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Application of two frequencies sub-bottom profiler technique for mapping the bottom of Shatt Al-Arab River

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Abstract

Shatt Al-Arab River is one of the most important Iraqi waterways. It has suffered from different types of natural and man-made variations, specifically the past 40 years such as dramatic declination in water discharges due to recent hydraulic constructions. These changes affected the bottom, sub bottom, and geomorphologic features of the river bed. To images these changes, a marine geophysical survey represented by high-resolution Sub–Bottom Profiler was carried out to describe the morphology, structure, and sub-bottom layers of Shatt Al-Arab river. Four sub-bottom transverse profilers were carried out by Strata Box transducers, 10 kHz at Al-Sendebad Island, Al-Ashaar, Um Al-Rasas Island and Sihan meandering areas.

The results of the sub-bottom profilers showed that the used technique is an essential tool to map sub-marine geological features and locate the buried structures in the river bottom. Specifically, at Al-Sendebad Island, there is a depositional process have increased about 5 m, the recorded depth was 18 m, but it was about (24-22 m) in previous studies. In Al-Ashaar site section, many types of sub bottom layers formed by recent and old deposits were correlated with well-log data, the bearing strata is located at 20 m under the bottom of the river. At Um Al-Resas Island, there is no indication of tectonic activity which may form the Island. The highest depth of the river bottom recorded at Sihan meandering is about 22 m. These changes may due to the changes in the hydrological and depositional systems of the river. At Sihan meandering, there are many prominent features like large depths, river meander, buried channels of ancient streams and a possible trace of fault which may be an indication of neotectonic activity.

Key wards*:* Shatt Al-Arab River; Sub–Bottom Profiler (SBP); Bottom morphology

1.Introduction:

Rivers are the most prominent of the natural morphological features that have impact on the earth`s shape through deposition and erosion processes. Rivers are sensitive to any development and variations which caused by many reasons, such as morphological processes, tectonic activations and man-made affection. Tectonic activations are closely associated with active structures [1], which in turn are responsible for changings in channel morphology, hydrological characteristics and fluvial processes of the river system.

There are two main rivers flow through Iraq, Euphrates and Tigris. The two rivers confluence at Qurna city in Basra Governorate to form Shatt Al-Arab river. Specifically, during the last 40 years, Shatt Al-Arab river exposed for many natural and man-made affection, such as declination of water discharges dramatically due to modern hydraulic constructions, and subsequently occurred many changes in geomorphologic setting of the river, these changes includes: river bottom, deposition and erosion issue, river sinuosity, existing the sunken wrecks and debris, the delta area, as well as changes in geomorphologic units such as islands, bars and point bars[2] and [3].

Marine geophysical observations by underwater acoustics such as high-resolution mapping Sub Bottom Profiler (SPB) is now essential for subsurface mapping to obtain information about the sediment deposits, morphological features and structures of the rivers and coastal bottoms. Also, this method is used to determine physical properties of the rivers, identify geological acoustic reflectors below the seafloor designed to acquire information about geological boundaries well below the seafloor, and information relating to surficial and near-surficial sedimentary environments [4] and [5].

The present study attempts to image the morphological features, bottom structures and to identify geological acoustic reflectors below Shatt Al-Arab river bottom using SPB technique.

2.The study area:

Shatt Al-Arab river is about 200 km length and runs through Basra city/ southern Iraq. Part of it, about 70 km, represents the Iraqi-Iranian borders at the south-western side of Iran. This study focused on part of Shatt Al-Arab from Basra city center down to Fao town southernmost Iraq (Figure-1), with the total targeted distance is approximately 60 km. The northern part of Shatt Al-Arab is bordered by the marshland area (e.g., Qurna northward, Al-Hammar lake northwest, and Al-Haweizeh marsh at the northeast). Shatt Al-Arab ends at the Arabian gulf.

