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Sedimentological Model for Underground Tigris Terraces Channel in Sallahuddin Oil Refinery, Beji, Iraq

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Abstract: The study area is located structurally southwest Makhulplunge. Quaternary deposits overlying unconformably Fat'ha and Injanah Formations. The Quaternary deposits beneath Sallahuddin oil refinery display topsoil and the third stage of Tigris river terraces. The latter is represented by braided to meandering river channels composed of; conglomerates, sandstones, and siltyclaystones. The conglomerate reflects channel deposits and longitudinal bars, whereas the sandstones and siltyclaystones represent the channel levee with occasional crevasses play. From the available data of 81 boreholes and vertical pits and trenches, a depositional model was built for the main and subsidiary channels, the water flows during flood times only due to its relatively higher altitude compared with the main channel. During groundwater levels rise due to pipe leakage of industrial acid water and the infiltration of the surface runoff water, the foundations of the civil and industrial buildings of oil refinery could be affected. In conclusion, this impact will change the lithology by the dissolution of the cementing materials of the conglomerates and hence, the geotechnical characteristics of the conglomerate and other lithology will decline to result in building foundation disturbances.

Keywords: Sedimentological model, Underground channel, Tigris terraces, Sallahuddin oil refinery, Beji

The results of the study of sub-surface fluvial sequences and the relationship of the facies with each other in terms of overlap and extension, by comparing them with classic facies are used to give a concept about the nature of the sedimentary environment (Colombera and Mountney 2019). The study of fluvial sediments is complicated by lateral, vertical, upstream and downstream accumulations of river sediments (Zang et al 2020). Distinguishing and describing sub-surface fluvial sequences based on reginal correlations and mapping, that help identify the characteristics of the faciess and their relationships with each other and reflect the sedimentary environment (Rizqi and Purnomo 2021). The Sallahuddin Oil Refinery is located north of Beji city and southwest Fat'ha area in nearly flat terrain areas (Fig. 1). On the behalf of the project "Geophysical investigation of cavities and leakage areas in Sallahuddin Oil Refinery(SOR), Beji" the idea of accomplishing the sedimentologic model of the underlying rockshasarisen. The seismic survey conducted by revealed the presence of an ancient Tigris river meander channel at the internal fence of the SOR. The channel is directed due west and bends to the south (Al-Saigh 2007). Most of the civil and industrial buildings were established above this channel. Eighty-one boreholes were conducted in a network covered SOR. Their logs reflect a stage of Tigris river terraces beneath the refinery and surrounding areas to the south in an attempt to speculate the movement and distribution of the groundwater. The elevation differences approach about six meters within the study area. The valleys were directed due southwest and deviated to the south to connect with the present Tigris river channel.

Structurally, the area is located in the northeastern edge of the Samarraa syncline and southwest Makhul anticline according to the geologic and tectonic map of Iraq (Fig. 1). The river terraces have overlain Fat'ha and Injanah Formations in an unconformable way. These terraces were party covered by soil. NEDECO Company conducted a study on Al-Tharthar valley in 1959 for oil exploration including the study area (NEDECO 1959). They performed a structural map for the area restricted by Al-Qayyarah in the north, Baghdad in the south, Hemrin, and Makhul Mountains in the east, and Tharthar basin in the west, their study revealed; Fat'ha Formation foundin the core of both Hemrin and Makhul anticlines and their extensions, in addition to the Al-Jazera east Al-Tharthar basin. On the contrary, the outcrops of the Injana Formation restricted to the limbs of Makhul and Hemrinanticlines and in the uppermost part of the Samarraa syncline (Jassim and Buday 2006). The Injana Formation extends to the south runs parallel to the eastern bank of Al-Tharthar lake.

The most prominent geomorphological features in the area are Makhul and Hemrin mountains. The V-shaped valley is a characteristic feature of the limestone layers forming flat iron topography. The valley's gradients decrease towards the west - southwest and become low to the very low gradient at (SOR) near Samaraa syncline axis (Fig. 2). The valley system in the area attains NE-SW direction west of the area confined between the Makhul anticline and the axis of the Samaraa syncline. The valley patterns are sub-dendritic to sub parallel. A geomorphologic work conducted assured that the present study area is related to the Tigris river terraces that were deposited at the Pleistocene.

During the study of the Fat'ha area, in the Tigris river left four stages of terraces, the oldest stage is the highest one and the youngest is the lowest one (the present river stage). The terraces formed mostly of conglomerate forming elongated lenses (tens to hundred meters in length) as outcrops. The covered 3rd terrace stage beneath the refinery was almost found as groundwater channel paths. The terraces are composed mostly of conglomerate, sandstone, siltyclaystone, and claystone. The oldest two terraces stages (1st and 2nd) are characterized by the presence of longitudinal and transverse bars which indicate braided river channel type. The (3rd and 4th) stages represent the meandering channel according to (AL-Jubouri et al 2001) as the case of the present rivers stage. The thicknesses of these stages range between 3 meters for the first stage near Al-Fat'ha to more than 10 meters for the 3rd stage (studied stage beneath SOR).

MATERIAL AND METHODS

Eighty-one boreholes were dug in a network fashion covered (SOR) and surrounding areas. The borehole network constitutes nine lines directed in NE – SW direction, and nine boreholes on every line. The distance between lines is about 200 m and the distance between boreholes on the same line is about 500 m (Fig. 3). The boreholes range in depth (6-12 m). The boreholes lithology is described in detail. Correlation of boreholes on every line performed forming groups. These groups correlated with others to estimate the real geological and depositional model beneath the studied refinery. Besides, many vertical pits have about 3 m depths found within the area were also described.

