20-50 m in the study area (Al-Mubarak and Amin, 1983).	Lagoonal
Dammam	(E-L.Eocene)	Variable carbonate rocks mainly limestone, dolomitic limestone, chert nodules. The thick of formation of 20-500 m in the study area.	Shallow neritic
Euphrates	(E. Miocene)	limestone with textures ranging from oolitic to chalky, which locally contain corals and shell coguinas (Jassim and Goff, 2006). It has a thickness between 30-40 m.	

Because of the shallow depth of the Lake (1.5-2 m), the user manual recommends that the distance between the transducer (its lower submerged surface) and the sea bottom should not exceed 2.5 m, as well as the noise was very high. Therefore, the reflectors of the Lake bottom beds are not appear in the SBP sections. During the survey, many of SBP track lines are recorded, the aim of these measurements are to test the equipment and tune parameters (e.g. setting the optimal signal gain) as well as to detect the recharge site of the Lake with water. One transvers track line has been preformed with SW-NE trend having a length of about 650 m, in order to determine the structural situation the recharge site referred to the Lake with water (Fig. 3A). This site had been chosen depending on the field observations, the energy of the water was highly flow in this location as shown in Figure (3B).

The SSS is an active system consisting of a long acoustic array providing a beam which is wide perpendicular to the array and narrow parallel to the array's long axis.(Mazel, 1985; Urick, 1983). It device that emits conical or fan-shaped pulses down toward the seafloor across a wide angle perpendicular to the path of the sensor through the water, which may be towed from a surface vessel or submarine, or mounted on the ship's hull. The intensity of the acoustic reflections from the seafloor of this fan-shaped beam is recorded in a series of cross-track slices. When stitched together along the direction of motion, these slices form an image of the sea bottom within the swath (coverage width) of the beam. The SSS survey had been carried out using the Imagenex Model 872 "Yellow Fin" marine geophysical Instrument (produced by Imagenex Technology Corp., USA).

SSS survey plan consists several track lines to be completed, and because the Lake bottom is devoid of any distinctive geomorphological feasure. The depths of the Lake are very shallow (1 m) in large parts of the Lake, the survey is focused at the recharge site which is located at the center of the Lake. Two SSS track lines have been carried out, the first is trending SW-NE with length of about 650 m and the second has NW-SE trend with length of about 400 m (Fig. 3A).

In addition to the SBP and SSS surveys, sea bottom samples (rock and sediments) and under-water observations or imagery (photo and video) have been applied to determine the best characterisitic of the sea bottom.

Hydrochemical and Isotopes:

In order to characterize the recharge sources and hydrochemical analysis of the lake. Six samples have been collected from the surface and different depths from the recharge site of the lake (in December 2013). Samples are choosed for isotopic (δ^2H, $\delta^{18}O$), anions (Cl^-, SO_4^{2-}, HCO_3^-), and cations (Ca^{2+}, Mg^{2+}, Na^+, K^+) determination. Insitu, temperature and pH were measured, using the WTW portable electronic instruments model (3210 SET 2 and 3110 SET 1), respectively. The groundwater samples are collected in clean polyethylene bottles following sampling routines set for water quality studies (Hem, 1991). Cation and anion analysis were conducted at the Chemical Laboratory, Geology Department in Marin Science Center (University of Barsah). Major ions (Ca^{2+}, Mg^{2+}, Na^+, K^+, HCO^{3-}, Cl^-, SO_4^{2-}) are analyzed according to standard methods as described in APHA (2005). Sodium and potassium are determined by flame photometer (JENWAY PEP7). Calcium and magnesium are titrated with 0.01 N Na_2EDTA. Chloride was determined volumetrically by titration with 0.01 N $AgNO_3$. Sulfate was determined by spectrophotometer (CEIL CE292) using turbidity method and bicarbonates are determined volumetrically by titration with 0.01N H_2SO_4.

