Geophysical study of the Chame - Rezan Dam Site, Sulaimaniyah City, NE IRAQ

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Abstract

A 1D and 2D resistivity surveys were carried out over the area of Chame Rezan dam site which is located about 33 km to the Northwest Sulaimaniyah City, NE Iraq. Schlumberger array were conducted in 34 locations with AB/2 spacing equal to 200m, as well as two representative Winner-Schlumberger profiles were laid out with electrode spacing equal to 5 m. The study concluded that the combination of 1D and 2D resistivity surveys is successful in identifying and producing a complete high-resolution image of the subsurface. The results were obtained show excellent correlation with the several bore holes were drilled on the recommendation of the surveys. The depths obtained by interpretation of 1D sounding points is slightly smaller than the actual depths recorded from the boreholes at the location of both dam abutments where the dip of the beds is ranging from 40 to 70 degrees. Consequently more reliable depths are obtained in the same locations from 2D resistivity profiles as well as the range of resistivities and lateral changes were obtained by 2D tomography are most reliable. In addition, the study reveals to the existence of a recent sediments has thickness ranging from 7 to 25 m overlain a low resistive Kolosh Formation.

دراسة جيو فيزيائية لموقع سد جم ريزان، مدينة السليمانية، شمال شرق العراق

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الخلاصة

اجريت مسح الاحادى و الثنائى البعد فى الموقع المقترح لسد جمى ريزان الذى يقع على بعد ٣٣ كم شمال غرب مدينة السليمانية، شمال شرق العراق. اخذت القراءات فى ٣٤ محطة باسخدام اسلوب شلمبرجر و بمسافة AB/2 تساوي ٢٠٠ م. بالاضافة الى اخذ مسارين تم مسحه بطريقة ثنائي البعد وباسلوب فينر-شلمبرجر و بمسافة بين الاقطاب تساوي ٥ م. اظهرت النتائج بان استخدام هذين الاسلوبين يعطى صورة دقيقة تحت السطحية دقيقة واضحة حيث اوضحت هذة من خلال توافق كامل للنتائج المستحصلة من المسوحات مع عديد من الابارالتي حفرت بناءا على التوصيات لهذة الدراسة. بينت الدراسة ان الاعماق التى استنتجت من المسح الاحادى البعد قليلا بعض الشيء عن الاعماق الوقاعية والمسجلة عند حفر هذة الابار وخاصة فى الموقعى الاكتاف للسد عندما يتراوح ميل الطبقات بين ٤٠ الى ٧٠ درجة فى الوقت الذى تم حصول على نتائج عمقية دقيقة فى نفس هذين الموقعين و ذلك باسلوب طريقة ثنائي البعد و بالاضافة الى هذه فان المديات المقاومية و التغيرات الجانبية المستحصلة من المسح الثنائي البعد كانت اكثر واقعية. كذلك اظهرت النتائج وجود طبقة سطحية من الترسبات الحديثة ذات سمك يتراوح بين ٧ ال ٢٥ م تغطى تكوين الكولوش الذي يتميز بمقدار المقاومية قليلة جدا.

Introduction

The geoelectrical survey was conducted by 1D vertical electrical sounding and 2D Resistivity Tomography for the proposed Site of Chame Rezan Dam and its surrounding areas. The area is located about 33 km to the northwest of Sulaimani City, northeastern part of Iraq (Fig.1), at the intersection of latitude 35° 49' 57" and longitude 45° 02' 12". On topographic map, it is appearing a u-shaped valley. It has relatively wide inlet and also wide outlet (mouth) forming suitable discharge site for dam building as well there is enough wideness behind and at upstream of the gorge to be suitable for dam building. The study area is located within high folded zone. Therefore, the area was highly deformed due to active tectonic movements during the past geological time. As a result, several secondary folds have been seen especially on the north-eastern limbs of the anticlinal and synclinal structures.