RESULTS AND DISCUSSION

The study of every single borehole and their stratigraphic correlation revealed that the questioned refinery (SOR) is located on the quaternary deposits. The soil thickness ranges between (1->5m.), constitutes of top transported soil few centimeters of fine to a very fine grain size of loss sands, and the flood plain deposits. It displays flood plains of the third stage of the Tigris river terrace. This stage furnished the ground of the foundation of the SOR. The flood plain deposits after severe weathering exposed changes gradually to residual soil. This type of soil is characterized by brown to yellowish-brown color, friable nature, and secondary gypsum coexisted with the soil together. The gypsum behaves as cementing material for the soil and dissolves easily with water. Variegated plant roots and rootlets co-existed on the upper part of the soil horizon. The recent soil of the present stage of the Tigris River has about 13m. as maximum thickness, covers whole the flood plains deposits. It is composed of silty claystone and fine sandstone beds. This bed intercalates lenses of conglomerate not exceed 1m thick, pinch out laterally, appear in the vertical pits. Often, these conglomerate lenses have flattened lower surfaces. The prevailing colors for these deposits are brown and yellowish-brown, they are medium tough except for some fine sandstones lenses. Their bedding surface is unclear in most of the vertical pits.

The conglomerate represents the channel lag deposits of the 3rdstagechannels of the Tigris river terraces, where the coarse pebbles are laid down at the bottom of the channel followed by medium-size pebbles and then fine pebbles at the top forming fining upward size gradations. It intercalates lenses of sandstones and silty claystone 0.5-1m.in length and a few centimeters to 0.5 m in thicknesses. The dominant cementing materials constitute secondary gypsum, which grows around the pebbles as a satin spar. In the whole borehole sections, there were very thin lenses of secondary gypsum a few millimeters thick (Figs. 4-13). The 3rd Tigris river terrace stage can be divided into three lithofacies according to lithologic variations; the conglomerate, the sandstone and the silty claystone.

Conglomerate lithofacies: The correlation diagrams (Figs. 4-13) showed that the maximum thickness of the studied boreholes reaches about 12m, some boreholes do not penetrate the conglomerate layer completely, though the thickness could increase to 15m. It can be compared by the same terrace stage (3rd) in Mosul, Hammam Al-Alil, and Sherqat area (AL-Jubouri et al 2001). The pebbles of these lithofacies range in diameter between a few millimeters to 15cm. It is composed mainly of metamorphic rocks like schist, gneiss, marble, and quartzite, and a subordinate amount of sedimentary rocks like limestone, sandstone, and chert with scarce pebbles of igneous origin. The pebbles are mostly rounded to sub-round. The gneiss and schist pebbles are almost discoid and flattened in shape, but the other components mostly have good sphericity and badly sorted. This lithofacies refer to the dominance of longitudinal gravel bars, where the area between the bars is filled with finer-grained sizes, deposited in cases of low discharges (Saikia 2017). The parallel gravel bars and their bifurcating channel,

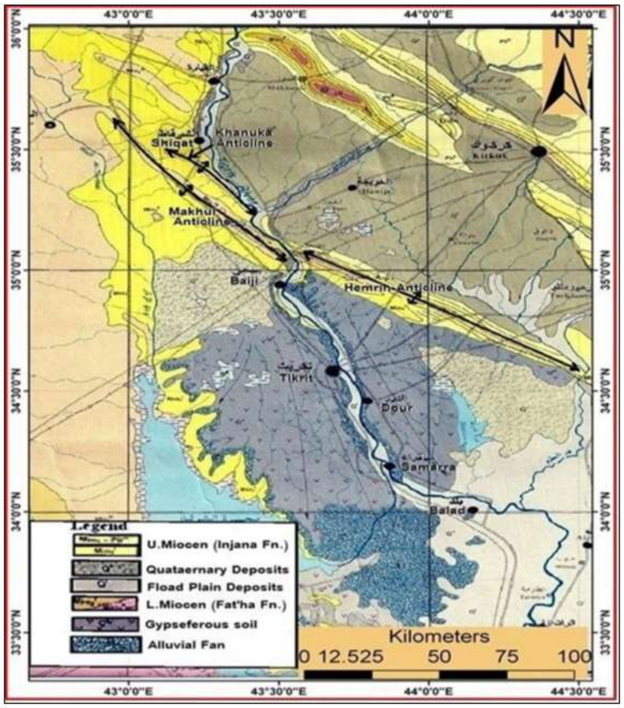

Fig. 1. Geological and tectonic map of the studied area. (General Company for Geological Survey and Mining)

and the presence of sandstone beds on their edges can be explained as transversal bars migrate laterally toward the channel between bars (Sigdel and Sakai 2016). During a flooding storm, the channel incised and then the river laid down its bedload in a relatively short period (Nehyba and Roetzel, 2015). The sediments were almost badly sorted. The depositional cycle appeared to be incomplete and not clear (Colombera and Mountney 2019). Often, the dominant matrix of these sediments are mixtures of clay, sand, and silt with different percentages, giving rise to weakening rock strength, washing clay easily (Rits et al 2016) and consequently producing groundwater passages along with the terraces. The conglomerate lithofacies can be divided into four lithosubfacies according to their matrix and cementing materials;

Clayey conglomerate lithosubfacies: The matrix and cementing materials are composed of clay with little calcium carbonate and secondary gypsum. Consequently, this lithosubfacies is mostly friable and loose which caused pebble collapse during drilling in some boreholes.

