ISSN: 0067-2904
GIF: 0.851

Delineation of Quaternary Aquifers by Using Long 2D Imaging in Southern Al-Shihaby Area (Wasit Governorate), Eastern Iraq

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Abstract

An electrical survey was carried out by using 2D imaging technique at (15) station. The study area is located southern Al-Shihaby area, south-east of Wasit governorate, Eastern Iraq. The numbers of the employed electrodes were (120) and the (a) spacing equal to (10m), and the total length of survey line is (1200m). The inverse models of 2D imaging showed one Quaternary aquifer located in the Quaternary deposits which comprises in alluvial fan and wind deposits of (Pleistocene – Holocene) ages. Layers of aquifer consist of gravel and sand with little silt. Low resistivity values reflected the presence of clay layers, and increasing salinity of water gradually with the depth. The aquifer occurs at minimum depth equal to (12m) approximately in the inverse model of 2DSh10 station and maximum depth equals to (153m) approximately in 2DSh2 station. In addition, the minimum thickness of aquifer was (7m) approximately as appeared in 2DSh15 station and the thickness increased to (91m) approximately in 2DSh4 station. The results indicated that the type of aquifer is unconfined.

Keywords: 2D resistivity imaging, Quaternary aquifer, Al-Shihaby area.

تحديد خزانات العصر الرباعي باستخدام التصوير ثنائي البعد الطويل في جنوب منطقة الشهابي (محافظة واسط) شرق العراق

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الخلاصة

نفذ المسح الكهربائي باستخدام تقنية التصوير ثنائي البعد في (١٥) محطة. وتقع منطقة الدراسة جنوب منطقة الشهابي، جنوب شرق محافظة واسط، شرق العراق. وكانت عدد الأقطاب المستعملة (١٢٠). أما المسافة القطبية (a) فتساوي (١٠م). لذلك كان الطول الكلي لمسار المسح (١٢٠٠م). أظهرت الموديلات المعكوسة وجود خزان جوفي يعود إلى رواسب العصر الرباعي والتي تتكون من ترسبات المراوح الغرينية والريحية، وهي ذات أعمار (البليستوسين– هولوسين). وظهر الخزان الجوفي على عمق (١٢م) تقريبا" في محطة ثنائي البعدين (2DSh10) ويزداد إلى عمق (١٥٣م) تقريبا" في محطة (2DSh2). أما سمك الخزان فكان يتراوح بين (٧م) تقريبا" في محطة (2DSh15) ويزداد إلى (٩١م) تقريبا" في محطة (2DSh4). بينت النتائج أن الخزان الجوفي من النوع غير المحصور.

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Introduction:

Geophysical explorations are comprised of many methods which used with a variety manners. The electrical methods are taken as a distinct role in the geophysical explorations, especially; the resistivity method [1, 2, 3, 4]. The one dimensional (1D) and two dimension (2D) resistivity techniques are used widely in the electrical surveys. One of the most important is using to delineate the ground water aquifers [5, 6, 7, 8, 9]. The 2D imaging technique used with different types of electrodes arrays such as; Dipole-dipole, Wenner, Wenner-Schlumberger and Gradient arrays [10, 11, 12, 13, 14]. The study area is located between latitudes (32°36'-32°53') north and longitudes (46°23'-46°45') east, in southern Bagsaya (Al-Shihaby) area, and (south east) of Wasit governorate, eastern Iraq Figure-1.

The study area is nearly (≈ 500 km²), which is part of Mesopotamian zone. It represents flat surface with the presence of some rugged places in the north-eastern part and slopes gradually in the direction of the south-west. In the north-eastern part, the highest point reaches (95m) above sea level and the lowest point is (25m) above the sea level in the south-western part. Geology of the study area and adjacent areas comprise of geological formations and Quaternary deposits. The Quaternary deposits cover most of the study area.

It was comprised mainly of alluvial fans and wind deposits. Alluvial fans are a result of several cycles of sedimentation. Wind deposits are located south of the study area. The Wind deposits were derived from alluvial fans, where these are often rich in grains of the older Miocene-Pliocene molasses [15, 16]. In belt of the wind deposits, the sand consists of quartz and limestone grains that were derived from outcrop of Eocene and Miocene Formations [2]. The geological formations include; Injana (Upper Fars)**;** Mukdadiya (Lower Bakhtiari) and BiHassan (Upper Bakhtiari). The Quaternary deposits are unconsolidated and usually finer grained than the underlying pebbly sandstone of Mukdadiya and Bi Hassan Formations [17]. The Formations and Quaternary deposits have ages (Late Eocene – Holocene). The contact between the formations and the Quaternary deposits is overlapping because of wide and heterogeneous erosion for the layers.

The pervious hydrological information [18, 19], and the geological sections of drilled wells as well as specifications and quality of groundwater are used to compare with the inverse models. The twelve wells were distributed in the different villages and the near of 2D measuring stations and they were drilled in previous years by General Commission of Ground Water [20]. Many parameters and lithology of wells can be obtained from them Figure-2. The depth of the wells was ranging between (36-60m) and the static level of groundwater was between (3-15m). The chemical analyses for the wells water shown, the electrical conductivity was between (2950-5520 µs/cm) [20]. The aim of the study is to delineate the thickness and depth of groundwater aquifers in Quaternary deposits.

Data acquisition:

The field work was commenced after determining the locations of measurement points, in addition to complete all the requirements of the stations survey. Wenner-Schlumberger array was used, because it is more appropriate to the aims of the study. Fifteen stations of 2D resistivity imaging were selected in the study area (Sh1,……. Sh15) as shown in Figure-1, and the direction of survey lines of the measuring stations is in (NW-SE), (NE –SW) and (N –S). The numbers of the employed electrodes are (120), and the (a) spacing equal to (10m). Therefore, the total length of survey line is (1200m), and the data coverage for the whole stations is equal to (3753) reading.