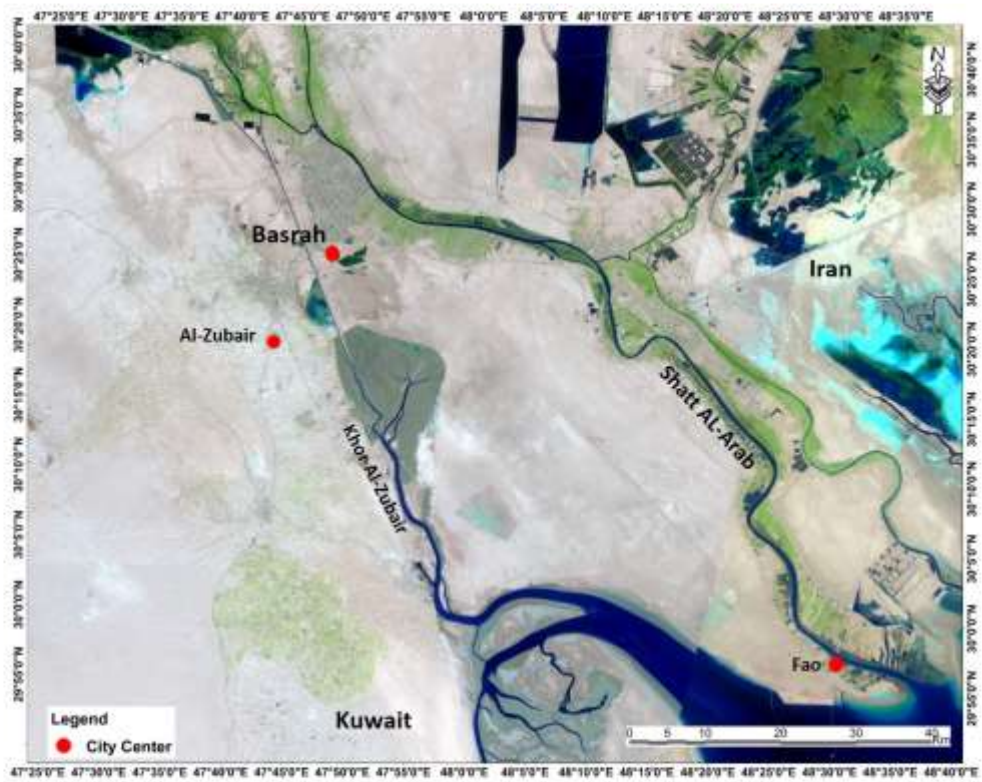

Figure (1) Map of the studied part of Shatt Al-Arab River.

Geologically, the study area lies within the Mesopotamian plain which is mainly covered entirely by the Quaternary deposits. The thickness of the Quaternary deposits varies from site to site and averaged about 100 m. Both Pleistocene and Holocene deposits are existed in the area [6]. The sediments of the Mesopotamian plain are represented by gravel and sand [7]. The upper part of the sequence is usually lithologically very monotonous composed of fluviatile flood silt with strong aeolian admixture [8].

The Pleistocene fluvial deposits consist mainly of an lithified sediments. These sediments may be classified into fine medium sand grain sizes, sand mixed with clay and silt. Normally, facial changes and vertical lithological variation are quite frequent in fluvial deposits. The origin of these deposits is the Tigris and Euphrates flood plain system. The upper contact with the Holocene deposits was taken at the top of yellowish to brown clay in a silty clay bed. The clay bed contains large gypsum crystals which has often abrupt contact with the overlying deposits. The Holocene deposits mainly consist of fluviatile, lacustrine, sabkhas and marine [9].

Tectonically, the study area is part of the shallow basin of the Mesopotamian zone, that is a part of the Arabian plate foreland [10]. The Mesopotamian basin is located in the northwest of the Arabian gulf, which is remnants of the Neo-Tethys sea, that represents an old oceanic basin [11]. Neo-Tethys sea has closed at the Late Cretaceous as a result of the collision occurred between the Arabian and Iranian plates [12]. Shatt Al-Arab river and the surrounding area are located in the Zubair subzone, the southernmost of Mesopotamian. The Mesopotamian zone is characterized by the existence of many gently plunging subsurface structures of different sizes, these structures are surface and subsurface faults and salt plugs.

The river is formed by the confluence of the Tigris and Euphrates Rivers, which flows through Mesopotamian plain, central and eastern Iraq. A third river, the Karun River, which rises in west-central Iran and drains the Zagros mountains meets Shatt Al-Arab just north of the modern delta, [13] concluded that Shatt Al-Arab river probably have been formed during (2000- 1600) years ago. The Tigris and Euphrates Basin and their extensions, Arabian Gulf, occupy a zone of subsidence flanked by mountains and/or desert. This elongated depression was formed during mountain building movement initiated in the Early Tertiary that continues with the movement of Arabian plate against the stable landmass of the Iranian Plate.

3. Methodology:

To identify small scale sedimentary structures and processes, the sub-bottom profiling systems can be used by high spatial resolution. The marine geophysical acoustic sub bottom profilers technique have been used in this study.

The SBP is an acoustic investigation technique that maps the sub-bottom by attaching the probe to a boat and dragging it through the water. The acoustic pulses generated may be described as a single-beam, the acoustic pulse travels through the water column at a rate determined by water temperature, salinity and suspended material concentration, and penetrates the sea-floor. SBP is used to acquire penetration of sub-bottom sedimentary beds with high imagine resolution depend on the use of low frequency echo-sounders (1 kHz and 50 kHz). The SBP survey has been carried out by using the Strata Box™ marine geophysical Instrument which produced by SyQwest, Inc., USA.

The Strata Box is a portable high-resolution marine geophysical instrument. It is capable to detect 6 cm of sub-bottom marine sediment strata resolution underneath the sea-floors and rivers with penetration of up to 40 m by low power using frequency of 10 kHz [14], therefore it is water-resistant marine sediment imaging device. Generally, it is designed for inshore and coastal marine geophysical survey with depth of water up to 150 m, for getting high penetration of up to 80 m, it can be applied with frequency of 3.5 kHz. The aims of SBP survey is to carry out a sequence of measurements along a measuring line to obtain detailed information concerning the composition of the sub-bottom, describes the morphology, structure and sub bottom layers of the study area.