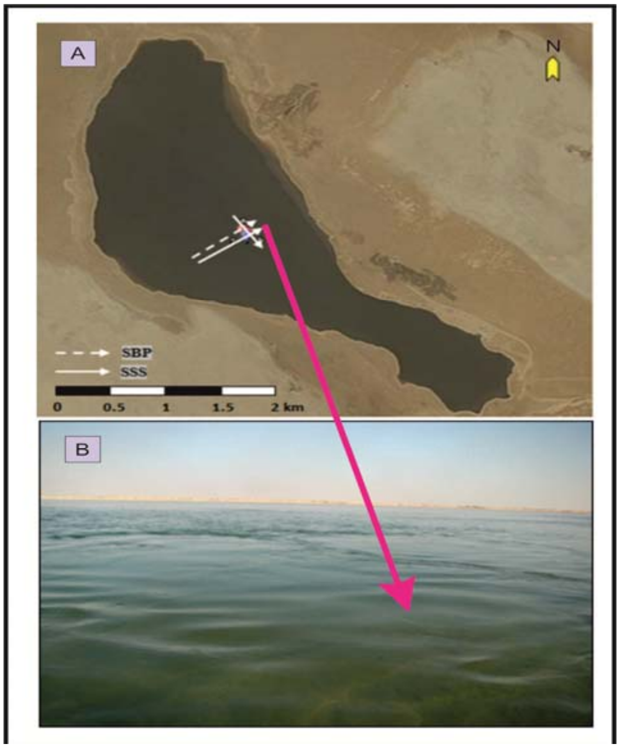

Figure 3. A: The SBP and SSS track lines, B: The Lake water recharge site.

The accuracy of the Lake water analysis is estimated for each sample from electrical balance (E.B.) where cations and anions are expressed as mill equivalents per liter (meq/ℓ). Electrical balances are calculated using the following equation (Appelo and Posma, 2005):

$$\text{EB}\ (\%) = \frac{\sum\text{Cations} - \sum\text{Anions}}{\sum\text{Cations} - \sum\text{Anions}} \times 100$$

Charge balances ranged between ± 5 % is typically considered to be acceptable for most groundwater analyses.

The Stable isotope analyses (δ^2H and $\delta^{18}O$) are conducted at the Laboratory of Stable Isotopes at the University of California, Davis in the USA. Isotopic ratios are measured using an 1RMS (Isotope Ratio Mass Spectrometer). The results, are reported as isotopic deviation δ(‰). Also Sample isotope ratios are standardized using a range of working standards that have been calibrated against IAEA standard reference materials (VSMOW). Precision for water samples at natural abundance is typically <0.3 permil for ^{18}O and <0.8 pernil for D/H. Final $^{18}O/^{16}O$ and D/H values are reported relative to VSMOW (UC Davis Stable Isotope Facility, 2013).

Results and Discussion

Geophysical Survey:

The results of SBP survey showed that the depth of the Lake is shallow and ranged between 1 m in areas near the coast of the Lake and 2 m in the vicinity of the recharge site, indicating the continual decreasing in the water depth of the Lake for the 5 years ago. This due to the decrease in recharge the lake with water, either through rains or through groundwater, as well as the increase in the evaporation.

The section of SBP is defined the recharge site exactly, the site represents a hole with dimeter of 45 m (Fig. 4A) and depth about 20 m. That is not the real depth, but this depth of penetration of the signal device, the depth may be greater, and the surface bottom of the hole does not appear clearly, probably due to the great depth of the hole, which may be ecceed than 200 m (representing the penetrating signal of device), and surface bottom of the hole may have been subjected to distortion due to fractures and cracks which caused flow of water through with high energy.

This led to the emergence of a high proportion of noise in the section, specifically above the center of the hole, also, this is seen by the disappearance of the pulses produced by a device when it pass above the hole so that the reflection of the surface bottom of the hole was not clear.

Also, the section shows that theis a discontinuities layering on either side of the hole walls, this owed to existance of the caves with different dimensions and forms extended inot several meters under the bottom of the Lake (Fig. 4 A and B).

The caves are confined by underwater observations and photos that have been taken during the dive, also, with indication of a biological activity as small fishes (10 cm) (Fig. 4C).