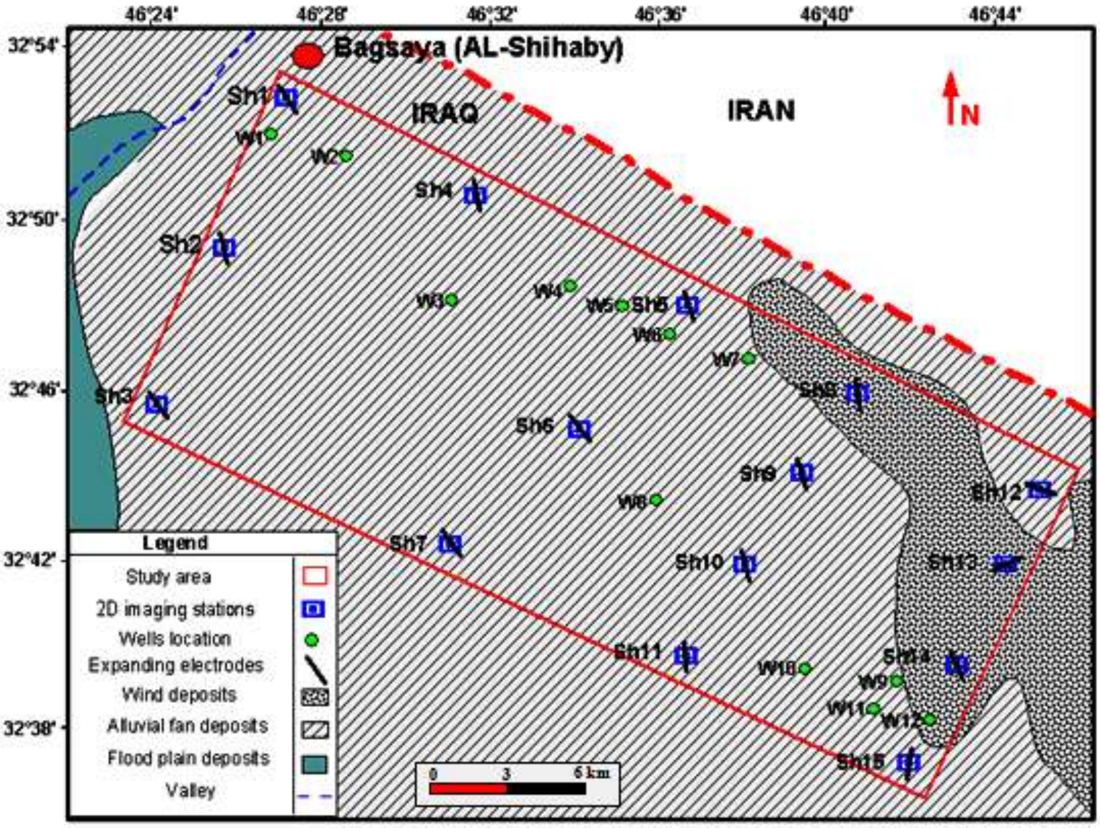

Figure 1 – Geological map with the distribution of the 2D stations and the drilled wells in the survey area [4].

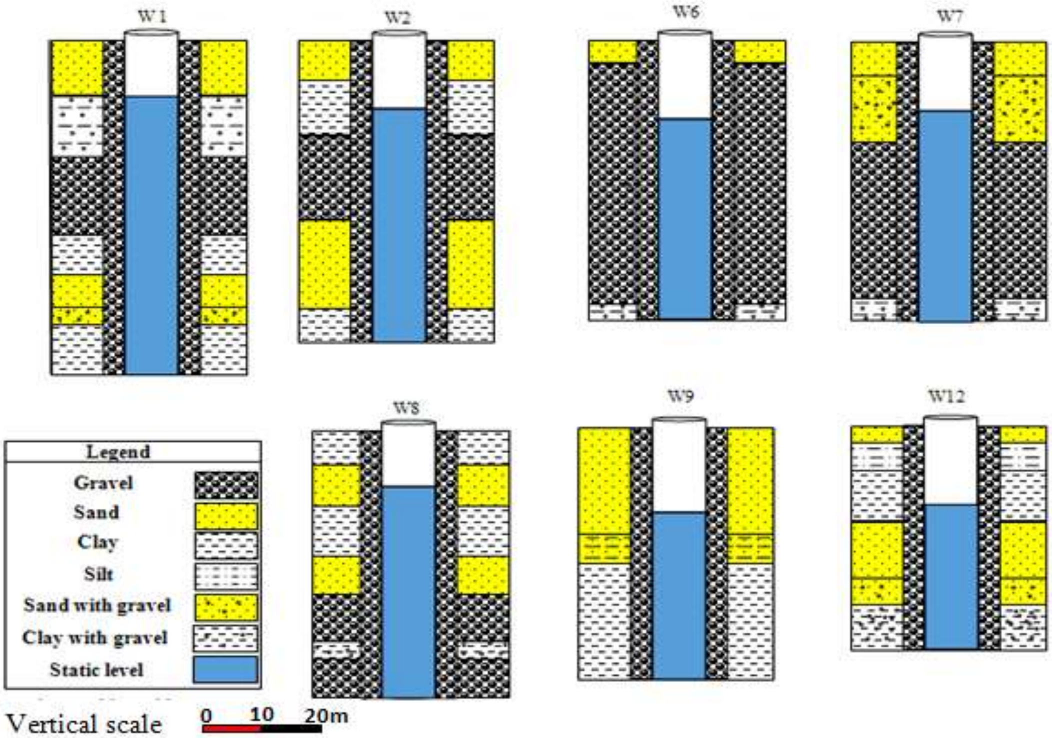

Figure 2 – Geological sections of the drilled wells in the study area [20].

Data processing and Interpretation:

The processing of the obtained field data was carried out by using (Prosys II) and (Res2dinv) programs [21]. These programs can remove the bad data that accompanying and distorts the field data, because it gives wrong perceptions in the interpretation of 2D imaging stations. The processing method was done either manually or automatically [21, 23].

Inverse models of 2D imaging stations and geological sections of the drilled wells with the hydrology information provided by the General Commission of Groundwater were used in the interpretation to get good pictures of the subsurface layers. The inverse models are created by using the Res2dinv program version (3.59).

In this program many variable data of area parameters must be selected to create the inverse models which are appropriate with the area data [22, 23], such as the initial damping factor equal to (0.200) while the minimum damping factor was (0.1), because the presence of the noises near the ground surface. While, the (Vertical/Horizontal) flatness filter ratio equals to (0.5), because the anomalies elongated horizontally. The ratio of RMS error in the inverse models is ranging between (2.7%-15.5%) with different iterations.

-Interpretation of 2DSh1 station:

The inverse model of 2DSh1 station shows presence of four electrical horizons Figure-3. The resistivity values decreased with the depth and have range between (1) to more than (292Ω.m) approximately at the depth of (21m). According to a geological section of the drilled well number (w1), the layers consist of dry sand and silt. In addition, the static level of ground water at the depth (12m) [20]. The second horizon reaches to a depth of (21-46m) approximately. It consists of gravel layers. Resistivity values of this horizon are ranging between (25.6-292Ω.m). Low resistivity values are caused by the presence of saline water. It has conductivity about (5520 µs/cm). After this depth it can be noted the decreasing of the resistivity from (5.06) to (67.35Ω.m) that are related to sand and clay layers at a depth of (46m-70m) approximately. The depth of these horizons represents Quaternary aquifer, which has thickness range between (34-58m) approximately.

