Analyzing Sediments Assessment and Distribution Using Bathymetric Survey: A Comprehensive Study of the Abu Abdullah Canal, Southern Iraq

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Abstract

The Abu Abdullah canal, an essential part of the Garmat River, serves as the feeder to the water injection station for the Basrah Oil Company's southern region's oil fields, playing a significant strategic. This study thoroughly investigates the sedimentation rate and distribution processes within this critical canal. The canal was built in the 1980s, with a depth of 3 meters planned. In 2017, RSK Company, in partnership with the Basrah Oil Company, started a comprehensive bathymetric survey of the canal to investigate its depth characteristics. The survey yielded intriguing results, revealing notable variations in depth along the canal's course. Depths ranged from 0.4 m at the canal's edges to an average of 1.6 m in the middle, indicating a significant decrease of 1.4 m in the middle region and 2.6 m at the edges. The collapse of the canal banks, induced by the proximity of Buffalo breeders' residences near the canal, is the primary source of this depth variation. Incidental entry and traversal of Buffaloes lead to gradual structural degradation of the banks, exerting a substantial influence on sediment distribution within the canal. Moreover, Buffalo standing in the middle of the canal induces compression on the channel bottom, altering the sediment transport dynamics. The study's outcomes are critical for sustainable canal management and environmental conservation. Understanding the complicated interaction between human activities and natural processes for shaping canal morphology is vital for developing effective strategies aimed at safeguarding canal banks and preserving their ecological functions. This research significantly advances the understanding of canal sediment dynamics, presenting practical applications in hydraulic engineering and environmental management.

Keywords: *Sedimentation, bathymetric survey, Garmat Ali waterway, sediments transported.*

Introduction

Abu-Abdullah Canal is one of the strategic projects in oil production, which works to transfer water to the water injection station for oil fields, which is branched from the Garmat Ali waterway. This canal suffers from sediment accumulation, which leads to a decrease in its efficiency. Sedimentation is the process by which sediment or particles are deposited on the bottom of a body of water. Sediments are generally described as solid particles transported by a fluid (Orji and Dike, 1991).

Sediments come from various sources, such as eroded soil, rock, or organic matter. Sediments can form naturally through erosion, weathering, and natural processes (Tucker, 2001). In the cases briefly mentioned above, the accumulation of sediment should be monitored regularly using appropriate methods. Based on the results of these studies, protective and corrective actions should be taken as necessary. One of the monitoring methods used in this regard is precise bathymetry. By performing bathymetry at regular intervals, changes in channel bed topography can be monitored, and sediment transport and accumulation rates can be calculated by depth measuring devices. Sediments are rocky crumbs transported, suspended, or deposited by flowing water (Hayter and Gailani, 2014). All constituents of the parent rock material (silts and clays, sand, and mud) are usually found in the sediment and transported by water from the place of origin to the place of deposition. In watercourses, sediment is the alluvial material carried in suspension or as a bed load. Sedimentation is settling and depositing by the gravity of suspended matter in water (Cech, 2010).

In channel beds, soil particle accumulation can decrease the losses of the maximum bed depth and water use potential and shorten channel lifetime by causing changes in the channel bed topography. Other negative results of channel sedimentation are the reduction of flood attenuation, changes in water quality, and damage to pumping machines' valves and the channels (Maloi *et al*., 2016). Sedimentation leads to many issues, such as the operation and maintenance of engineering infrastructures, the

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economic feasibility of the project, and environmental issues through the social dimension (Jolly, 1982).

Bathymetry measures and maps the depth of bodies of water, such as oceans, rivers, and lakes. The survey was conducted using an echo sounder, and data obtained from the survey was used to create bathymetric maps showing the shape and depth of water bodies. Thus, a bathymetric survey or channel sediment retrieval is performed to monitor the changes in the bed topography by measuring the thickness of the layer of accumulated soil particles and calculating siltation rates (Brunner, 2012). There are several methods to estimate sediment accumulation. Generally, they can be categorized into two groups: indirect and direct methods. Indirect methods are the measurements of suspended sediment fluxes and sediment traps or estimating runoff/sediment yield. Direct methods are bathymetric surveys and sediment coring of accumulated sediments. The bathymetric approach, among them, is based on a comparison of the measured bed topography at two different times. First, one is at the time of the channel construction and design depths with enough accuracy, and the second is at the time of the survey (Brunner, 2012).