The SSS sections showed the homogeneity of the Lake bottom, and has not any diacritical features (only some aquatic vegetation), the inferred depths are not exceed 2 m. The SSS section (with a NW-SE direction) was detected the location and shape of the recharge site as a hole (not as springs according previous studies), it have a longitudinal axis of 50 m with a NW-SE trending (Fig. 5).

This trend resembles the trending of the longitudinal axis of the Lake (with Euphrates fault trending). The maximum width of this hole ranging from 23.0-29.5 m. The shape of the hole corresponds largely with the shape of the Lake, where the edges of the hole are rising to a depth of 1 m relative to surrounding areas of the Lake bed and contains a number of fractures and cracks.

Regarding the evolution of the Lake, it is suggested that it has passed into many stages during the history. In the first, it was a small Pool or basin, which represent the present form of the hole (Fig. 6A), this hole was formed due to the structural framework of the studied area highly influence the hydrological and hydrogeological systems.

In the stage 2, when the hole feeds the Lake, the water flowed in a NW and SE directions because of the topography of the land. By the time when high present barriers were completed. Because of the decreasing recharge, the basin’s water capacity becomes less than the available water, the Lake′s levels decreased largely during the past ten years as a result of decreased recharge (rain and ground water) and increased evaporation rates (Fig. 6 B and C).

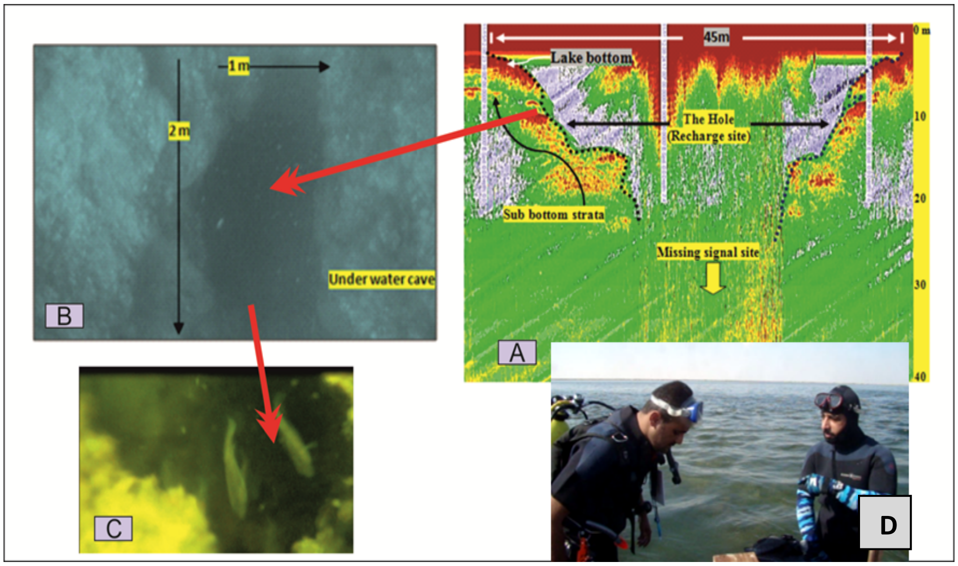

Figure 4. A: The SBP section, surface bottom of the hole does not appear clearly, this may be due to the great depths of the hole and high proportion of noise caused by which caused by a high flow of water energy. In the lift, under water, B: under-water cave, C: biological activity as small fishes, and D: photo. in March, 2012.