Four of SBP transverse profilers were carried out by Strata Box transducer 10 kHz. in four stations over the study area, with lengths ranged between 170 m in station-3 to 442 m in station-1(Figure-2). Table (1) illustrates the numbers and coordinates of the station with the lengths of the SPB profilers.

Figure(2) Map of the study area with SBP survey stations.

Table (1) The stations, lengths and their coordinates that are done by SBP survey.

St.	Site	Length(m)	Coordinates	
1	Sindebad Island	442	30°34'47.44'N	47°46’23.91”E
2	Al-Ashaar	273	30°30'37.80"N	47°51'5.21"E
3	Um Al-Resas Island	170	30°25'36.71"N	48°9'35.30"E
4	Sihan meander	280	30°18'53.95"N	48°12'45.00"E

4.Results and Discussion:

Generally, the results showed that the depth of the river bottom is different at each site and even in the same section sometime. The highest depths are about 18 m at st.1 and 22 m at st.4. The penetration of the acoustic waves was 20 m under River bottom due to the existence of medium-coarse sand and some material which tend to absorb these waves. The first strata is appeared as a thin bed having thicknesses ranging between 10-30 cm for the river bottom that are distributed with a uniform pattern in all sections. The shallow water exacerbated the problem of multiples in the sonar data. Multiples are generated by sound energy reverberatoin in the water column as opposed to penetrating into the sub-bottom.

In the sub-bottom profiles, the presence of multiples, which are essentially parallel to the river bottom, mask the presence of possible deeper reflection events. SBP sections provide important information about submerged landscapes, as they can survey large areas relatively quickly and are non-destructive. In particular, when used in combination with core data, they can provide valuable data for the reconstruction of past environments. In this study, the information and results of the subsurface bed for two sides of the river which mentioned in [15] that have been used for matching SBP data and borehole data to detect of sub bottom strata (Figures-3).

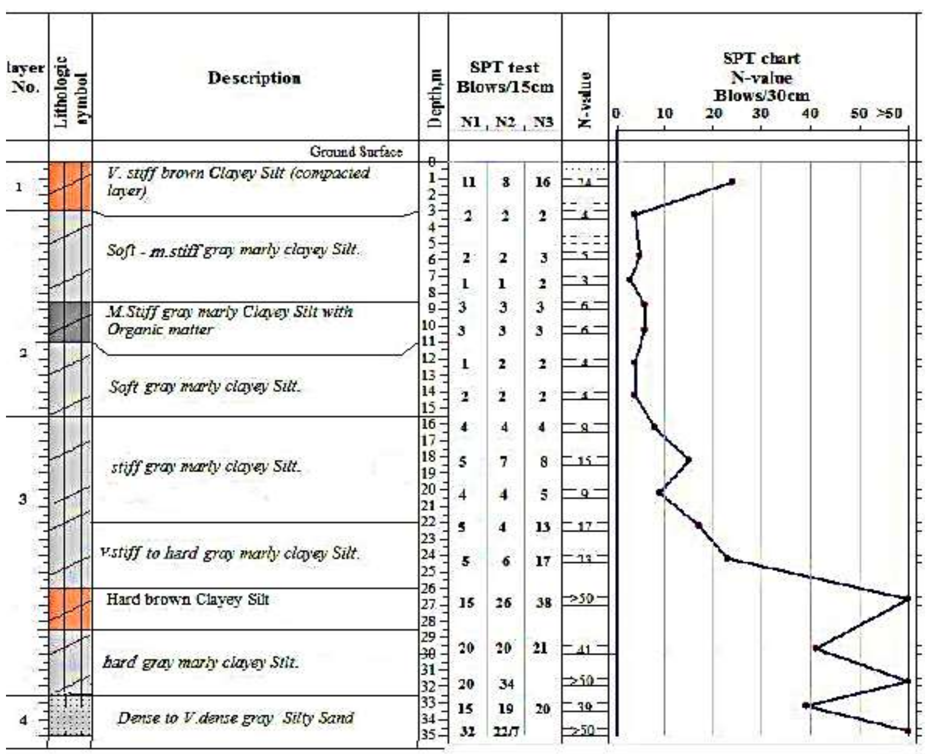

Figure (3) Log data on the Shatt Al-Arab left bank (Al-Ashar District) at 3.06 elevation of sea level [15].

In St.1, the length of this section is about 442 m, from the right bank (Basra city side) to the left bank. The SBP cross section showed there is an irregularity of the river bottom shape, and the depths ranged between 2 m near the two banks to 18 m in the distance with 100 m of the section toward the left bank. Particularly, the depth at this site changes rapidly, and we can see a decreasing in the depths at the middle of the river course, this shallow area may be an extension of Al-Sendebad Island (Figure -4). Previous studies revealed that this section have the deeper point at the river bottom, which ranged between 24-22 m [16]. In the present study, the high recording depth was about 18 m, that means there is a depositional process has been accrued in this deep site, the sediment column reached 5 m (Figure -5).