Silty conglomerate lithosubfacies: The matrix and cementing materials constitute calcium carbonate and low to

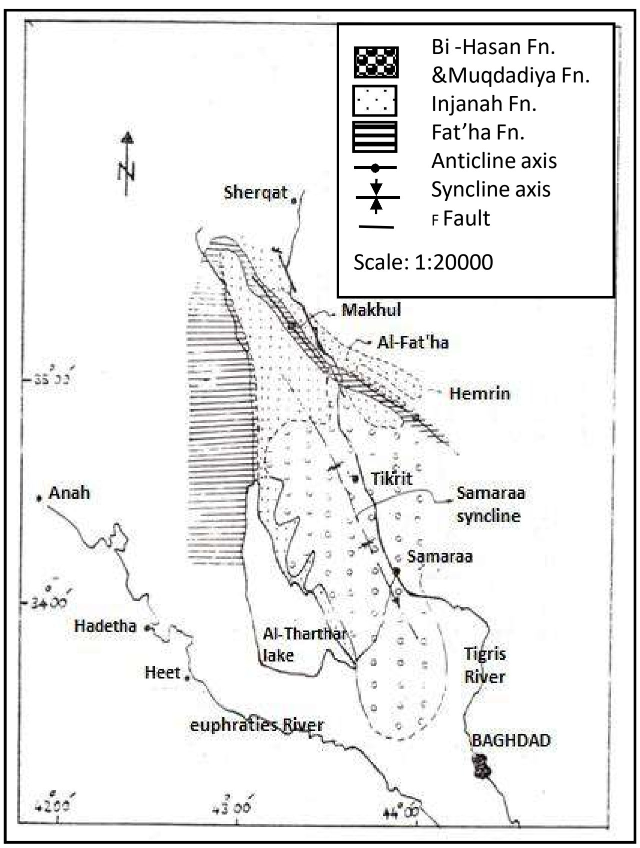

Fig. 2. Geomorphological map of the middle of Iraq (NEDECO Co., 1959)

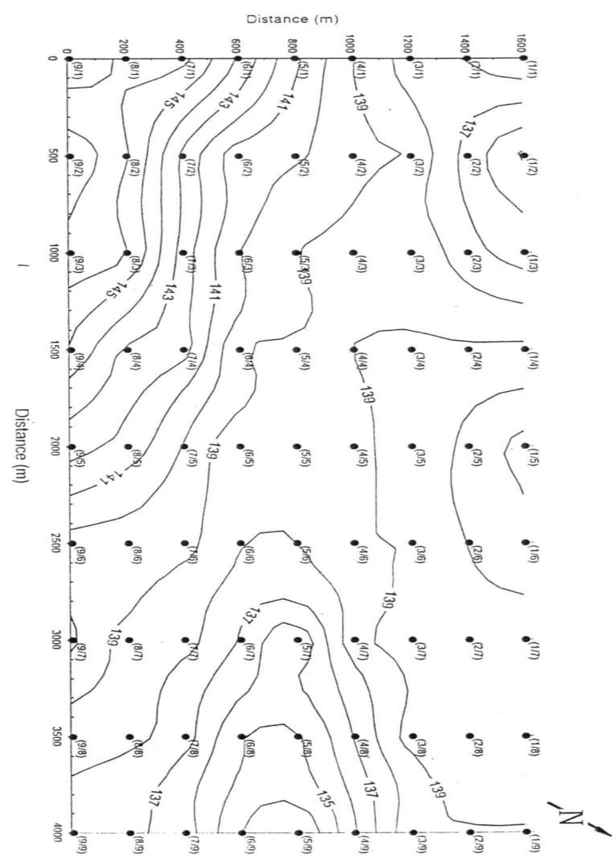

Fig. 3. The topographic map and Borehole locations (watertable elevations m.a.s.l.)

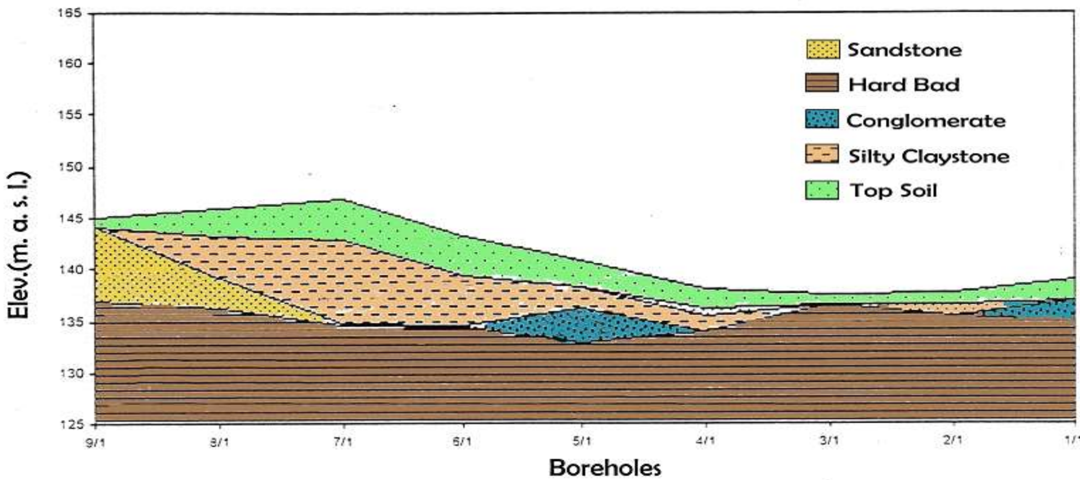

Fig. 4. The correlated geological section of wells (group 1) along the nine traverses.