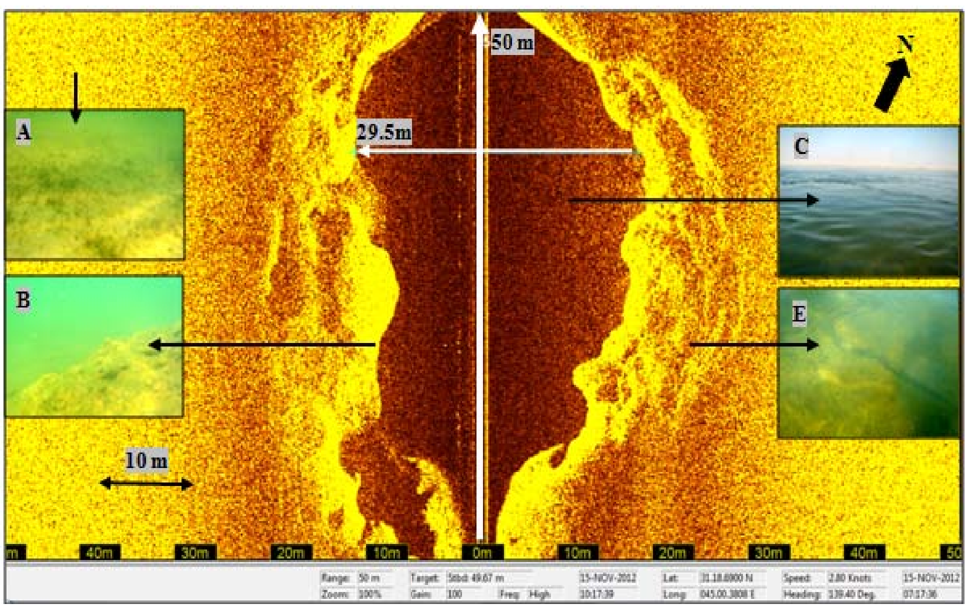

Figure 5. The SSS section, the Recharge site as a hole, A: The lake bed with aquatic vegetation, B: The hole edge with depth of 1m, C: Center of the hole with high flow water energy, E: The fractures in the hole edges.

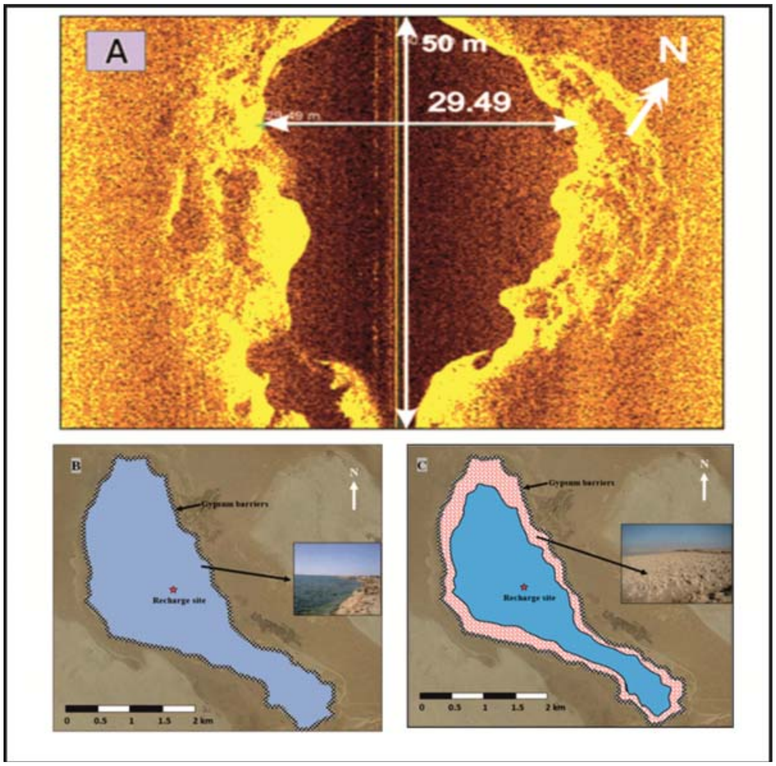

Figure 6. Suggested evolution of the Lake, A: The first shape fo the lake as a pool or small basine, B: The lake shape befor 10 years, C: The present lake shape.