The variation in bottom depths during these years is due to reducing the discharge of the river, then the River energy for erosion increased, therefore the river became unable to carry the sediments for far distances. The river discharge decreased from 300 m^3/ses in the 1990s[17]; [16] to 50 m^3/sec at the present time. The decreasing discharge resulted by decreasing the current tides as well as decreasing the branches rivers discharge, this led to reduce the effect of these branches for increasing the depths of the Shatt Al-Arab River in the connection sites, thus that the mouths of these branches became a perfect sites for deposition in the present time. Therefore, the depositional and post-depositional processes play a major role in determining the nature and spatial distribution of rivers sediments, integrating factors such as discharge, sediment supply, geological setting, as well as anthropogenic effecting.

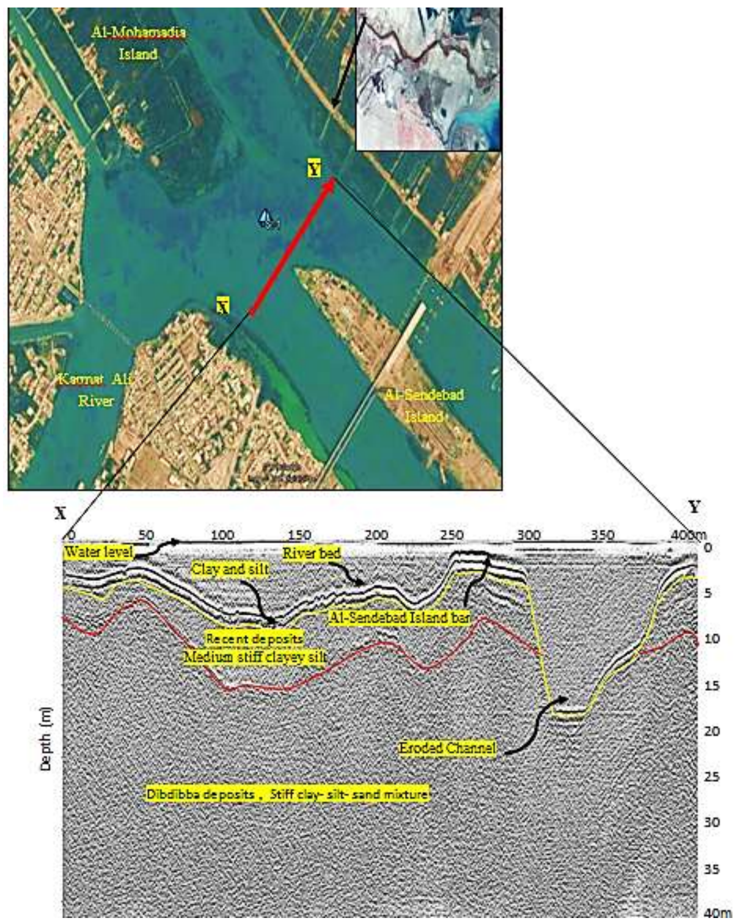

Figure (4) SBP of station-1, the variation in depths and sub-bottom beds.

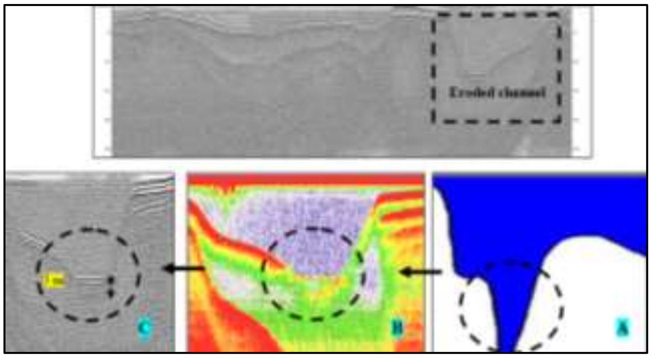

Figure (5) The depositional in eroded channel for many years, A- in 2006 [16]; B- in 2012 [18]; C- in the present study.

St.2, this section acquired in Al-Ashaar area with distance about 273 m, from the right bank to the left bank, northern Al-Salhia Island along Al-Tanuma Bridge (Figure -6).

The profiler acquired at this site to identify the lithological sequence under the bottom, and then detect the depth of bearing strata which appropriate for engineering constructions (e.g., bridges, dams, etc). By correlation the SBP results with log data, many types of sub bottom layers (recent and old deposits) have been identified to recognize the lithological succession conditions the results of borehole data were mentioned in [19] as well as[15].