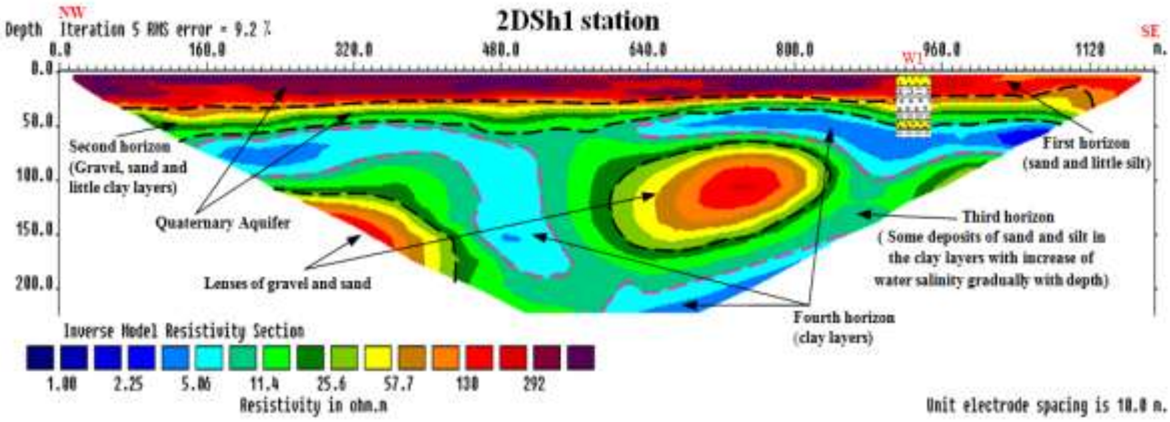

Figure 3 – Shows the inverse model resistivity section for 2DSh1 station.

The third horizon consists of lenses of gravel and sand deposits lenses inside the clay layers. The resistivity values are decreasing gradually with the depth to the end of the inverse model where the clay layers are existed. The fourth horizon appears with red border. It has a resistivity value less than (8.23Ω.m), because of the presence of clay layers and with gradual increase in water salinity.

- Interpretation of 2DSh2 station:

Figure-4 shows the inverse model of 2DSh2 station, where four electrical horizons are outlined. The first horizon with blue color is located in the upper part of the inverse model at a depths ranging between (22-107m) approximately. It extends along the inverse model except under electrodes numbers (25-39). It has resistivity value less than (5.06Ω.m) that is related to clay layers, and the horizon has tongues extended into the second horizon. Inside these layers there are lenses of sand and silt deposits. It has resistivity values ranging between (25.6Ω.m) to less than (5.06Ω.m). The second horizon extends at depths ranging from (107-183m) approximately as indicated red border. It may be consisted of clay layers with little sand deposits. The resistivity values of this horizon are ranging between (5.06-11.4Ω.m). The third horizon (black border) occurs at the depth (22-153m) with presence of discontinuities under the electrodes (60-84). It comprised of sand and silt deposits. The third horizon may be represented the Quaternary aquifer. The resistivity values range between (11.4-57.7Ω.m) approximately, and the thickness varies from (69-123m) approximately. At the last horizon, the resistivity values are decreased with depth and it has resistivity values less than (5.06Ω.m). The layers of this horizon may be consisted of clay with an increase in water salinity.

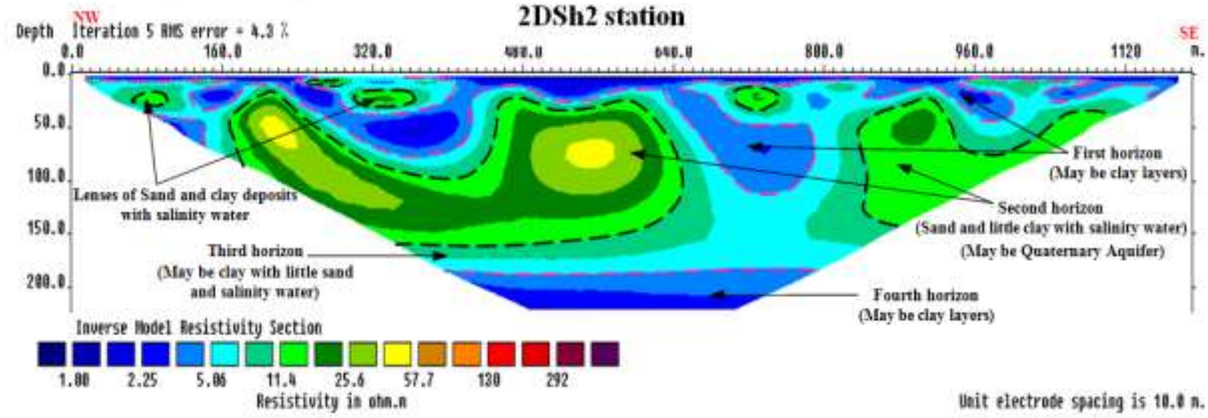

Figure 4 - Shows the inverse model resistivity section for 2DSh2 station.

Interpretation of 2DSh3 station:

This station is located in the end of alluvial fan deposits, therefore, most of these deposits consist of clay, silt and a little sand layers as well as increasing the saline water with the depth. The inverse model of 2DSh3 shows four electrical horizons Figure-5. They are reflecting the variation of resistivity values. The first electrical horizon (blue color) extends along the inverse model, it has resistivity value less than (3.65Ω.m) at the maximum depth equal to (25m) approximately may due to presence of clay layers. The second electrical horizon (black border) has resistivity values and depths ranging between (11.4-57.7Ω.m) and depth of (25-88m) approximately. The thickness of this horizon is ranging between (7-71m) approximately. It may be comprised of sand and silt layers. This horizon is located on the left side with surrounding medium of third horizon. The second horizon may be considered as Quaternary aquifer. The third horizon represents presence of clay layers with little deposits of sand with saline water. The maximum depth of this horizon reaches up to (141m) with thickness ranging from (19-123m) approximately. In addition to, under electrodes numbers of (76-78) there is discontinuity in this horizon. The resistivity value of this horizon is ranging between (5.06-11.4Ω.m). The last horizon is located in the bottom of inverse model. It has a resistivity value less than (5.06Ω.m) that it may consists of clay layers.

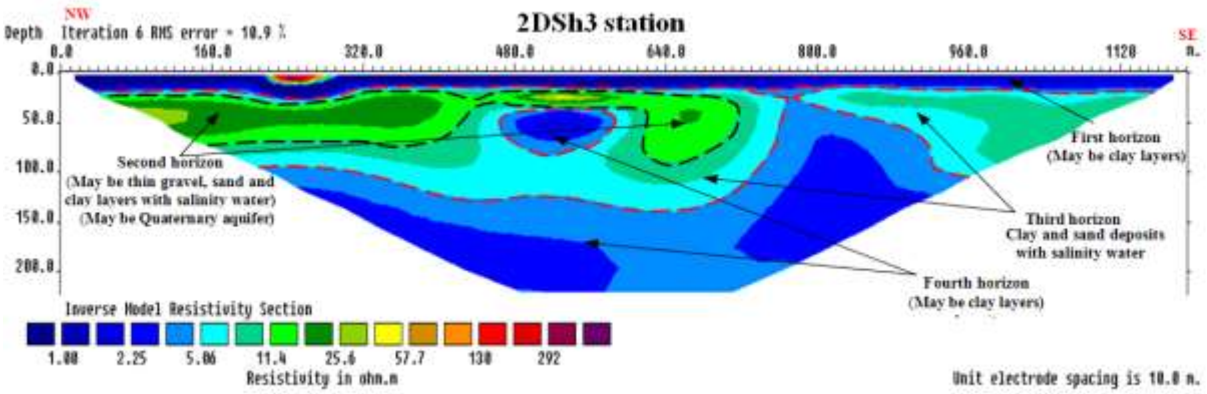

Figure 5- Shows the inverse model resistivity section for 2DSh3 station.