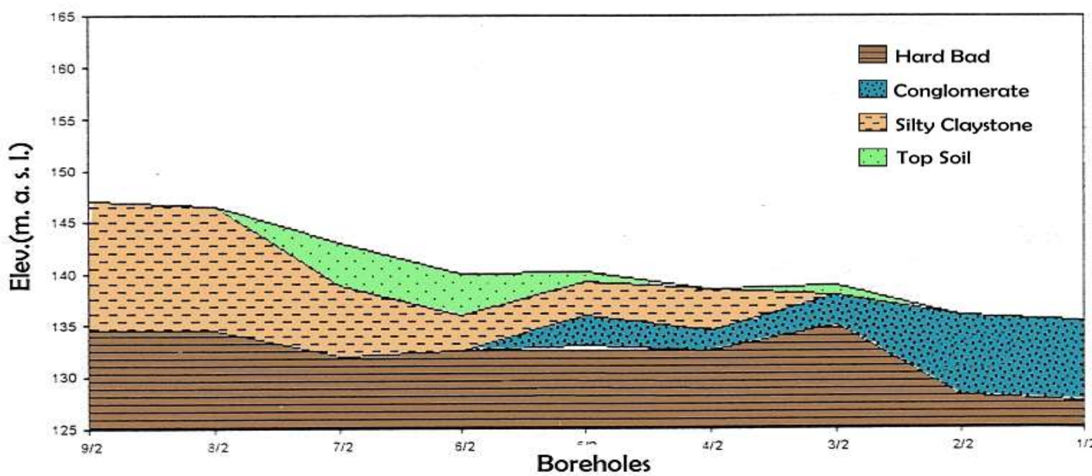

Fig. 5. The correlated geological section of wells (group 2) along the nine traverses.

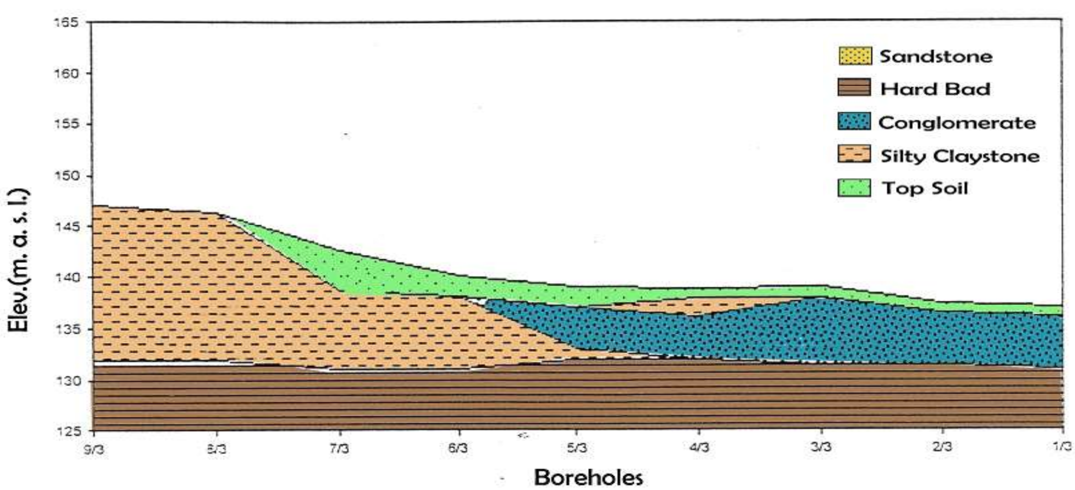

Fig. 6. The correlated geological section of wells (group 3) along the nine traverses.

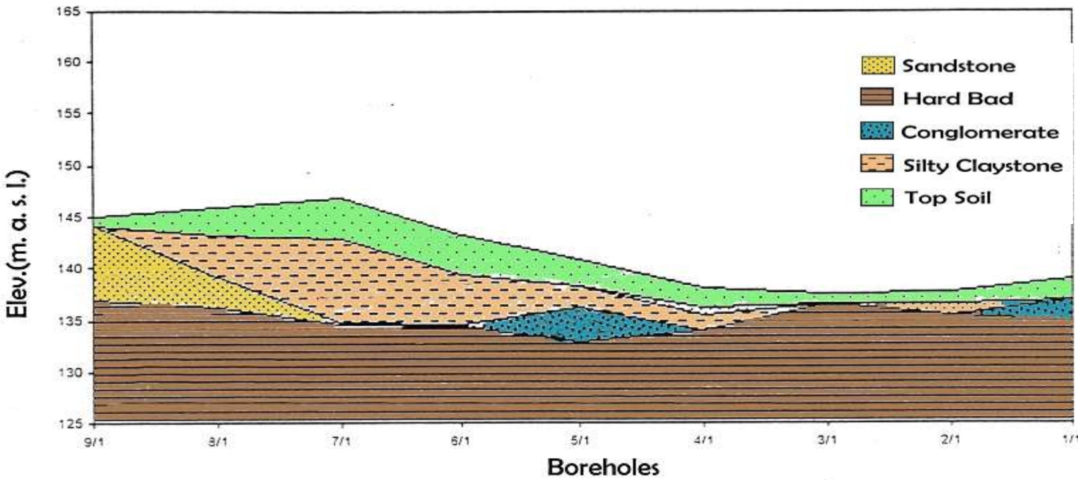

Fig. 7. Correlated geological section of wells along the nine traverses(group 4)

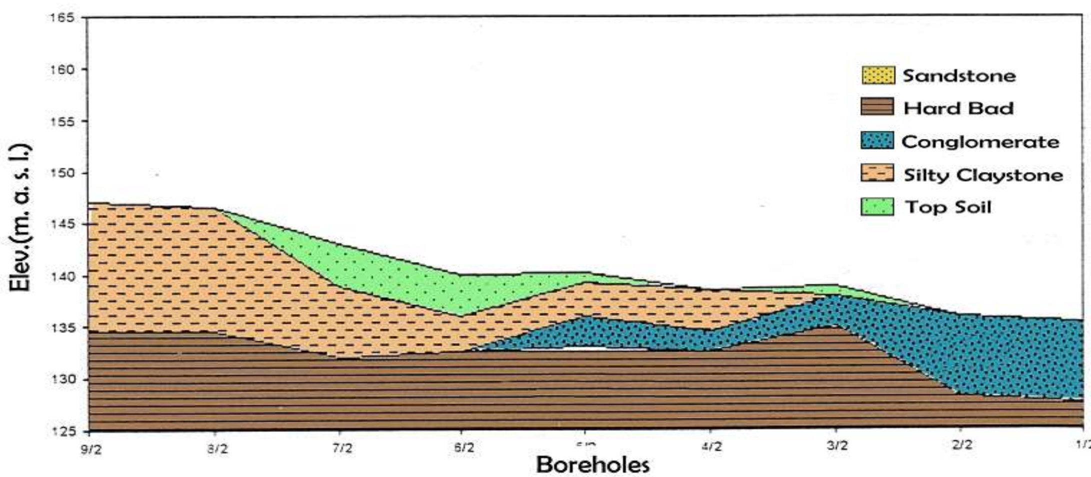

Fig. 8. Correlated geological section of wells along the nine traverses(group 5)