The main aim of the survey is to study the feasibility of the area for construction of a large dam as well as the comparison of results obtained by both 1D and 2D surveys. The area and it is surrounding had not being studied in geological and geophysical points of view, so the current study is considered as a first attempt in such field. In recent years, application of geoelectric study by 1D and 2D resistivity studies for feasibility of dam sites have widely increased , several researches were carried out related to this topics such as [1,2,3,4]

Electrical resistivity surveys have progressed from the conventional vertical soundings, which provide layer depths and resistivity at a single place, to techniques that provide 2D and even 3D high resolution electrical images of the subsurface;[5,6]. This development started with the introduction of geoelectrical tomography field systems and was soon followed by post-processing and inversion algorithms, to transform the measured apparent resistivity pseudo-section in a true resistivity cross-section model or ERT [7] Several researches were carried out using both 1D and 2D for comparing the 1D and 2D inversion results of the subsurface resistivity distribution in areas where the lateral resistivity variation cannot be neglected, such as , [8,9,10].

Fig. (1) Location of the study area.
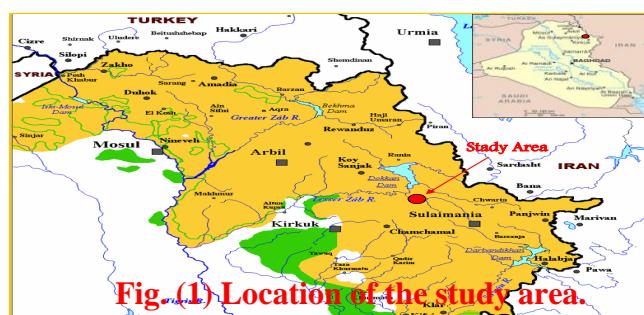
Geology:

The area is covered by thin recent sediments with rock fragments of Sinjar limestone Formation scattered on the surface. Kolosh Formation has cropped out in some limited locations and it is underlain the recent sediments.

The age of recent sediments is Pleistocene, covering a wide range of the area. They compose of alluvial fan, river terraces, and flood plain deposits, which usually consist of clay, loam, silt, sand and gravel, poorly sorted containing weathered products of the mentioned formations. Slope sediments have formed along the flanks of the structures, usually in narrow belts; along high mountains, thick accumulations of limestone scree occur. The sediments filling the synclines consist mainly of a mixture of gravel and clay.

Sinjar Formatio is regarded as an important source of limestone rocks in northern Iraq. The major exposure of this rock appears in areas surrounding Sulaimani City, while its type locality locates at Jebal Sinjar near Mamissa village. The formation composed of limestone showing elements of algal reef facies and shoal nummulitic facies. It has thickness reaches 120 m in both embankments of the dam.

Kolosh Formation represents sediments of the deep part of the basin (Lower Eocene-Palaeocene), composed mainly of grey to black clastic rocks such as sandy limestone, black shale and sandstone. Calcareous shale and thin beds of limestone have been seen at the top part of the formation near the conformable contact to Sinjar Formation.

Methodology:

The SYSCAL Jr switch-72, a new modern computerized static type resistivity meter was used, the complete system consists of the resistivity meter (from IRIS company), portable computer, switching unit (link box), six reels of multi-core cables with take-out at electrode points, 72 electrodes and their joining wire, car battery and chargers.

The fieldwork for performing the resistivity survey started at 1/11/2008 and ended at 10/11/2008. Three profiles were laid out and surveyed continuously by 1D resistivity using Schlumberger array and two other profiles were surveyed by 2D resistivity tomography using Wenner-Schlumberger array with electrode spread equal to 5 m. They are covered the whole area under consideration as shown in Fig (2). The length of each profile of 1D survey is equal to 310 m while for 2D the length of the profiles are equal to 355 m.
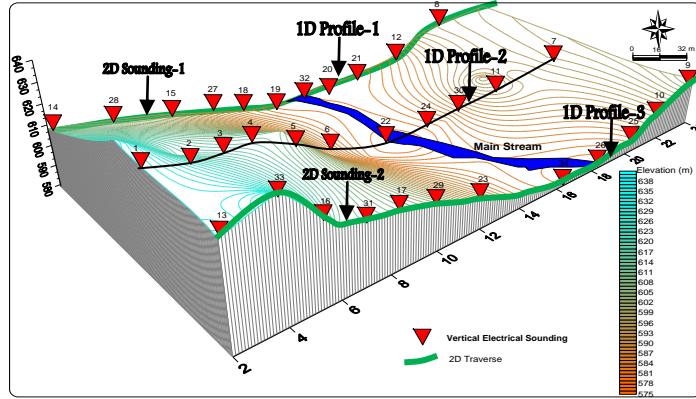
Fig. (2) three dimensional view of the study area.