-Interpretation of 2DSh4 station:

The inverse model of 2DSh4 station shows three major electrical horizons Figure-6. It reflected the variety of the lithological layers. The geological section of well number (W2) is used to compare with inverse model of this station. The first horizon extends along inverse model at the depth of (103m) approximately. Layers of the horizon have resistivity value more than (41.65Ω.m). Thickness of the horizon is reached (91m) approximately in the (NW) part of the model. The high resistivity values are caused by gravel and sand layers as well as the groundwater level was at (12m) [20]. The first horizon may be considered as Quaternary aquifer. The second horizon extends into the end of model and has resistivity values ranging between (11.4-41.65Ω.m). These layers may be consisted of clay with little overlapping silt layers as well as gradually increasing of saline water with the depth. In this layer, there are lenses of sand, and this layer has resistivity values between (25.6-93.85Ω.m). The third horizon is inside the second horizon in the left and right bottom with a red border as defined by the depth equals to (123m) approximately in the end of the model. It has resistivity value less than (41.65Ω.m). The layers of this horizon may be consisted of clay layers with increasing saline water gradually with depth.

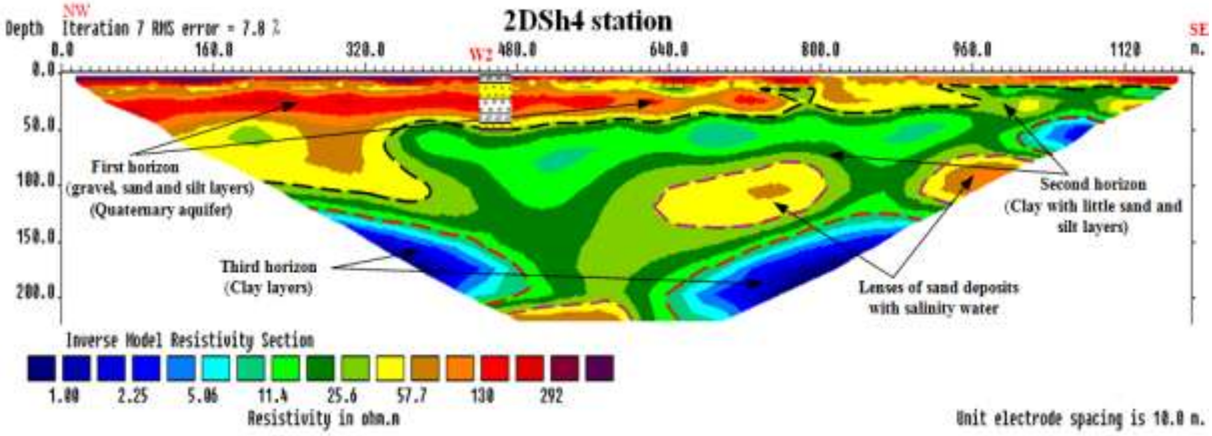

Figure 6- Shows the inverse model resistivity section for 2DSh4 station.

-Interpretation of 2DSh5 station:

Figure-7 shows the inverse model of 2DSh5 station. The inverse model exhibited three major electrical horizons. They reflected the presence of three lithological layers. The first horizon has resistivity values between (25.6Ω.m) to more than (292Ω.m) approximately and a depth of (64m). According to the geological section of well number (W6), the layers consist of sand and gravel. The static level of groundwater in this station was (14m), and thickness of the horizon is ranging between (36-50m) approximately. It can be considered as Quaternary aquifer. The second horizon extends to the end of the model. The layers of this horizon have resistivity values ranging between (11.4-25.6Ω.m), it consists of clay with overlapping silt deposits. The third horizon is inside the second horizon lenses and has resistivity value less than (11.4Ω.m). It is reflects the presence of clay layers with the increase of water salinity.

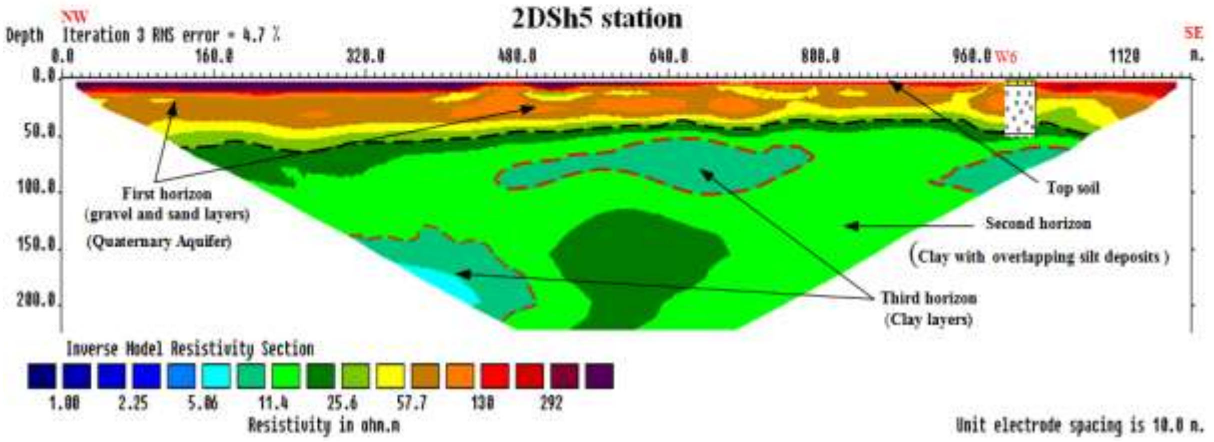

Figure 7 - Shows the inverse model resistivity section for 2DSh5 station.

-Interpretation of 2DSh6 station:

The inverse model of 2DSh6station Figure-8 shows four electrical horizons. Resistivity of the first horizon has value of less than (5.06Ω.m) at a depth equal to (15m) approximately. According to geological section of well number (W8), the layers of the horizon are consisted of clay. This horizon is not appeared in some positions of the upper model. The second horizon (red border) extends to the depth of (15-113m) approximately and has resistivity values between (5.06-8.23Ω.m). The layers of this horizon comprise of clay with saline water. The third horizon with (black border) is located inside the second horizon as lenses. It has resistivity values ranging between (8.23-11.4Ω.m) at depths ranging between (15-64m) approximately. The layers of horizon reflected the presence of sand and gravel which is considered as Quaternary aquifer. The thickness of the aquifer is ranging between (13-41m) approximately. This aquifer is not extended along the model. The fourth horizon consists of clay layers with the increase of water salinity gradually with depth. It has resistivity value less than (5.06Ω.m).