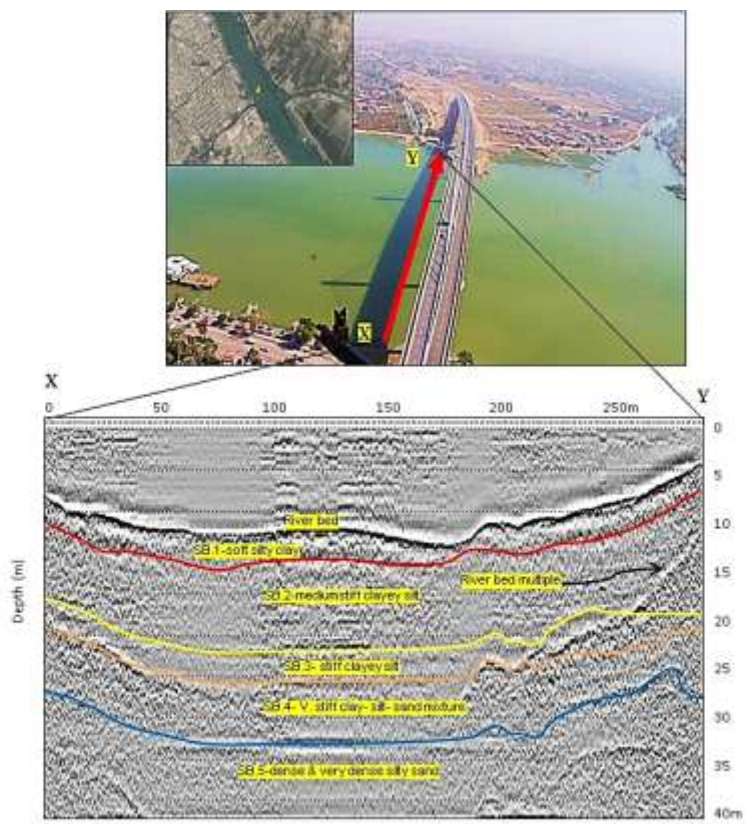

Figure (6) SBP of station-2 the variation in depths and sub-bottom beds.

Five sub bottom beds identified in addition to the river bed. The first strata SB1 (layer1) is soft silty clay, many studies mentioned that most of Shatt Al-Arab River sediments are clay and silt [17]; [20]; [21] and [16].The second strata SB2 is medium stiff clayey silt, the third strata SB3 is stiff clayey silt, the fourth strata SB4 is stiff clay-silt- sand mixture and the fifth strata is SB1dense and very dense silty. The layers SB1, SB2 , and SB3 are of 5m to 10 m depth under the water level, and belong to Hammar Formation, Pleistocene age [22] and [23]. From 10 m to the lower section (SB4 and SB5), the sediments of these sub bottom layers were reworked from Dibdibba deposits (upper Miocene-Pleistocene) [24]. SB5 is considered as beginning of a bearing strata.

St.3, the length of this section is about 170 m from the left bank to the right (Figure -7). It is considered the shortest section because the site represents an international border with Iran which is impossible to collect complete transvers profiler to the river cross section. This site was chosen for several reasons: First, having Um Al-Resas Island on the Iraqi side, the second having the Karun River on the Iranian side, the third reason is that the site is one of the sites that have high depths of the river relative to the other sites.

The previous studies [18] pointed that Um Al-Resas Island resulted by tectonic activity. However, this hypothesis does not match our observation from several points. The small size of this Hyperbola on the section in comparison to the size of the Island and it may not be related to uplifted; the structure have not only 25 m, as well as, the section illustrates the layers beneath bottom on the near side of the island are almost horizontal. Therefore, this present study inference that Um Al-Resas Island may be a result of Al-Karun River sedimentation and reworked by tidal currents.

The previous studies indicated that Al-Karun river was isolated from Shatt Al-Arab, despite the possibility of small streams which connect between them or their branches and each river has its own estuary into Arabian Gulf. For this reason, the commander of Alexander's fleet (Niarkus) which came from India seal wrongly for a far distance in Bahmsheer river until he discovered that he was taken the wrong route into his final destination (Missan city). About 364 H (989 AD) the Buwaihi's ruler Adhud Al- Dawla created a canal joining between Karun and Shatt Al-Arab rivers, which named by his name Al-Adhudi river and now known as Al-Hafar canal, this connection between Karun and Shatt Al-Arab rivers during the fourth Hijri century (tenth Christian century) had a major impact on the expanding of coastal shoreline southward to Arabian Gulf and retreating of the sea water shore line [25].