Hydrochemical characteristics of Sawa Lake:

The results of chemical analysis of water samples are tabulated in Table (2). Na^{+} and Cl^{-} are the dominant ions; the other elements in abundance are Mg^{2+}, Ca^{2+} for cations and SO_4^{2-} for anions. The relatively high content of Na^{+}, Mg^{2+}, Cl^{-} and $SO4^{2-}$ is expected to be issued from relatively recent karstic origin and not a relic of a mid-Holocene marine incursion (Jamil, 1977). The Sawa Lake water samples are plotted on the Sttif diagram (Fig. 3). The Sttif diagram showed significant variations between the different depths of Sawa Lake water (Fig. 3), which that mean the lake fed from different sources. On the other hand, the sodium-chloride type water for all samples that taken from different depths in the Sawa Lake of marine origin. This source of the Lake water is due to Abu Jear Fult, cracks and joints to be mixed with shallower water of aquifers underneath the Lake, especially the Euphrates, Dammam and Umm Er Radhuma aquifers (Jamil, 1977). It reaches the surface filling the depression with water forming the Lake body. This Stiff pattern, with very high TDS arising mainly from sodium and chloride, is typical of water from formations of marine origin (TDS = 25823 mg/l) (Weiner, 2008). Also, this diagram of lake water may indicate that the different origin which are characterized by Na^{+} and Cl^{-} (Fig. 7). The high value of Na^{+} and Cl^{-} is attributed to the strong evaporation, which are clearly seen in the studied areas, as a result of rising the temperatures very high in the region.

Stable Isotopic Composition of Sawa Lake:

The δ^2H and $\delta^{18}O$ values of the Sawa Lake samples are listed in Table (2) and plotted on a δ^2H - $\delta^{18}O$ diagram. These values compared to the global meteoric water line (GMWL) and Iraqi Meteoric Water Line (IMWL) (Fig. 7). The $\delta^{18}O$ and δ^2H composition of surface waters from Sawa Lake. Figure (7) Show that the isotopic composition for all sample lie on a LEL and below the IMWL and GMWL. This means that water in the lake has been significantly affected by evaporation. On the other hand., three surface water samples from the Sawa Lake plotted along the same evaporative line with a slope of about 4.5 (Fig. 7), implying similar isotope systematics, including kinetic effects transported during evaporation. Also, The isotopic enrichment of water from the Sawa Lake system (δ^2H = 36-36.9 ‰, $\delta^{18}O$ = 7.56-8.1 ‰) is related to significant evaporation, due to either a longer residence time of water or by recharging it from deeper groundwater (Euphrates and Damon aquifer).

Another part of evidence for the origin of recharge of the selected samples from the lake is gained from the value of the deuterium excess (d-excess) (Ghalib, 2014). The deuterium excess (d), is introduced by Dansgaard (1964) which is defined as $d = \delta D - 8 * \delta^{18}O$. The d-excess parameter an index showing the evaporation effect on the physical-chemical characteristics of water, that is, if the water evaporates, the d-excess decreases. The d-excess values fall below the reference value of 10. (Values << 10 can indicate strong evaporative effects) (IAEA, 2004).

The slope of 4.65 in local evaporation lines (LEL) is characteristic of evaporation processes in free water bodies under relative humidity conditions approaching 50%, which is consistent with the values measured in the study site during this period (Clark and Fritz, 1997). According to the isotopic data, it is concluded that the recharge of the aquifer is diffused recharge, because the groundwater that is recharged by diffusion recharge is more enriched in stable isotopes than that which is recharged directly.

Table 2. Physical parameters and major ions concentrations of Sawa Lake samples.

Parameters	No.				
	1	2	3	4	5
Depth (m)	0.2	1	15	17	19
TDS (mg/l)	23940	25823	11491	9952	20498
EC (µS/cm)	27912	29205	13560	11875	24115
pH	8.42	8.31	8.31	8.36	8.30
Na (mg/l)	5535.0	6486.2	2496.9	2255.0	4272.2
K (mg/l)	205	255	85	72	160
Ca (mg/l)	520	535	510	515	520
Mg (mg/l)	1475.76	1471.80	774.18	547.80	1411.74
Cl (mg/l)	7632	8165	3372	2840	6567
SO_4 (mg/l)	8100	8477	3845	3471	7200
HCO_3 (mg/l)	429	408	376	204	333