Several studies are interested in this topic, including Zeleke (2019), who studies reservoir sedimentation at the Legemera micro-earth dam reservoir in northern Ethiopia, and he noted in his study that the reservoir's annual capacity reduction was 6.94% per year. This study is considered a preliminary study to determine the amount of sediment transported at the canal transferring water to the water injection station of the Basrah Oil Company. For this purpose, bathymetry was carried out using the most modern geodetic equipment, execution of a bathymetric survey near the Garmat Ali Area to determine the depth and mapping of the geometry of the canal. Due to the development of oil production processes and the government's program to increase oil production, the need for water sources in oil production has been studying this canal to be considered the primary source of water supply to the southern oil fields, noting there are no previous studies on this canal in this direction.

The site area is located in Basrah Governorate, Garmat Ali City. (Figure 1.) (47°41'33.64"E, 30°35'2.60"N). It is one of the two branches of the Shatt Al-Basra.

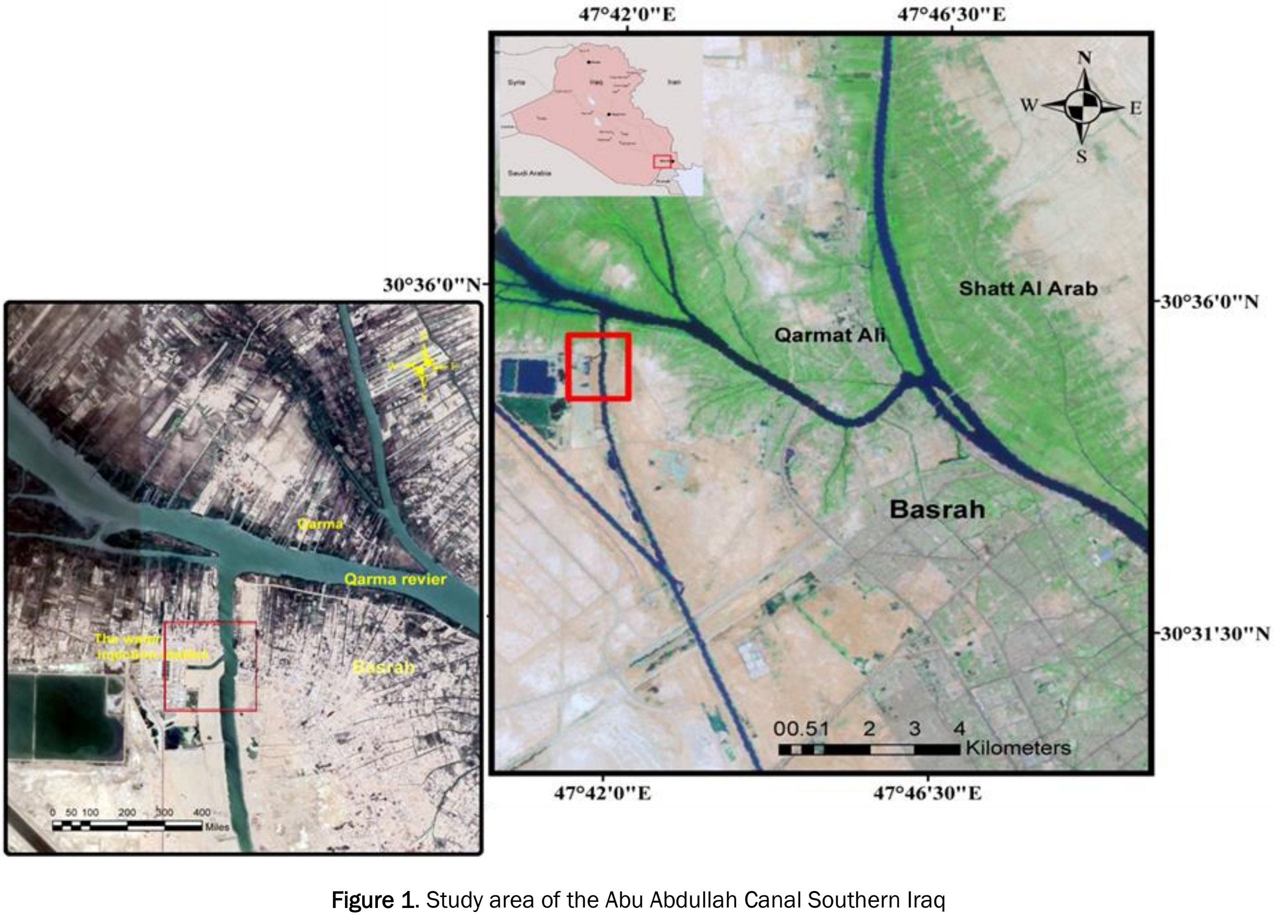

Figure 1. Study area of the Abu Abdullah Canal Southern Iraq

Abu Abdullah Canal is linked to the Garmat Ali waterway, which is linked with the Main Outfall drain (MOD). It is located near Al-Mashab and Al-Sallal branches, southern of Al-Hammar Marshes. It is a lower part of the Mesopotamian plain. The history of marshlands originated during the Holocene period, followed by the end of the Last Glacial Maximum (LGM). Shatt Al- Arab- Tigris– Euphrates–Karun region was subjected to an extensive marine transgression in the middle and late Holocene, resulting in a shoreline far north of its present position in response to rapid sea-level rise. A delta progradation followed this due to eustatic sea-level changes (Larson and Evans, 1978; Evans, 1978; Yacoub *et al*., 1981; Al-Azzawi, 1986; Baltzer and Purser, 1990; Aqrawi, 2001).

Tectonically, the area is part of an unstable shelf characterized by thick sedimentary cover and anticlinal subsurface structures separated by synclinal subsurface structures (Buday and Jassim, 1987). These structures are one of the most important reservoirs and oil fields in Central and Southern Iraq. It is worth mentioning that these structures have no reflection on the surface, but their effect reflects on river channel characteristics (cross-section, sinuosity) (Al-Mayahi, 