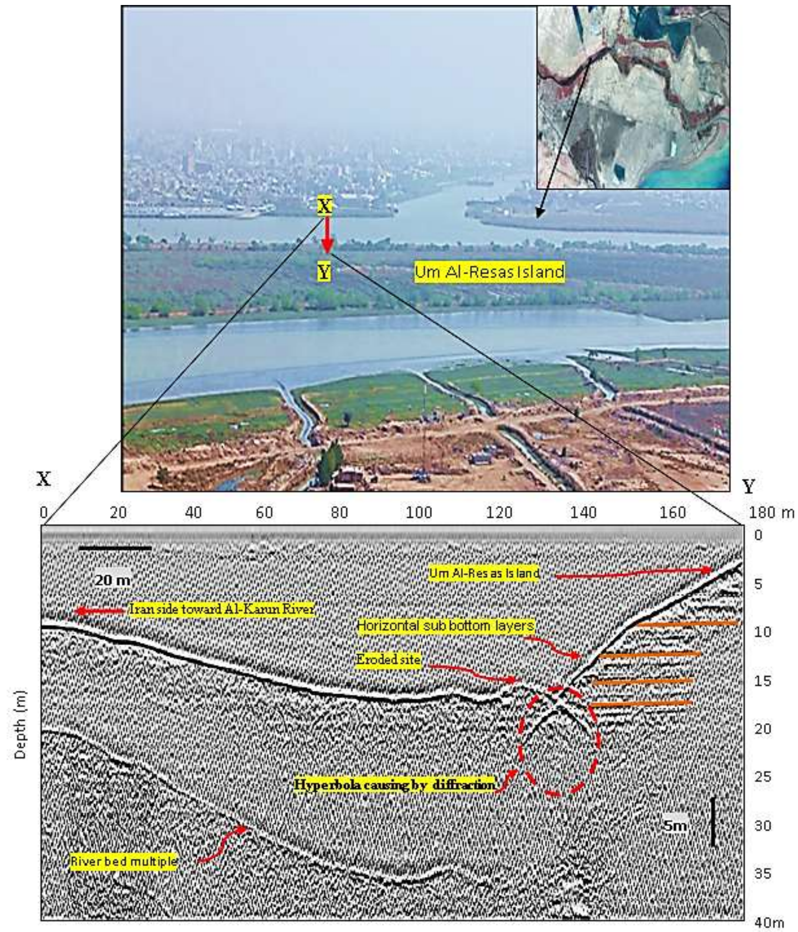

Figure (7) SBP of station-3, the variation in depths and features of the bottom.

The maximum depth of the river at this location reached about 22 m. whereas previous studies recorded the maximum depth in sections-1 and 3 (22 m). The depth in this site has not been changed in the past (during 20 years) according to the previous studies which were carried out by the Marine Science Center, unlike the sites 1 and 3, this can be caused by a meandering in the river course, and the river was affected by tidal currents coming from the gulf, as well as the increase in intermittent discharges coming from Karun River, thus the river energy to stay (within a certain level) capable of erosion in this site.

St.4, this SBP section was performed in Sihan district. The length of this profiler is 280 m from the right bank (the Iraqi side) to the left bank (the Iranian side) . The river at this site is considered a common border with Iran. The reasons to choose this site is to map the sub bottom of the river because Sihan area is located at meandered site which considered the maximum meandering at the river in addition to the presence of Mehela Island (Figure -8).

Also, the section shows that the maximum depths is at the Iraqi side as a result of high erosion rate associated with meandering. In contrast, the Iranian side shows the minimum depth due to deposition. Consequently, the erosion and deposition system on both banks may lead to lose more land from the Iraqi side are create more dry are to the Iranian side. [2] indicated that the area of Mehela Island increased about 280m^2 during 30 years in average about 9.5 m^2/ year (Figure -9). It means that this nature process causes increase in Iranian territorial land and decrease the Iraqi territorial land, this process needs manmade interference to protect banks in such cases.

Two type of bottom sediments may be concluded (echo-types). The top, soft bottom represented by silt and clay deposits towards the Iranian side, and the base hard bottom composed of sand deposits towards the Iraqi side (Figure-10). Also, section-5A shows a buried paleo-channel beneath the river bottom at the depth of 30 m from water surface.

This channel may represents an old course of the river. This buried channel in section-5 B exists at the same depth but close to the Iranian side. Another feature showed on section-5B illustrated a convex shape toward the Iranian side; it may point to a trace of a fault which suggests a structural uplift at this site.