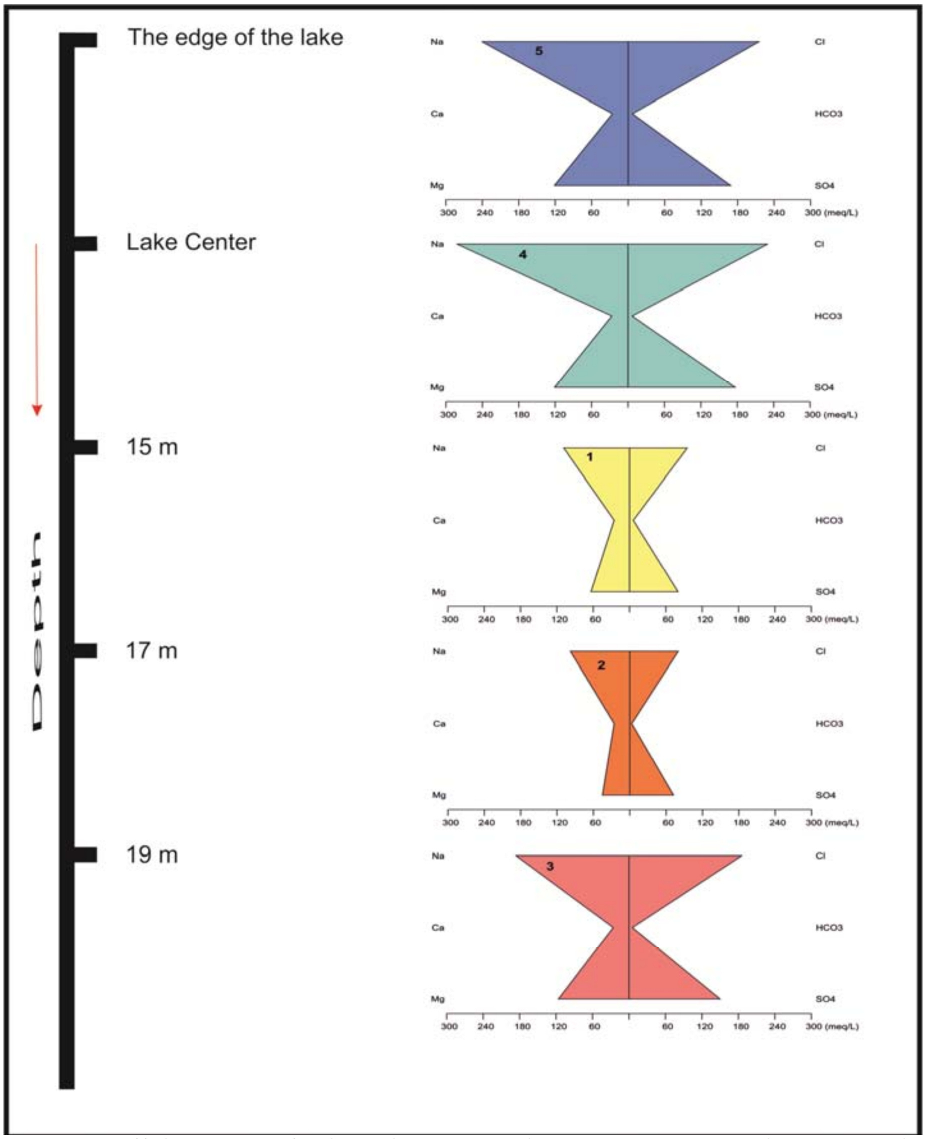

Figure 7. Stiff diagrams of selected water-quality constituents in the Sawa Lake, the samples of 15m, 17m and 19m have been collected from recharge area.

The values of d-excess of Sawa Lake water in studying area shows depleted and very slight variation (Table 3). This mean, the surface water of Sawa lake was suffering from significant evaporation in the study area. The d-axis value of this preliminary IMWL (7.57) is lower than that of the GMWL (10). This reflects the source of not precipitation to the study area, which is predominated by deeper groundwater moving bottom to up and mixed with surface water. The results of this study for Sawa lake showed a low value of d-excess, (less than 5 ‰), which reflects the pale-recharge.