2011; Hussein, 2011). The geology of the area is characterized by thick Quaternary sediments, which are represented by floodplain sediments of the lower Mesopotamian basin that belong to the Pleistocene Period. The Holocene period is represented by the Marsh (Active, Dried) and the fluvial sediments for flood plains of the Tigris, Euphrates, and Shatt Al-Arab Rivers (Yacoub and Roufa, 1992). These sediments are grey-colored and fine and contain organic material and particles of Mollusca and Ostracoda mixed with carbonate, clay, silt, and sand. Hammar Formation underlays these sediments is marine and lacustrine sediments, belonging to the early Holocene (Yacoub, 1992, 2011).

Hydrologically, the Shatt Al-Arab is the river formed by the confluence of the Euphrates and the Tigris rivers near Qurna city, and it empties into the Arabian Gulf after a course of 200 km. Shatt Al-Arab River was affected by the tide regime. It is a mixed type ranging from (diurnal to semi-diurnal), but the semi-diurnal is the dominant type. The ebb-tide period is greater than the flood-tide period, as well as the rates of current velocities (Al-Ramadhan and Pastour, 1987). The water of Al-Mashab and Al-Sallal entering Garmat Ali waterways and then Shatt Al-Arab River during the ebb-tide period negatively affected the water quality of Shatt Al-Arab because of increasing salinity concentrations (Al-Tememi *et al*., 2015)

Materials and Methods

A shallow water survey was performed near the Abu-Abdullah Canal site area (Figure 2.). The fieldwork includes the following measurements and works: (1) Hydrological Survey by monitoring the water level variations in the canal in case of flood or low water using the Level and Staff Gauge, depending on the benchmark. (2) The speed of the Currents was measured by an ADCP device manufactured by Instruments (RDI) calibrated, a company specializing in the design and manufacturing of Acoustic Doppler Current Profilers (ADCP). ADCPs are instruments used to measure water current velocities in oceans, rivers, and other bodies of water. RDI ADCPs are widely used in various applications. The speed of the currents was measured at an average of 13 hours, half a tidal cycle at the top of the canal. (3) Water samples were taken over a 13-hour half-cycle tidal by water sampler. According to the method (Milliman and Meade, 1983), suspended load calculation is used through the filtration method of water samples by the filtration apparatus and sheets 45 microns.