Results and Discussion

The apparent resistivity field curves are classified into several types. Generally they are refers to the existence of three to five horizons. Some examples of the field curves are shown in the Fig (3) to Fig (10).

In all types of the mentioned curves the fist horizon is represented by a thin heterogeneous top soil layer with a variable range of apparent resistivity values ranging from 71 to 473 Ohm.m, which reflect a great lateral variation of the surface layer, it has thickness ranging from 0.8 m to 3.4 m. The second horizon represents recent alluvial deposits, composed of clay, and limestone rock fragments of the Sinjar Formation, the thickness of recent sediments is ranging from 7 to 25 m. The third horizon of low resistivity ranging from 8.7 to 18 Ohm.m represents the black Shale of the Kolosh Formation.

Apparent resistivity cross sections are drawn by. The procedure includes transferring all the measured values of apparent resistivity with their half current electrode separations (AB/2) on Y−axis from (100m) to (200m).The output results of apparent resistivity contour sections are shown in Fig. (11) to Fig.(13).

In most cases linear scale are used instead of logarithmic scale for the purpose of reducing the effect of near surface layers [11]. The apparent resistivity values will be function of both (AB/2) and their sites on the surface. Three resistivity sections were constructed, each section hold several soundings, they are trending NE-SW. The following are interpretation of these traverses:

The length of this traverse is about 313 m. The section shows the appearance of two different zones of different resistivity, blue color of low resistivity represents the Shale components of

the Kolosh Formation. The first layer represent a top soil covers the surface has high resistivity representing by yellow to red color. The second layer, which is representing by red,

yellow and green colors represents the clay and rock fragments of the recent sediments, which show high resistivity ranging from 40 to 350 Ohm.m., Fig (11). Below the whole area a layer of low resistivity is appeared that composed mostly of black Shale, it shows resistivity ranging from 7 to 20 Ohm.m. This layer extends to deeper portion of the area.

Traverse-1

Traverse–1 VES–14

N	ρ	h	d
1	181	0.453	0.453
2	650	3.51	3.96
3	119	23.7	27.7
4	15		

Fig (3) Interpretation of the sounding 14.

Traverse–1 VES–15

N	ρ	h	d
1	71.8	0.422	0.422
2	643	0.882	1.3
3	32.9	7.88	9.18
4	11		
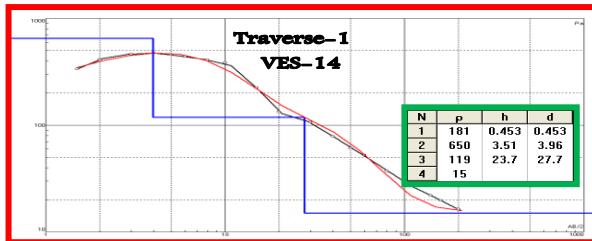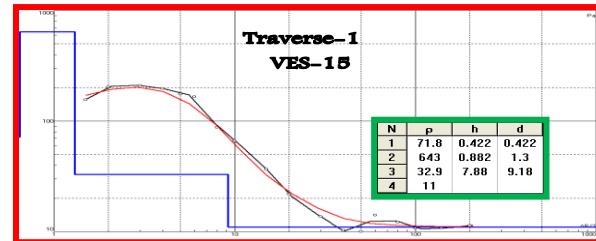
Fig (4) Interpretation of the sounding 15.

Traverse–1 VES–18
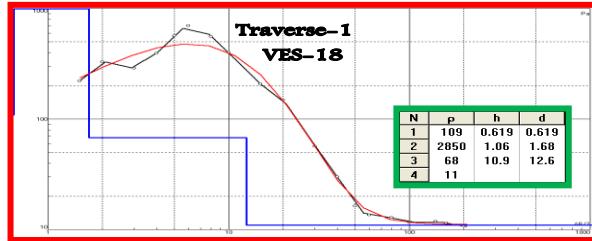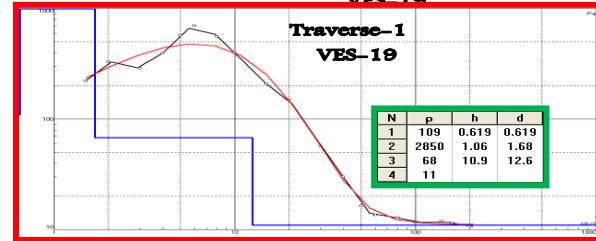
N	ρ	h	d
1	109	0.619	0.619
2	2850	1.06	1.68
3	68	10.9	12.6
4	11		

Fig (5) Interpretation of the sounding 18.