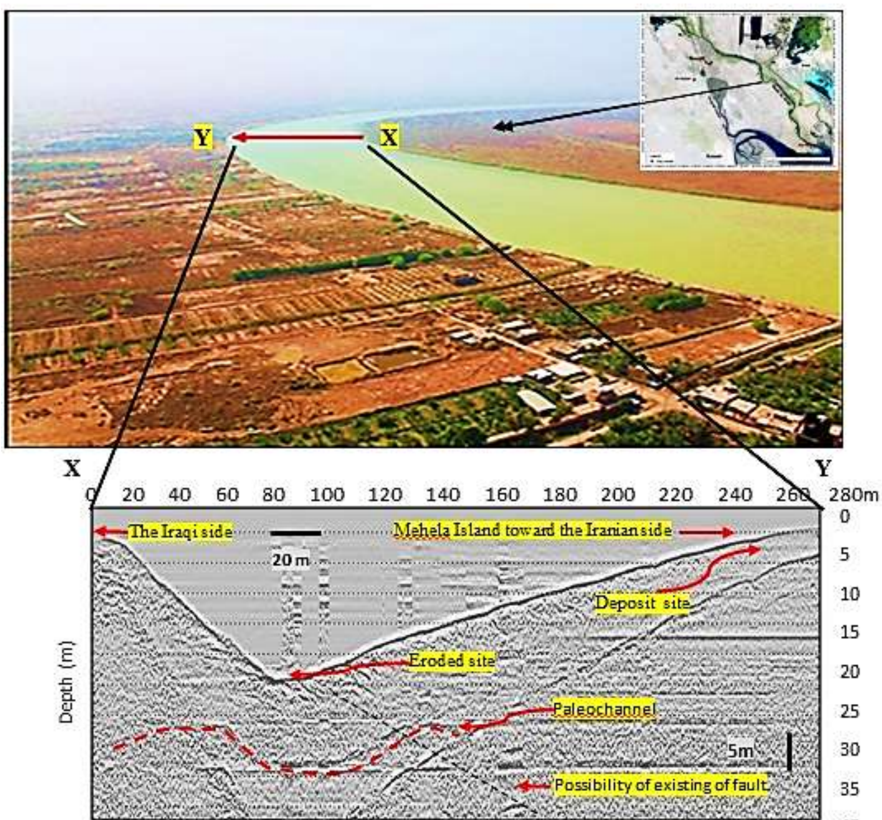

Figure (8): SBP of station-4, the variation in depths and features of the bottom.

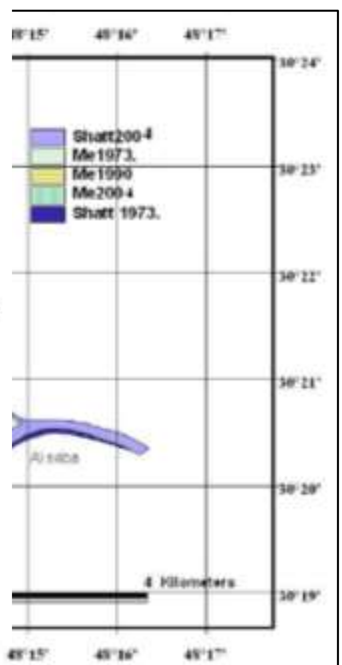

Figure (9) The Sihan meander and Mehela Island [18]

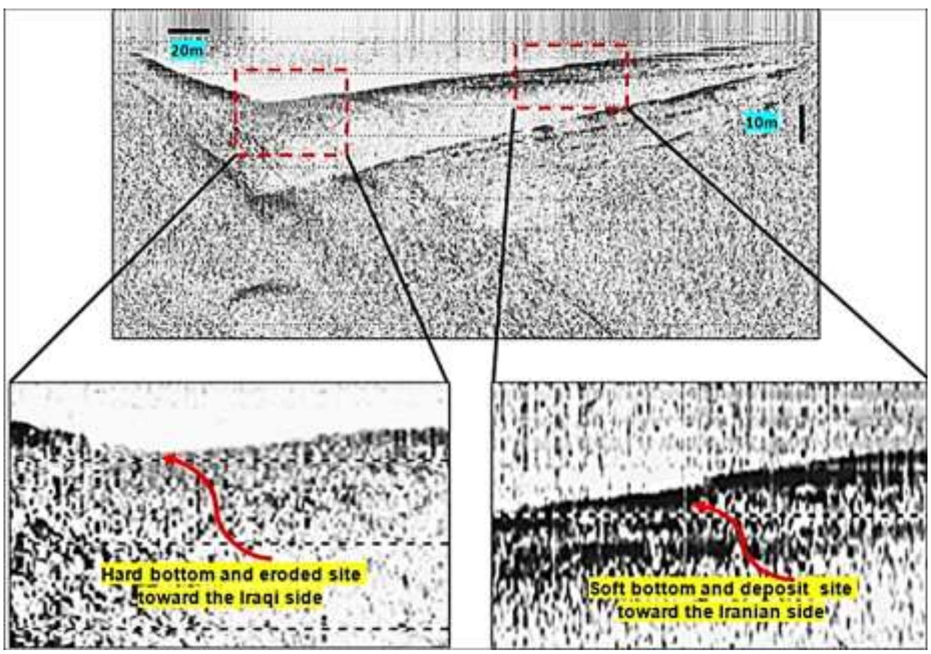

Figure (10) SBP section-4, the changing in the reflection bottom character, soft and hard bottoms.

The observed features in section-4 such as the high depths, meandering in the river course, ancient streams buried channels as well as a fault trace probably indicate that an neotectonic activity, the faults impact on the river valley slope which affects the river sinuosity, it is found that the rivers flows in areas influenced by faults, the morphological characteristics of rivers will changes, such as channel slope or river channel valley, valley width, braiding patterns channel, grain size distribution, stream power [26].

Moreover, which was pointed out to occur of neotectonic activity from the results of SBP section-4, it can observe that the river course has considerable deflection toward the east extend from Abi Al-Khaseeb city of Sihan district (Figures 8 and 9). Many studies on Shatt Al-Arab and the adjacent areas indicated that this deflection resulted by Siba structure.

In this site, the maximum values of neotectonic index reflect possibly neotectonic movement of the subsurface structures that called Siba Structure [3]. Siba structure is located in south east of Iraq. It borders from the north and north east with Shatt Al-Arab course. It continues southeastern into the Iranian territory [27]. After this large deflection, the river course has sudden change toward the west (the Iraqi side) forming Sihan meander, in other side Bahmenshir river (inside the Iranian border) meandered in the opposite direction (towards the east), this may refer to the area affected by structural uplift led to shifting the streams of both the river reversely, this a structural uplift may be presence of Mehela Island (Meno Island) on the Iranian side (Figure-9). [28] pointed out that this island was formed by a structural mechanism.