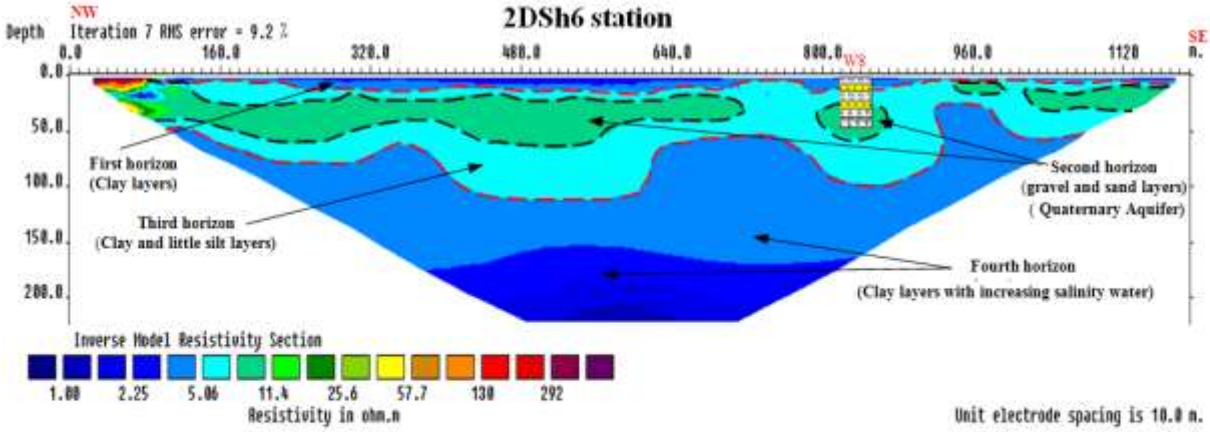

Figure 8 - Shows the inverse model resistivity section for 2DSh6 station.

–Interpretation of 2DSh7 station:

This station is located at the end of alluvial fan deposits, where, most of the layers are comprised of clay and little sand with silt as well as increased saline water content gradually with depth. The inverse model shows the presence of four electrical horizons Figure-9. The first horizon (blue color) has resistivity value less than (5.06Ω.m) at the depth of (40m) approximately, it consists of clay layers. The second horizon at depths from (12-92m) approximately reflected the resistivity value ranging between (5.06-8.23Ω.m). This value is due to clay content with few silt layers. The third horizon is distributed inside the second horizon as lenses, and has resistivity values ranging between (8.23-41.65Ω.m) at a depth from (40-79m) approximately, this horizon comprises of gravel and sand layers with little overlap of silt and clay layers. It may be considered as Quaternary aquifer. The thickness of this aquifer is ranging between (22-58m) approximately. The last horizon has resistivity values less than (5.06Ω.m) and in the end depth of the inverse model. It may be comprised of clay layers with increased water salinity that is gradually increasing with extending depth.

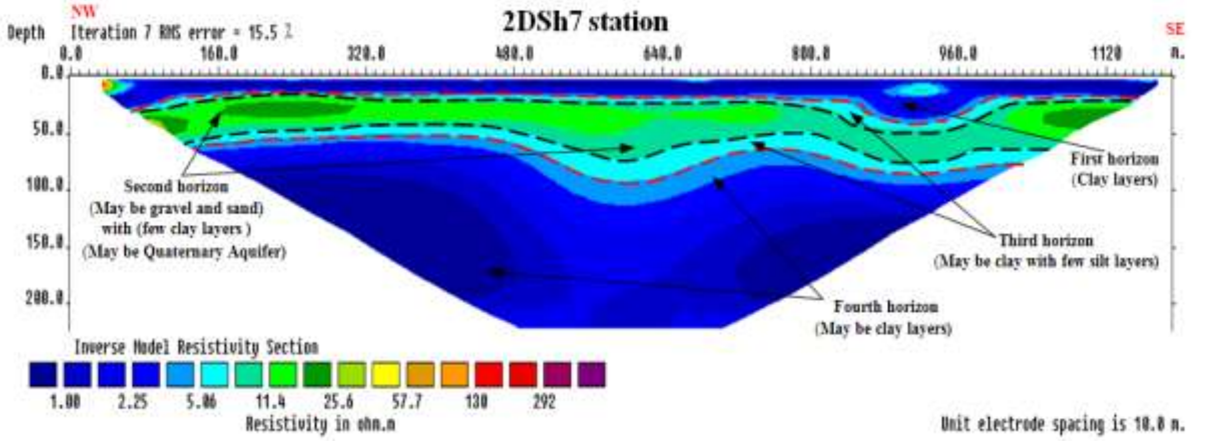

Figure 9 - Shows the inverse model resistivity section for 2DSh7 station.

-Interpretation of 2DSh8 station:

Figure-10 shows the inverse model of 2DSh8 station. It reflected the presence of three electrical horizons. In the upper part of the model for the depth of (55m) approximately, it can be considered the first horizon, according to the geological section of well number (W7), this horizon consists of gravel and sand layers. The resistivity of the horizon has values more than (41.65Ω.m) and this is considered as Quaternary aquifer with thickness reaches (31-43m) approximately.

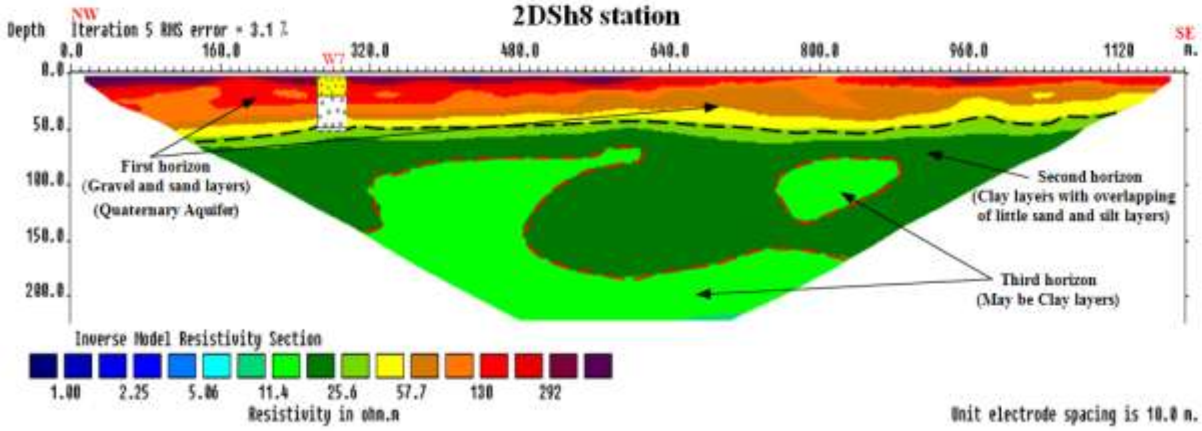

Figure 10 - Shows the inverse model resistivity section for 2DSh8 station.