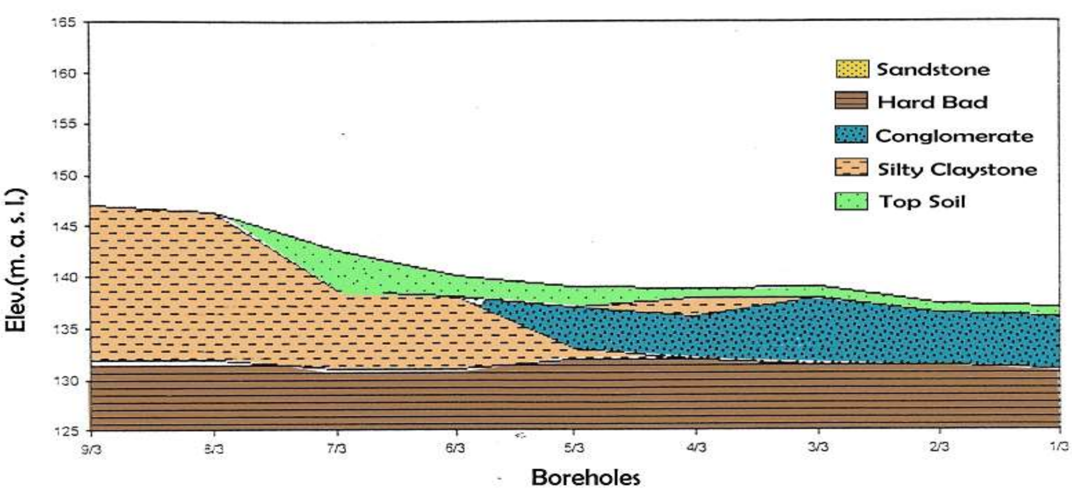

Fig. 9. Correlated geological section of wells (group 6) along the nine traverses.

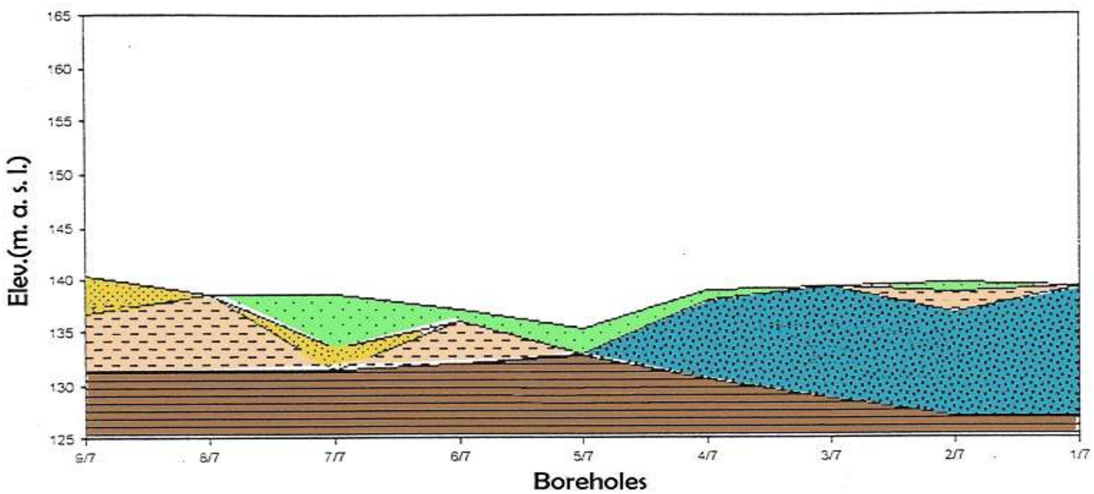

Fig. 10. Correlated geological section of wells) along the nine traverses(group 7)

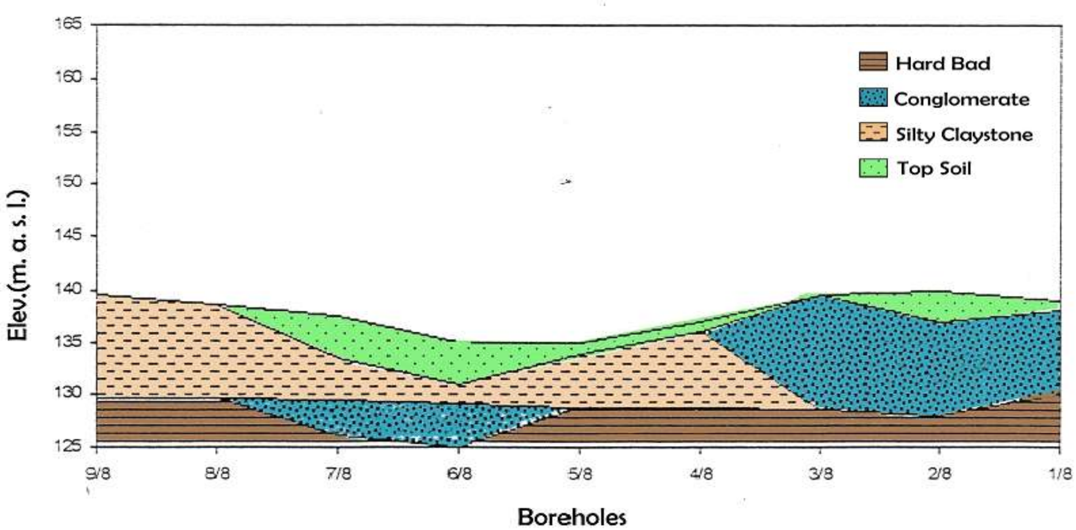

Fig. 11. The correlated geological section of wells along the nine traverses(group 8)