Many recent geological and morphological remarks of Shatt Al-Arab region and surrounding area refer to influence of neotectonic activation processes affected by presence of the subsurface geological structures, which latterly influence the changes and interruption of some ancient river courses [29] [12] and ; [30].

5. Conclusions:

1- SBP technique is an active method to be employed in order to map geological features and locate structures below the surface of river-bottoms. The current survey provids an overview of the sedimentary layers and their sub-bottom setting, as well as buried paleo channel under the river- bottom. The maximum depth of the river was recorded at Sihan meandering (st.-4), reached about 22 m, whereas the previously high recorded depth in positions of st.-1 about 24 m, but at the present time the recorded depth is 18m (at st.-1) due to the changes in hydrological and depositional systems of the river.

2- SBP sections image the submerged landscapes, as they can survey large areas relatively quickly and are non-destructive, when used in combination with core data. As well as SBP technique is suitable for determination of dredging and depositional sites as well as determining the sediment thickness and correlated with the times. Additionally, SBP is an active technique to distinguish between the soft and hard bottoms through the observation in the acoustic wave reflection on both bottoms, such as in Al-Sendibad site (st.-1).

3- Many factors influence the shape of Shatt Al-Arab sub bottom course, such as tectonic activity, hydrological and sedimentological situations as well as the man-made influencing. Um Al-Resas Island might not has a tectonic origin, due to the lack of distinctive features indicate to exist a structural uplift under the bottom vicinity the island. Adding to the layers underneath the bottom of the island near the bank river almost horizontal, the origin of the island may be caused by Karun river sediments.

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تطبيق تقنية المقاطع العرضية للقيعان باستخدام ترددين لرسم معالم قاع شط العرب

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ألملخص

يعتبر شط العرب من أهم المجاري النهرية في العراق، وفي الوقت الحالي يعاني النهر من العديد من التغايرات خلال الاربعين سنة السابقة نتيجة عدد من المؤثرات سواءً الطبيعية أو الناتجة من تدخلات الانسان، وأهم تلك التغايرات نقصان التصريف. نقصان التصريف سبب تأثيراً ملموساً على طبيعة النهر وحدوث تحولات في شكل القاع وما تحته، بل وحتى التأثير على مورفولوجية مجرى النهر. في الدراسة الحالية، انجزت مسوحات جيوفيزيائية باستخدام تقنيات الموجات الصوتية متمثلةً بتقنية المقاطع العرضية للقيعان ذات الدقة العالية ((Sub Bottom Profiler (SBP)) باستخدام تردد 10 كيلوهيرتز لرسم معالم قاع النهر وتحديد التراكيب تحت القاع فضلاً عن اعطاء تصور على مكونات تحت القاع. تم انجاز اربعة مقاطع عرضية للنهر موزعة في مناطق السندباد، العشار، ام الرصاص وسيحان بمسافات مختلفة من عرض النهر. بينت الدراسة الحالية ان التقنية المستخدمة تمتلك فعالية كبيرة في رسم المظاهر الجيولوجية وتحديد التراكيب وطبقات تحت القاع والتمييز بين القاع الصلب والهش، فضلا عن مناطق التعرية والترسيب في القاع.

أظهرت النتائج للموقع الأول بالقرب من جزيرة السندباد ان هنالك عملية ترسيب قد حدثت لاحد المواقع والتي كانت تعتبر ولوقت قريب من أعمق النقاط في قاع النهر، حيث بلغ سمك الرواسب الحديثة بحدود 5 م وتناقص عمق القاع ليصل الى 18 م. وفي الموقع الثاني في العشار تم تحديد عدد من الطبقات تحت القاع فضلاً عن تحديد عمق الطبقة التحميلية الصلبة الملائمة لإقامة المنشآت الهندسية تحت قاع النهر وكانت بحدود 20 م. في الموقع الثالث وبالتحديد بالقرب من جزيرة ام الرصاص أوضحت النتائج انه لا توجد اية شواهد يمكن ان تشير الى كون هذه الجزيرة قد نتجت بفعل تكتوني بحسب ما أشير في عدد من الدراسات السابقة. ولقد سجلت أكبر الاعماق في الموقع الرابع المتمثل بانعطاف سيحان وبلغ 22 م، ويعتبر هذا الموقع الاكبر عمقاً للنهر في الوقت الحالي. في موقع انعطاف سيحان، كشفت الدراسة عن مجموعة من المظاهر المتمثلة بعدم انتظام شكل القاع والتغاير الكبير في الاعماق ووجود مجاري قديمة للنهر مدفونة تحت القاع فضلاً عن وجود أثر لفوالق يمكن ان تشير الى تأثر مقطع النهر في هذا الموقع الى تأثير تكتوني حديث.