Traverse–1 VES–19

N	ρ	h	d
1	109	0.619	0.619
2	2850	1.06	1.68
3	68	10.9	12.6
4	11		

Fig (6) Interpretation of the sounding 19.

Traverse–2 VES–3

N	ρ	h	d
1	87	0.572	0.572
2	724	0.577	1.15
3	195	16.3	17.4
4	10.7		

Fig (7) Interpretation of the sounding 3.

Traverse–2 VES–6

N	ρ	h	d
1	111	0.612	0.612
2	457	0.859	1.47
3	144	10.6	12.1
4	8.62		

Fig (8) Interpretation of the sounding 6.

Traverse–3 VES–31

N	ρ	h	d
1	92.5	0.93	0.93
2	737	0.972	1.9
3	67.1	16.8	18.7
4	10.4		

Fig (9) Interpretation of the sounding 31.

Traverse–3 VES–17

| N	ρ	h	d
1	304	1.21	1.21
2	795	2.21	3.42
3	31.4	11.6	15
4	13.3		
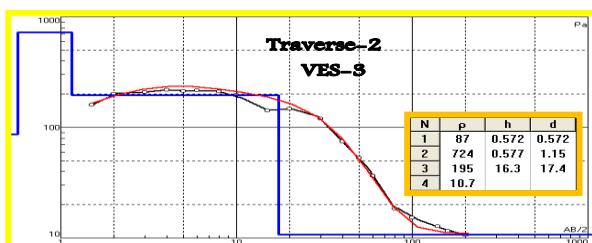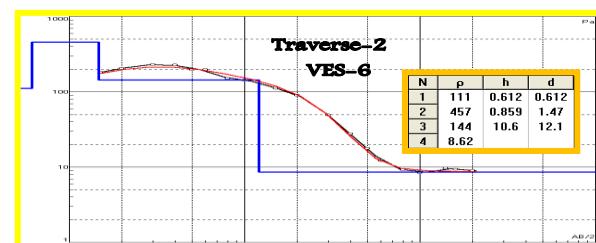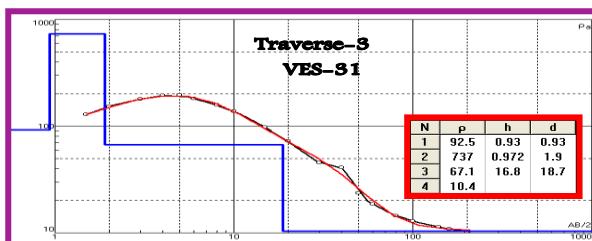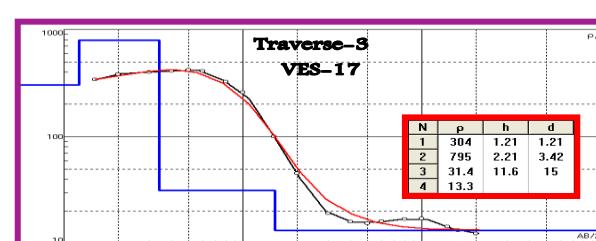
Fig (10) Interpretation of the sounding 17.

Traverse-2

The length of this traverse is equal to 315 m, it holds eleven sounding points. This traverse is shows two main zones, the first represents by variable color which represents the location of clay and rock fragments within recent sediments. The second zone is of low resistivity representing the upper part of the Kolosh Formation, Fig (12).

The section show obviously increasing of the recent deposits towards both right and left bank of the proposed dam.

Traverse-3

The length of this traverse is approach 318 m. It is show several anomalies of low and high resistivity, Fig (13). The first anomaly is appeared at shallow depth and exactly below the sounding points 33 and 17. The lower layer display low resistivity, this refers to the existence of the Kolosh Formation at depths ranging from 7 to 24 m.