Bathymetric survey

This study used Trimble or differential Global Positioning Systems DGPS (Teledyne). The canal was divided into transects (Longitudinal and Transfers) by the team of the Marine Science Center. This is necessary for fully covering the area. The custom integration of a survey grade single beam echo sounder with total water column return and real-time kinematic RTK-GPS receiver for precise horizontal and vertical positioning on the canal using this instrument potable with the boat vessel. The Bathymetric survey generates a map of the shallow water depths Figure 2.

Laboratory work

Laboratory tests of water samples taken through fieldwork were carried out by method of Milliman and Meade (1983).

Data acquisition and processing

It includes using satellite images Landsat 8 OLI, 30m spatial resolution, and Quick Bird satellite Images 0.6 m spatial resolution. Data acquisition, including information about the weather, was acquired from Basrah International Airport. See weather information in the Appendix.

All Data acquired from the Fieldwork are georeferenced into a suitable Coordinate System for the investigated area WG-48 38 Zone. Arc-GIS Environment performs the processing data in addition to Surfer 13 (Table 1.).

Data interpolation

Various interpolation techniques can be used to interpolate point data, *e.g.*, inverse distance interpolation, spline, and kriging. For the interpolation of bathymetric point data, we preferred kriging because the method gives more control over the interpolation due to using a semivariogram model. Surfer V. 13 draws the contour line.

Results and Discussion

In the eighties of the 20th century, about 40 years ago, the Abu Abdullah Canal was established to link the Shatt Al Basrah to the Garmat Ali waterway and from there to the Shatt al-Arab River for maritime transport during the Iran-Iraq war (Al-Taher, 2022). The average depth of the canal at the time of its construction was up to 3m, but it did not succeed, so it closed from the side of the Shatt Al-Basrah and remained open from the side of the Garmat Ali waterway (Al-Taher, 2022). When water was needed in oil production operations, a water injection station was established on this canal, as it was of strategic importance for preparing water for the southern oil fields to preserve this canal. It is necessary to know the factors affecting them in terms of productivity.

The speed of water currents in the canal was measured, noting that the canal is closed on the other side and the movement of water currents is the movement of tides only, and here, the tidal process is almost daily (Al-Kaabi, 2023). Without drainage, the water enters only from the Garmat Ali waterway during the tidal period and then returns to it during the ebb period. It should be noted that there is a difference in tidal discharge because the tidal wave is asymmetric, so the time of the tidal period is less than the period in the ebb period, and the energy of the tide is weaker than the energy of the ebb period (Khalifa, 2019). As for the all period, the average speed of the currents is 0.04 $m.s^{-1}$. The discharge rate of the canal is 23 $m^3.s^{-1}$ (Figure 3-A.). The average current speed in the canal was measured during the tidal period, and it was found to be less than 0.01 $m.s^{-1}$. At the same time, the canal discharge is 15.4 $m^3.s^{-1}$ (Figure 3-B.).

As evidenced by field measurements of the suspended load, its amount was less than 0.01 $g.L^{-1}$. Thus, it has a negligible effect on flow dynamics, with the amount of discharge flowing to the canal, which are few. The main reason (the primary source) of sediment accumulation in the canal is not from the Garmat Ali waterway. The incoming water is clear, there is little suspended load, the discharge is low, and the river currents are calm.