The second horizon extends at a depth from approximately (55-198m) and comprises of clay layers with little silt deposits but the water salinity is less than previous stations. The third horizon with (red border) has resistivity value less than (18.5Ω.m), it may be consisted of clay layers and the water salinity is more than the salinity of the second horizon. This horizon is continued to the end of the inverse model.

–Interpretation of 2DSh9 station:

The inverse model of 2DSh9 station shows three major electrical horizons Figure-11. The first horizon is located in the upper part of the inverse model to the depth of (36m) approximately, and has resistivity values more than (25.6Ω.m). The layers of this horizon are consisted of gravel and sand. It may be represented as Quaternary aquifer. The thickness of this aquifer reaches (14-28m) approximately. The second horizon extended to the depth of (186m) approximately, the resistivity values are ranging between (25.6-11.4Ω.m). The layers of this horizon consist of clay with little silt as well as the increasing of saline water. The third horizon (red border) occurs in the bottom of model and inside the second horizon as lenses with a thickness of (14-57m) approximately. It has resistivity values ranging between (11.4-5.06Ω.m). It may be consisted of clay layers as well as the water salinity content is increased.

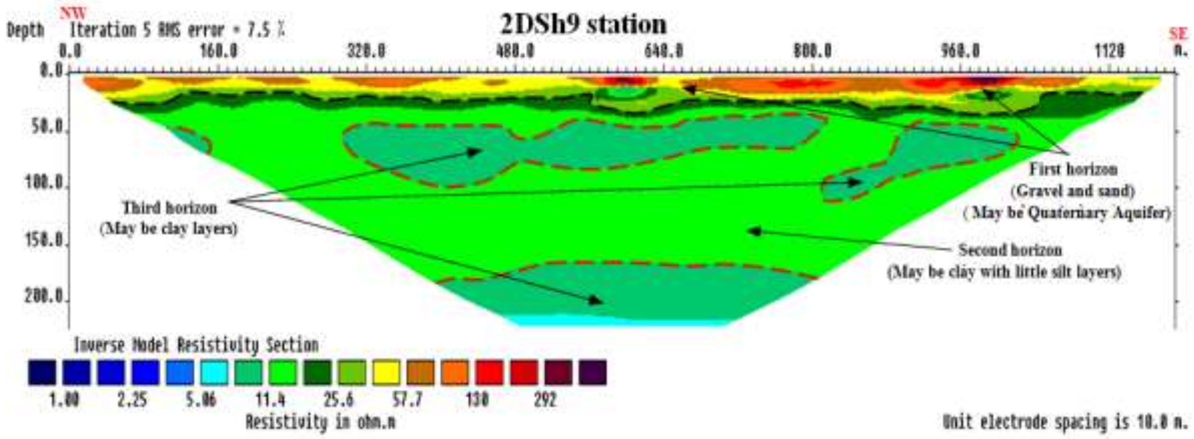

Figure 11- Shows the inverse model resistivity section for 2DSh9 station.

–Interpretation of 2DSh10 station:

Figure-12 shows the inverse model of 2DSh10 station. The inverse model appears three major electrical horizons. The first horizon with black border extends to the depth of (66m) approximately, the resistivity of this horizon has values ranging between (11.4-292Ω.m). The layers of this horizon comprise of gravel and sand layers with increase of water salinity gradually. It may be represented as Quaternary aquifer. This aquifer does not extend along the horizon and overlapping with the second horizon. Thickness of the aquifer ranges from (24-40m) approximately, the resistivity value is ranging between (5.06-11.4Ω.m) at the depth of (147m) approximately. It may be consisted of clay with few silt layers. The third horizon extends to the end of the inverse models and the resistivity value change gradually with depth. Resistivity of this horizon as value less than (5.06Ω.m). The layers of horizon may be consisted of clay layers with the increase of water salinity gradually with depth.

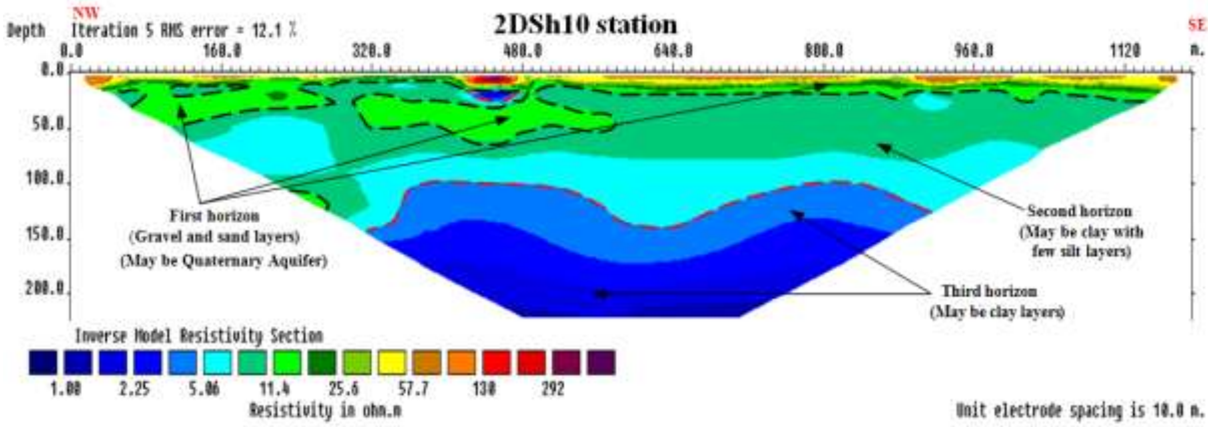

Figure 12 - Shows the inverse model resistivity section for 2DSh10 station.

-Interpretation of 2DSh11 station:

The inverse model of 2DSh11station shows the presence of three major electrical horizons Figure-13. The first horizon with blue color extends along the upper model to a depth of (22m) approximately, it has resistivity value less than (5.06Ω.m). Layers of the horizon may be consisted of clay with little sand as well as the presence of saline water. The second horizon with (red border) has resistivity value ranges between (8.23-25.6Ω.m) to the depth of (22-54m). It may be comprised of sand and overlapping of silt with little clay as well as the presence of saline water. This horizon may be represented as Quaternary aquifer, the thickness of the aquifer is ranging between (21-36m) approximately. The third horizon has resistivity value less than (5.06Ω.m), it extends to the end of the inverse model. The layers of this horizon may be consisted of clay and little silt as well as increase of water salinity gradually with the depth.