A plot of δ^2H vs. $\delta^{18}O$ for Sawa Lake water samples, where IMWL is the Iraq Meteoric Water Line (as calculated with data from Al-Paruany, 2013), GMWL is the Global Meteoric Water Line (as calculated with data from Craig, 1961) and LEL is the Local Evaporation Line (as deduced from the Sawa lake data) (Fig. 8).

Table 3. Stable isotopes data of Sawa Lake

Sample Name	δ^2H	$\delta^{18}O$	D-excess (‰)
Sawa 1	36.0	7.56	-24.48
Sawa 2	36.4	7.80	-26.0
Sawa 3	36.9	8.1	-27.9

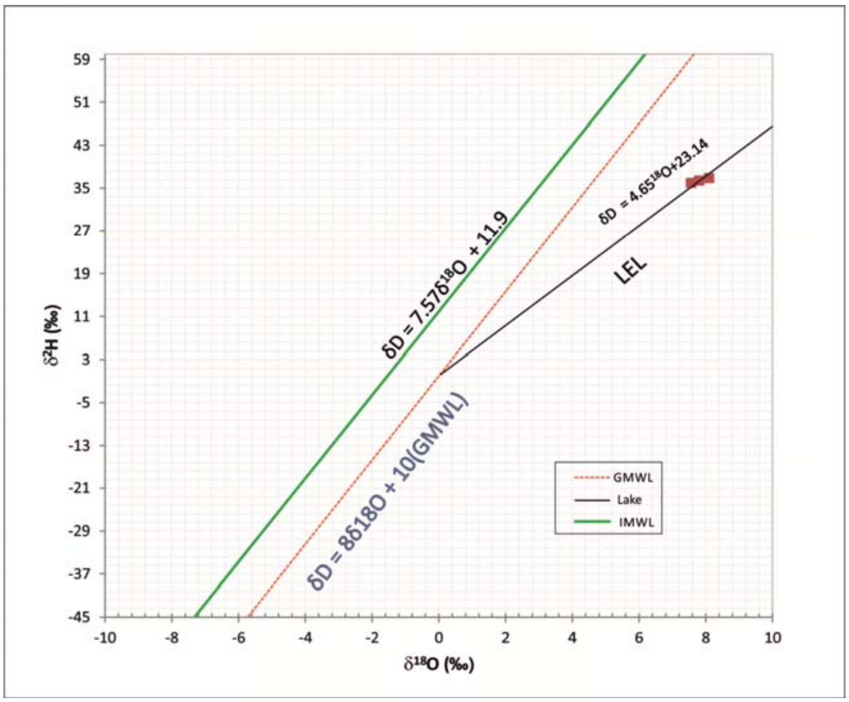

Figure 8. A plot of δ^2H vs. $\delta^{18}O$ for Sawa Lake water samples, where IMWL is the Iraq.

Conclusions

Recent technological improvements to marine geophysical techniques such as SBP and SSS systems and processing have increased the potential for resolving and explaining detail information morphology and structures of the water systems bed. In this study SBP and SSS survey integrating with under-water imagery concluded:

- The depth of Sawa lake is shallow, ranged between 1 m in areas near the coast of the Lake and 2 m in the Lake center, the Lake bottom a homogeneity and does not has any diacritical features, excepte of the Recharge site.

- The Recharge site which supply the Lake with water had been detected exactly, the site represents as a hole, have a longitudinal axis of 50 m with NW-SE trending, a maximum width of this hole ranging from 23.0-29.5 m. The shape of the hole corresponds largely with the shape of the Lake, where it was noted that the edges of the hole are rising to a depth of 1 m relative to surrounding areas of the Lake bed and contains a number of fractures and cracks.
- The penetration depth is about 20 m in the hole, but this may be not a real depth. The depth may be greater, because the emergence of a high proportion of noise in the SBP sections, this is seen by the disappearance of the pulses produced by a device when the survey boat pass above the hole.
- The layers on either side of the hole are discontinuited because of the exist a number of caves under the bottom of the Lake which extends into several meters with different dimensions and forms.
- Hydrogeochemically, the salnity of the lake water is flowing through the fault planes to the lake; due to the semi confined property of the aquifers in the area. The lake water sources is due to Abu Jear Fult, cracks and joints to be mixed with shallower water of aquifers underneath the Lake, especially the Euphrates, Dammam and Umm Er Radhuma aquifers. It reaches the surface filling the depression with water forming the lake body.
- According to the isotopic data, it is concluded that the recharge of the aquifer is diffused recharge, because the groundwater that is recharged by diffusion recharge is more enriched in stable isotopes than those recharged directly. Also, the isotopic parameter showed that the Sawa lake water suffering from strong evaporation.