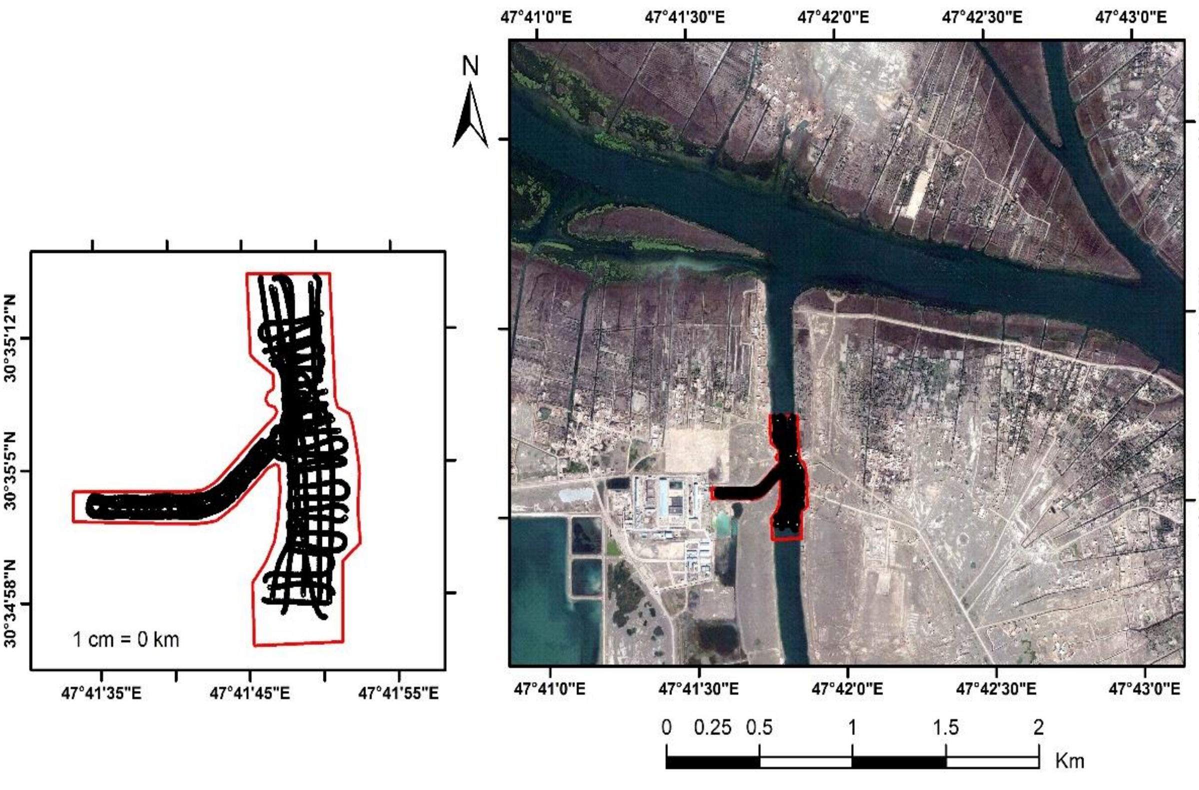

Figure 2. Bathymetric survey lines by single beam echo sounder

Table 1. List of programs and software used for processing Data

Software Name	Version	Processing Type
Arc-GIS Environment; Arc Map; Arc Catalogue; Arc Toolbox	V.10	• Georeferencing the data into the Coordinate System • Create points and Polygons for the Area of Interest • Mapping of study area
Golden Software Surfer	V.13	• Generate maps based on grading data and interpolates irregularly spaced XYZ • Data and map visualizing for post-processing and use it for scientific modeling purposes