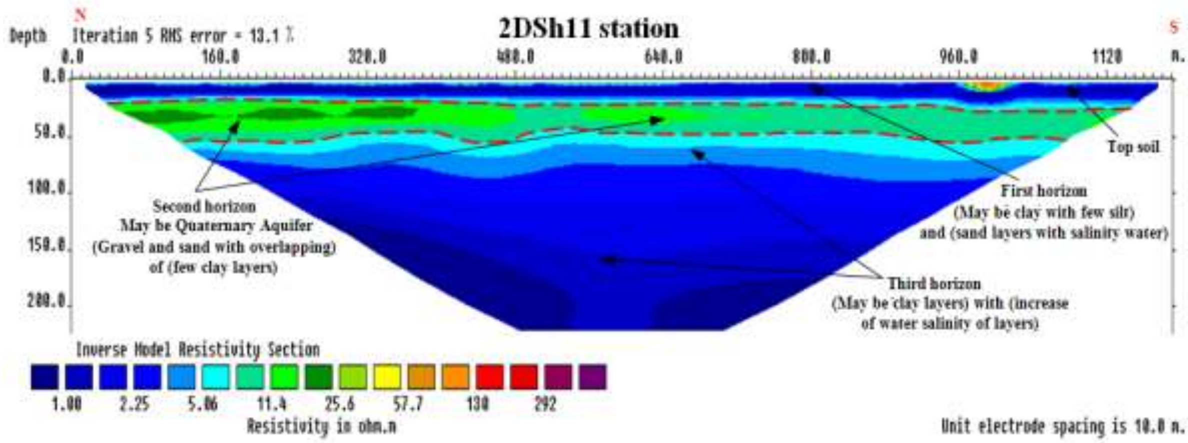

Figure 13 - Shows the inverse model resistivity section for 2DSh11 station.

–Interpretation of 2DSh12 station:

The station of 2DSh12 is located away from the source of alluvial fan deposits near the Iranian border. Therefore, the layers may be contains of gravel and sand in the upper part of inverse model. The inverse model of 2DSh12 station shows three major electrical horizons Figure-14. The first horizon has values more than (34.55Ω.m) at the depth of (68m) approximately. Layers of the horizon reflect the presence of gravel and sand. The first horizon may be considered as Quaternary aquifer, thickness of the aquifer is ranging between (32-61m) approximately. The second horizon reaches to the depth of (139-158m) approximately, it has a resistivity values range between (11.4-41.65Ω.m). Layers of this horizon may be contained of clay and little silt with gradual increasing of salinity water. This horizon extends to the end of inverse model. In the right part of the horizon there are two lenses due to the first and third horizons. The third horizon is located in the bottom on both sides of the inverse model. It may be contained of clay layers with increasing of water salinity gradually with the depth. The resistivity value of the horizon is less than (11.4Ω.m).

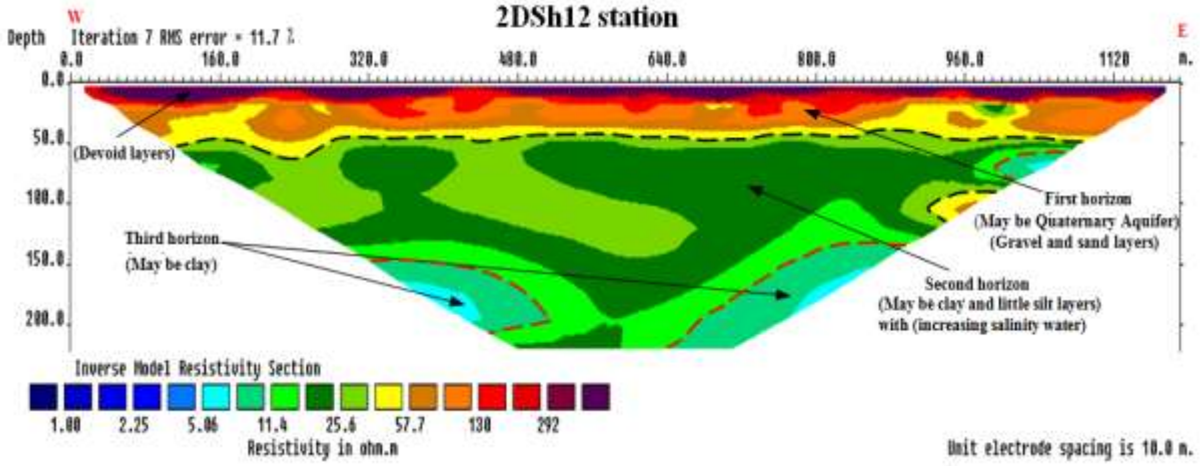

Figure 14 - Inverse model resistivity section for 2DSh12 station**.**

–Interpretation of 2DSh13 station:

The 2DSh13 station is located in the area covered by wind deposits. Therefore, most of lithological layers are consist of sand and silt. Inverse model of the station shows three major electrical horizons Figure-15. The first horizon appears in the upper part of the model to the depth of (82m) approximately. It has a resistivity value more than (11.4Ω.m), it may be considered as Quaternary aquifer. Layers of the horizon may be comprised of sand with silt layers. The thickness of aquifer is ranging between (12-51m) approximately. The second horizon with black border is located inside the first horizon at the depth of (4-29m) approximately, it has resistivity values between (5.06-11.4Ω.m). This horizon may be consisted of clay with little silt layers as well as increasing salinity water gradually with depth, the thickness of this horizon is ranging between (4-17m) approximately.

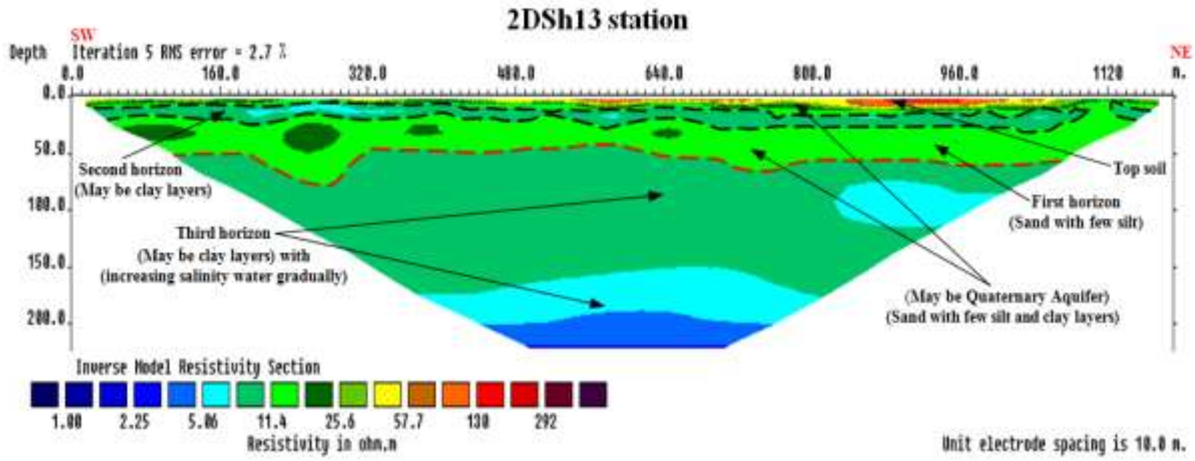

Figure 15 - Inverse model resistivity section for 2DSh13 station.