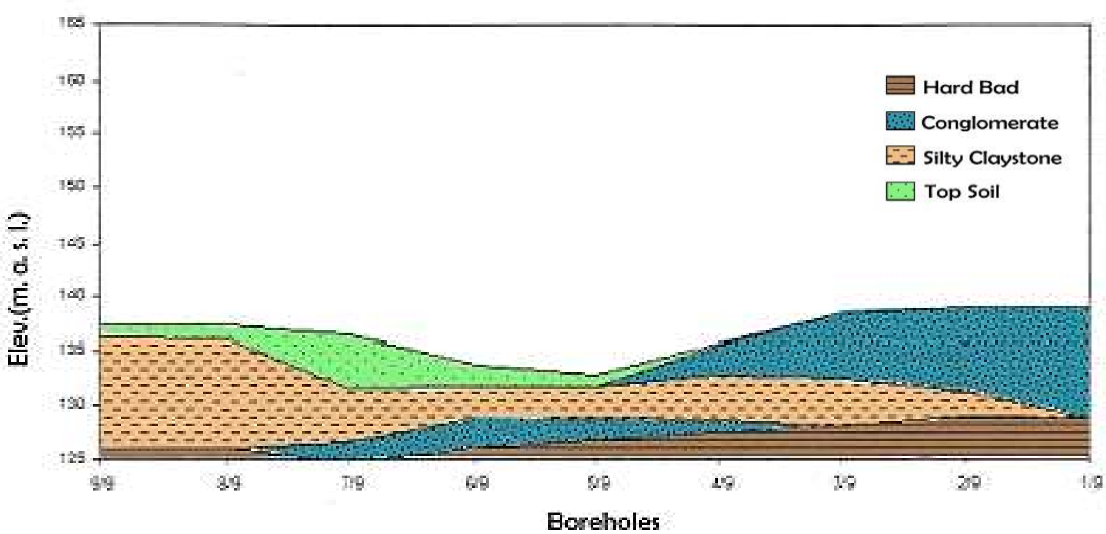

Fig. 12. Correlated geological section of wells along the nine traverses(group 9)

medium amount of secondary gypsum, therefore this lithosubfacies is mostly friable – medium tough.

Sandy conglomerate lithosubfacies: The matrix constitutes fine sand and silt, and again the cementing materials composed of calcium carbonate and a medium amount of secondary gypsum, produce medium tough – tough lithosubfacies.

Washed conglomerate lithosubfacies: It is rarely observed, represents the lower part of the channel, always washed and free of matrix. The main cementing materials are calcium carbonate with a subordinate amount of secondary gypsum.

The lateral extension of the conglomerate lithofacies exceeds 1200 m within (SOR). It changes laterally to clayey conglomerates, silty conglomerates sandy conglomerate, and even to washed conglomerates (Olusola and Samuel 2012). The change depends on the sediment load and the depositional scheme of the river (Sigdel andSakai 2016). The slopeis represented by the difference in elevations between the Fat'ha area and SOR.

Sandstone lithofacies: This lithofacies persists subordinately in comparison with the silty clayey lithofacies (Fig. 6). Its thickness ranges between 2–7m. Laterally changed to silty claystonelithofacies and its extension does not exceed 400m. Secondary gypsum grows near the top of the soil profile.

Silty claystone lithofacies: The lithofacies found in all boreholes. The thickness reaches 12m (Figure 7). Lenses of sandstones do not exceed 0.5 m intercalate this lithofacies. The silty claystone facies changed laterally to bad-sorted sandstone lithofacies, the width of the lithofacies reached more than 1400m. Secondary gypsum found within the upper part of the facies probably due to capillary action, ruled by thearid to semi-arid climate dominated the study area.

Depositional model: Lithofacies map (Figure 14) and isopach map of conglomerate (Figure 15) show allthelithological components like conglomerate, sandstone, and silty claystone. The questioned third terraces stage beneath SORis composed of two main channels. The first one is dissected by sandstone, silty claystone levees. It speared as a narrow elongated levee directly proportional with the paleo-river channel width 212-764m. Levees formed mainly of silty claystone and even conglomerate facies separate the two channels, the first and second leaving some small crevasse splay connected the two main channels.

This condition appears to be low sinuosity with restricted flood plain displays by the silty claystone facies (Sigdel and Sakai 2016, Colombera and Mountney 2019). The maximum depth of the first channel No.1 is (4 m), whereas the second channel No.2 is wide and continuous, with width ranges (411-1235m), and the depth exceeds (14 m). The second channel is considered as the main permanent channel of the river during annual normal discharges. The paleo-flow direction from NE to SW (Figure 16).