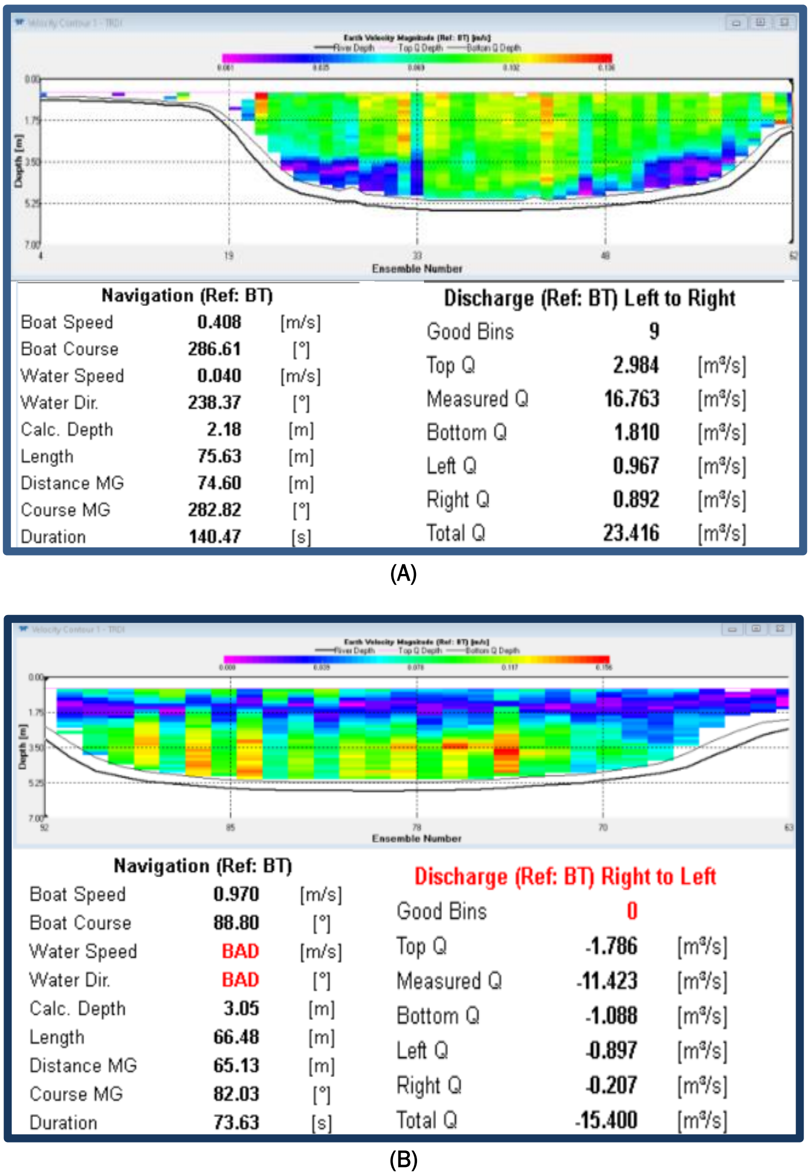

Figure 3. The speed of water currents and discharge in the canal (A. ebb, B. tide) period

After the bathymetric survey of the area was carried out by a survey boat and with tracks covering the study area, the average depth ranged from 1.6-0.4 m (Figure 4.). It is noted that there are several reasons for the difference in the depths of the area being inhabited by farmers and buffalo herders on both sides of the canal, which leads to the destruction of the canal banks being unprotected and the texture