The third horizon extends to the end of the inverse model, it has resistivity value less than (11.4Ω.m). The layers may be reflected of the presence of clay with gradual increasing of water salinity**.**

–Interpretation of 2DSh14 station:

The station of 2DSh14 is located within the wind deposits. The layers in the upper part of the model consist of sand and silt. The inverse model appears three major electrical horizons Figure-16. The first horizon in the upper part extends to the depth of (18m) approximately. The resistivity value is less than (8.23Ω.m). According to geological section of well number (9), layers of the horizon consist of sand as well as increasing of water salinity. The second horizon with (red border) has resistivity value ranges between (8.23-18.5Ω.m). Layers of the horizon consist of silt and thin clay with sand at the depth of (18-54m) approximately. The layers at the depth of (54m) are considered as Quaternary aquifer, the thickness of the aquifer is (29m) approximately. After this horizon, the resistivity values are decreasing to the end of the inverse model and have a value less than (8.23Ω.m). The layers may be comprised of clay with gradual increasing of water salinity.

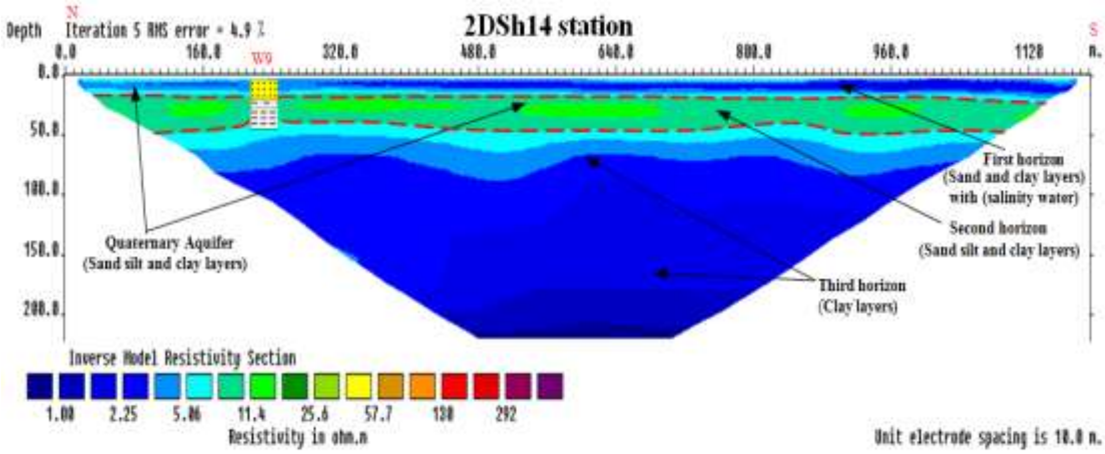

Figure 16 - Inverse model resistivity section for 2Dsh14 station.

–Interpretation of 2DSh15 station:

The inverse model of 2DSh15 station shows four major electrical horizons Figure-17. The first horizon has resistivity value less than (5.06Ω.m) approximately at minimum and maximum depths (14 and 22m). According to geological section of the well number (W12), layers of the horizon consist of clay and silt with sand as well as the water table reaches to (14m). The second horizon with (red border) extends along the inverse model at the depth of (23-75m) approximately, it has a resistivity values range between (5.06-8.23Ω.m). The third horizon with (black border) occurs inside the second horizon and has a thickness between (7-26m) approximately. It does not extend along the inverse model but disappears under the electrodes number (98-109). Layers of the horizon consist of sand and have resistivity values range between (8.23-11.4Ω.m). First and second horizons at the depth of (47m) approximately are considered as Quaternary aquifer. The thickness of aquifer is ranging between (7-26m). The last horizon extends to the end of inverse model and has resistivity value less than (5.06Ω.m). Layers of the horizon may be consisted of clay with gradual increasing of water salinity.

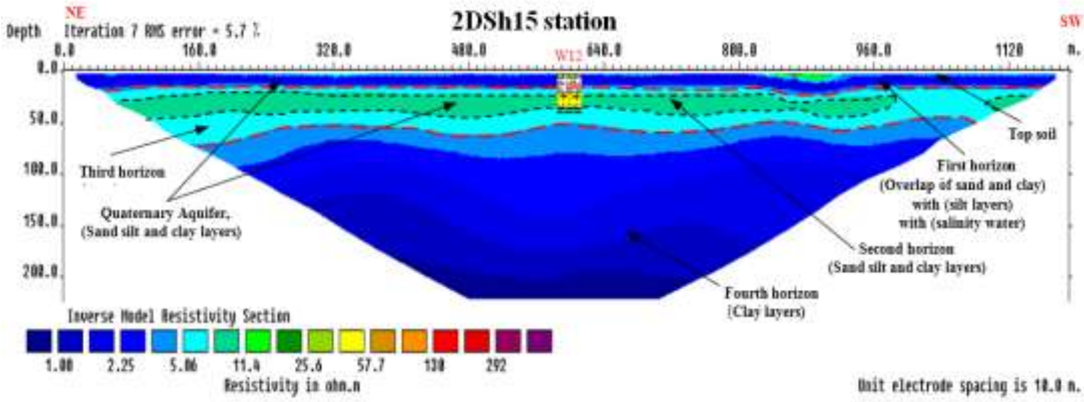

Figure 17 - Inverse model resistivity section for 2DSh15 station.

Conclusion:

The inverse models show identical results with geological section of the drilled wells in the study area. Most of the stations reflected clearly the location of Quaternary deposits such as alluvial fan and wind deposits. The inverse models of 2D imaging showed gradual decrease of the resistivity values with depth and have value between (1Ω.m) to more than (292Ω.m). The aquifer in the inverse models is occurred within the Quaternary deposits, and the layers of aquifer consist of gravel and sand with little silt. Low resistivity values reflected presence of a clay layers and increasing salinity water gradually with the depth. The aquifer occurs at minimum depth equal to (12m) approximately for 2DSh10 station and maximum depth equal to (153m) approximately for 2Dsh2 station. In addition, the minimum thickness of aquifer was (7m) approximately as appeared in inverse model of 2DSh15 station and maximum thickness was (91m) approximately in 2Dsh4 station, and the type of aquifer was unconfined.

Acknowledgments:

I would like to thank (Mr. Dhafer A., Hussein), the General Director of General Commission for Groundwater, to supply requirements of the field work, as well as giving all the facilities to finish this work. I would like to thanks (Dr. Ahmad Kadhum), the head of studies and investigation department. My thanks to the geophysicists Dr. Firas H. AL-Menshed, Mr. Mohammed M. AL-Hameedawie, Mr. Ahmed S. AL-Zubedi and Mr. Ahmed A. Al-Ibrahim for continues advices, and supporting in all work stages. My thanks to the geologist Mr. Mahdi Alwan.

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