Paleo - hydrogeology: Throughout the interpretation of Figures (14, 15, and 16), it seems that the estimated depositional model built (Fig. 16) for the studied area beneath SOR is composed of two channels. Channel 1 is the subsidiary channel, which displays dissected parts of conglomerate rocks; part (1a) includes two lines of boreholes (8 and 9) representing conglomerate rocks, connected with the main channel 2 by crevasse splay. A sandstone bar is separated between the two channels, and part (1b) is composed of sediments and clayey siltstone bar. Every one of these parts represents an underground aquifer for water derived from, precipitations and seeped industrial water, produced from leakage of industrial water pipes. These

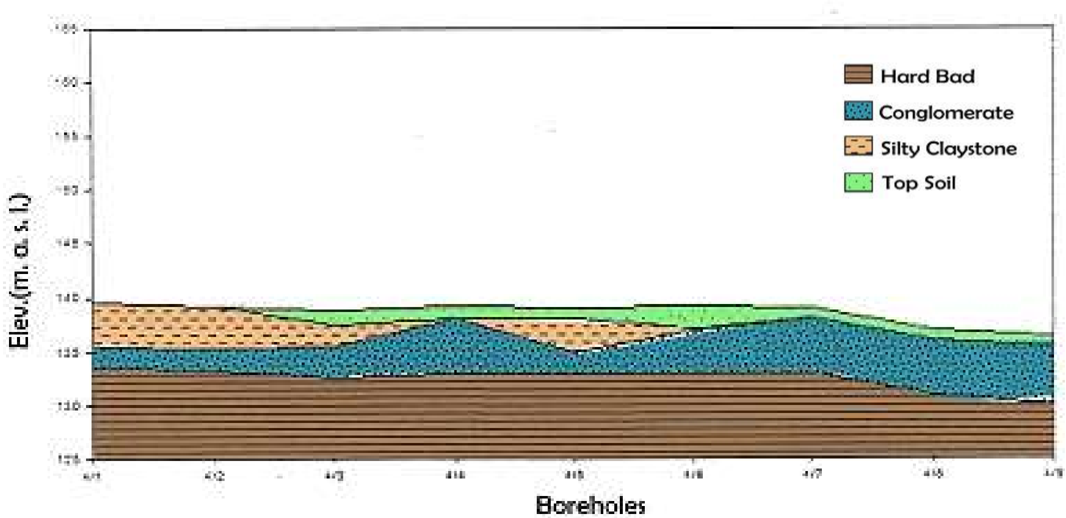

Fig. 13. Correlated geological section of wells (1 - 9) along the traverse No. 4.

aquifers are not connected with the main channel2 except with a few small connections, so it serves and attain water and no discharge occurs. In addition to, any water supply to this channel raise the groundwater table level GWTL for the storage water (Fig. 17) during the period (2000-2001), in this context, part (1a) of channel. 1 mark an increase in GWTL reach 40 cm. On the contrary, a decrease in GWTL took place between part (1b) and part (1c) reach to about (2-4 m), due to the direct connection of the two main channels by small crevasse splays at those parts.

The groundwater table levels increase in the channel (2) and decrease in the channel (1), (Fig. 18). However, the trials of lowering the GWTL fail unless pumping operation to the ground surface took place. In this sense, the discharge pumping operations could cause dangerous impacts on both civil and industrial buildings in the area. On condition that the