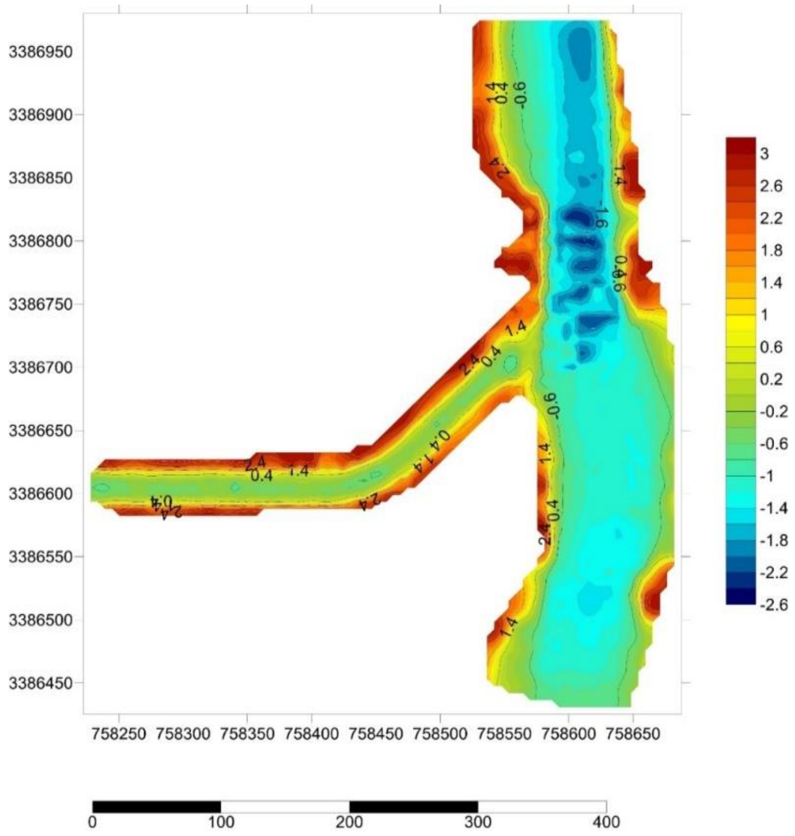

Figure 4. Contour map for the Abu-Abdullah Canal

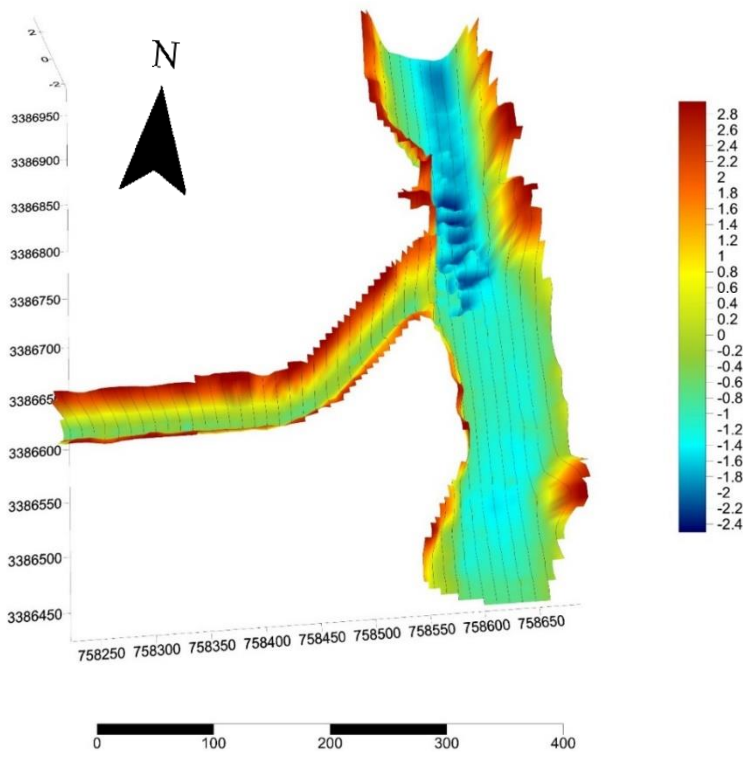

Figure 5. 3D Map for the Abu-Abdullah Canal Site Area

of the soil of the banks is an incoherent alluvial mud. Frauendorf *et al*. (2021), categorized the impact of animals in river ecosystems, including three types of legacies (Structural, Quality, and Biodiversity). The Structural legacy of the animal Buffalo may be defined by trampling and creating permanent tracks in and around the water that alter the riparian and river bottom topography (Naiman and Rogers, 1997). Buffalo tracks are visible in the middle of the canal (Figure 5). The human activities of the population living along the canal's banks and the movement of buffaloes that enter the canal during grazing cause the banks to collapse, thus allowing sediment to enter the canal. It turns out that the primary source of sediment in the canal is the bank's collapse. Simultaneously, the canal depths are impacted, with the depths near the bank's canal being less than the depths in the middle of the canal, which reach 0.4 m and 1.6 m, respectively, which indicates that the bank's canal was exposed to collapse and its depth decreased, hence its capacity.

Conclusion

It was found that the canal might change its depths because of the human activities of the residents who live on both sides of the canal. Also, the activities of buffalo grazing are directed by the region's residents, which leads to the collapse of the banks. Thus, the depths of the canal decrease, and this change will affect the equipment of the amount of water supplied to the pumping station. This method of investigation allows for an understanding of sediment's spread and distribution. It makes it easier to determine where sediment has accumulated, facilitating aqueduct maintenance—all measures to ensure the adequate protection of water resources and their management from a sustainable perspective. The most important source of information and decision-making is a depth map with up-to-date and sufficient resolution, created with high accuracy using the most modern techniques. It should be noted that according to new developments in measurement equipment technology and methods proposed and used in this study, the measurement process become more straightforward and more economical while reducing time, labor, and deposition process calculations. Therefore, the oil company had to prepare programs to protect the banks of the canal, thus preserving the depths of the canal and controlling the absorptive capacity of the canal.

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