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استخدام تحريات رسم المقاطع الجانبية ومقاطع السونار للقيعان مع التحاليل الهيدروجيوكيميائية والنظائر لبحيرة ساوة، محافظة المثنى، جنوب العراق

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المستخلص - تضمنت الدراسة الحالية تنفيذ مسوحات جيوفيزيائية بحرية بالتكامل مع المعلومات المستحصلة (صور ومقاطع فيديو) لعدة أعماق والمنجزة من قبل فريق الغوص العلمي، بالإضافة إلى تحليلات النظائر المشعة والتحليلات الهيدروكيميائية لبحيرة ساوة، والتي تعد احدى الظواهر المائية المغلقة المميزة في العراق. تضمنت المسوحات الجيوفيزيائية مقاطع لجهاز رسم المقاطع العرضية (SBP) وجهاز رسم المقاطع الصورية (SSS). أظهر تكامل نتائج المسح الجيوفيزيائي مع المعلومات المستحصلة من قبل فريق الغوص العلمي أن البحيرة ذات اعماق ضحلة تتراوح من 1 متر في المنطقة الواقعة قرب حافات البحيرة إلى 2 متر في وسط البحيرة. تم تحديد موقع مصدر تجهيز البحيرة بدقة (اكتشاف لأول مرة، تشرين الثاني 2012). يعتبر الموقع كحفرة أو فوهة (Hole)، لها محور طولي 50 متر باتجاه شمال غرب جنوب شرق وهو نفس اتجاه البحيرة وفالق أبو جير Abu-Jir. يبلغ أقصى عرض لها بين 23.0 – 29.5 متر. وجد أن شكل الفتحة يشابه إلى حد كبير شكل البحيرة الخارجي. قاع البحيرة متجانس ولا تحتوي على مظاهر مميزة. أظهرت النتائج أن عمق الفتحة يصل إلى 20 متر وليس من المؤكد أنه العمق النهائي، إذ قد يكون أعمق بسبب التشويش العالي الظاهر في المقاطع الجيوفيزيائية الناتج من طاقة الجريان العالية للمياه المتدفقة من الفوهة، وكذلك فقدان الأشارات المستلمة من أجهزة المسح عند مرور زورق المسح فوق الفتحة. كما بينت النتائج وجود طبقات متقطعة غير مستمرة من أحدى جوانب الفتحة تدل على وجود عدد من الكهوف تمتد إلى عدة أمتار بأشكال وأبعاد مختلفة. وجد أن نوع المياه هو كلوريد الصوديوم مع سيادة أيوني المغنيسيوم والكلور على أيوني الكالسيوم والكبريتات وذلك من خلال التحاليل الهيدروكيميائية لنماذج المياه المأخوذة بواسطة الغوص بكامل التجهيزات والمعدات إلى أعماق مختلفة في منطقة الفتحة المجهزة للبحيرة (في تشرين الثاني، 2012). أظهر مخطط ستيف تركيز عالي للأملاح الذائبة مع زيادة الصوديوم والكلور، حيث تشير إلى أن المياه ذات أصل بحري في الغالب. أظهرت بيانات الرسم البياني لقيم $\delta^{18}O$ و$\delta^{2}H$ للنماذج الثلاثة لمياه البحيرة انها تمتلك تركيب نظائري متشابه والذي يدل على ان مصدر التغذية للبحيرة هو من نفس النطاق لخزانات مختلفة. وبينت النتائج النظائرية أن البحيرة تعرضت الى تبخر شديد.