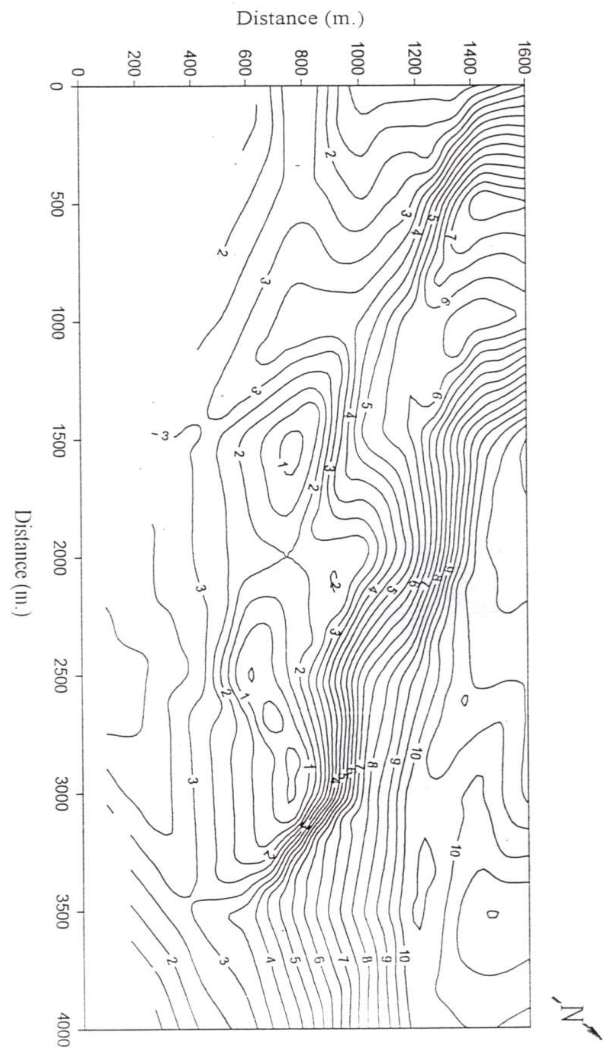

Fig. 15. The thickness isopach map of the conglomerate lithofacies

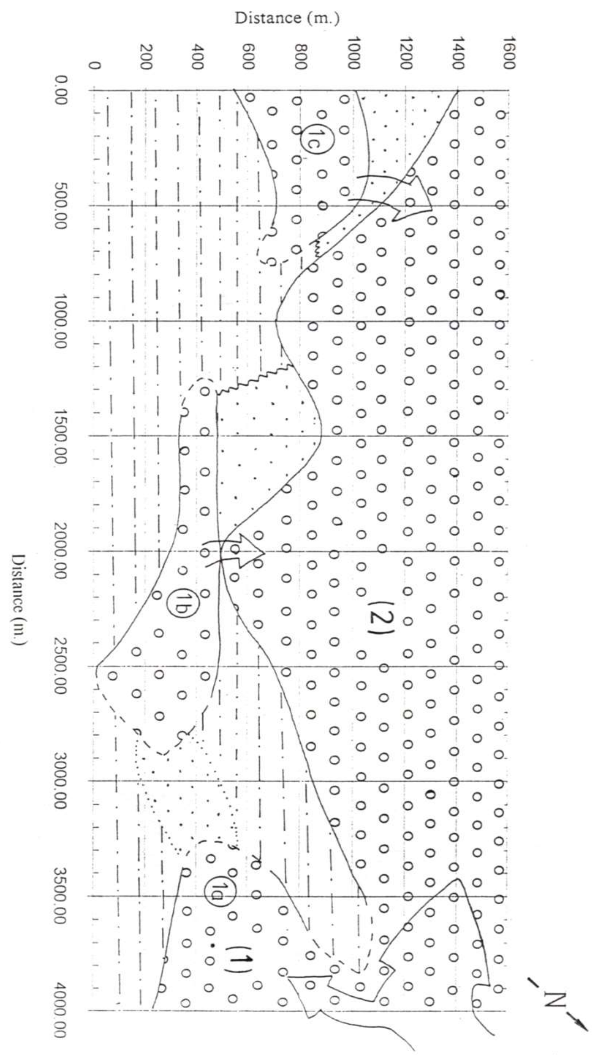

Fig. 14. The lithofacies map of the 3rd river terraces beneath the refinery area

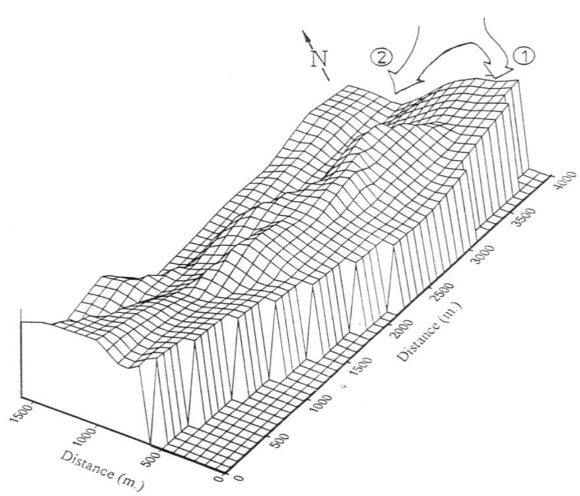

Fig. 16. Depositional model (3D) of the accent Tigris river channel beneath the refinery area

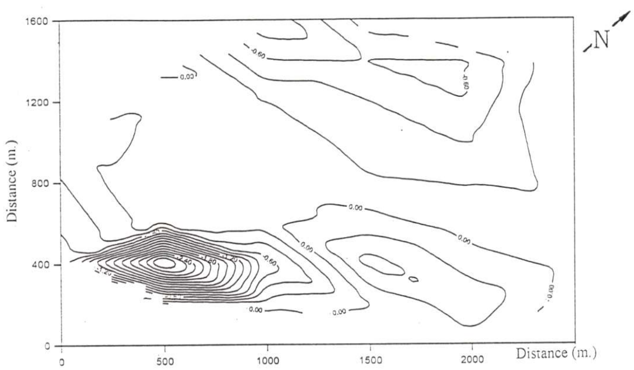

Fig. 17. Difference of water table elevations in the studied area (Al-Jabari 2001)

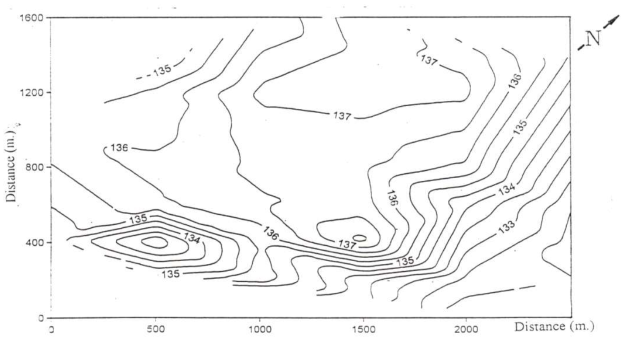

Fig. 18. Map of the water table elevations through the 1st six months of 2001 in the studied area (Al-Jabari 2001)

pumping must be slow and gradual for certain selected boreholes to minimize the impact on the foundation of the buildings. Another risk, the industrial seeped water stored in these dissected channels takes its time to dissolve all the carbonate cementing materials, which causes these rocks to be more friable and decrease the efficiency of the natural ground to bear the load of the buildings. The rise of GWTL in these secondary channels cannot be treated unless the shutdown of the seeped industrial water happens. Then the programming discharge must begin from these channels. After that, grouting of certain materials and for long time intervals must take place, to recover some of the lost cementing materials or at least to fill the ground mass among the gravels. Despite the continuous dissolution of the cementing and binding materials, there are natural discharges for the groundwater to the lower adjacent valleys, and the ground levels of their boreholes could decrease directly after the repairs of the broken and perforated industrial water pipes.

CONCLUSIONS

The Quaternary deposits represent braided and low sinuosity river channels with restricted flood plain deposits. It constituted alternations of conglomerate rocks, sandstone, and clayey siltstone. These deposits reflect the ancient paleo-channel of the third terrace stage of the Tigris River. The conglomerate reflects the main channels, sandstone, and silty claystone represent the deposits of the restricted flood plains. The estimated depositional model is mainly made up of conglomerate rocks, forming the main channel, continuously discharged groundwater, and secondary channel dissected by sand bars bearing groundwater only in flooding events. The presence of conglomerate beds beneath the refinery building has a significant impact on the building foundation of the refinery due to its industrial water contents. The long-term effect of the industrial acid water dissolved continuously the binding and cementing materials deteriorating the engineering properties and bearing capacity of the ground. There is need to conduct a study on certain materials as equivalent to the lost binding and cementing materials to afford the engineering and lithological support for the conglomerate rocks. Repair the industrial pipes during continuous monitoring of the GWTL in the boreholes. Conduct program for the pumping from selected boreholes, particularly in the channel (No. 1) part (1a) to the land surface, then transport the water by lined pipes to the valley area outside the refinery.

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