According to the resistivity recorded in this location the whole area under consideration composed mainly of recent sediments that contain coarser materials than finer materials such as large boulder and limestone blocks of the Sinjar Formation. All the mentioned sections denote to the decreasing of the recent deposits toward the trough of the valley and exactly near the stream.

Apparent iso-resistivity map:

Apparent iso-resistivity map of AB/2=10 m is drawn for approximate depth level equal to 5 m. Generally, apparent resistivity increase toward both right and left bank of the proposed dam as shown in Fig (14), this refers to the increase of the thickness of the recent deposits.

The central part of the area shows moderate resistivity ranging from 20 to 160 Ohm.m, it is denote to thin soil cover that saturated with groundwater. At the northeastern part of the area the resistivity is rapidly decrease to about 400 Ohm m due to existence of large blocks of limestone rocks.

The map of apparent iso-resistivity of AB/2=30 m is drawn for approximate depth level equal to 15 m. The apparent resistivity ranges from 7 to 540 Ohm.m. The map shows the same picture as the previous depth level map. The central part of the area is completely represents by Kolosh Formation of low resistivity, Fig (15). Both right and left hand bank till this depth level show high resistivity due to existence of limestone rock fragments with clay materials.The high resistive refer to more coarse materials such as rock boulders.
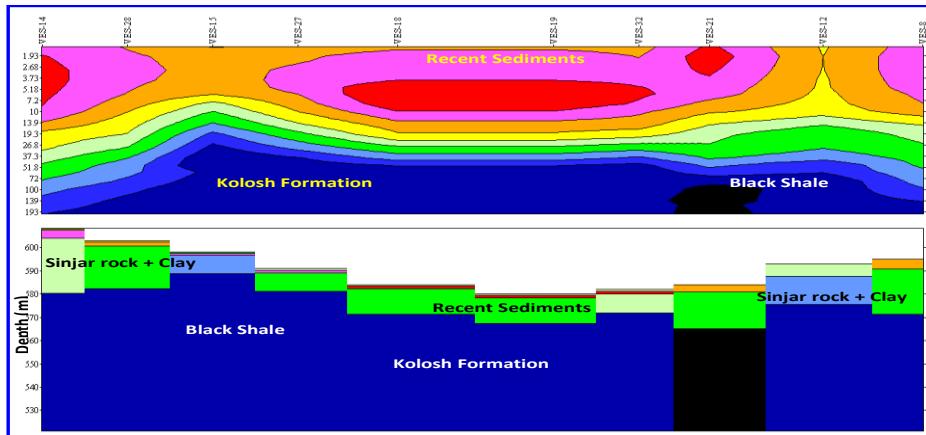
**Fig.(11) Interpretation section of the Traverse-1**
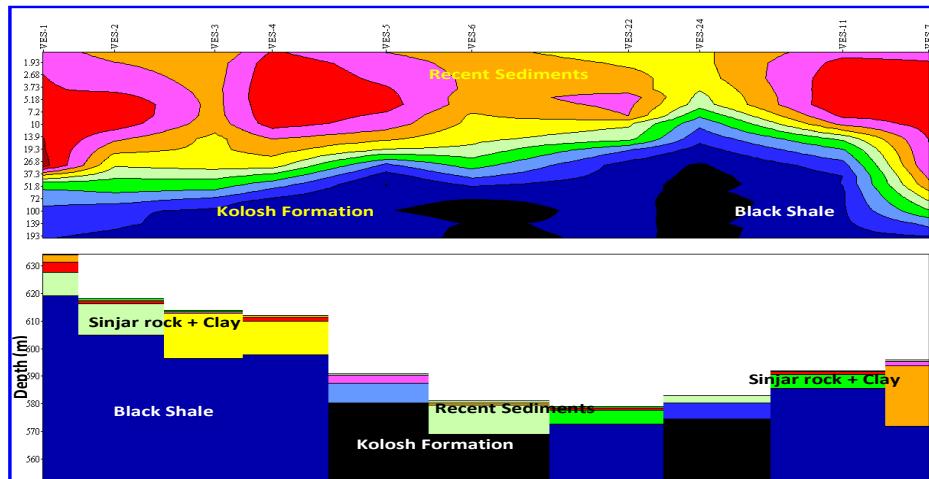

Fig.(12) Interpretation section of the Traverse-2
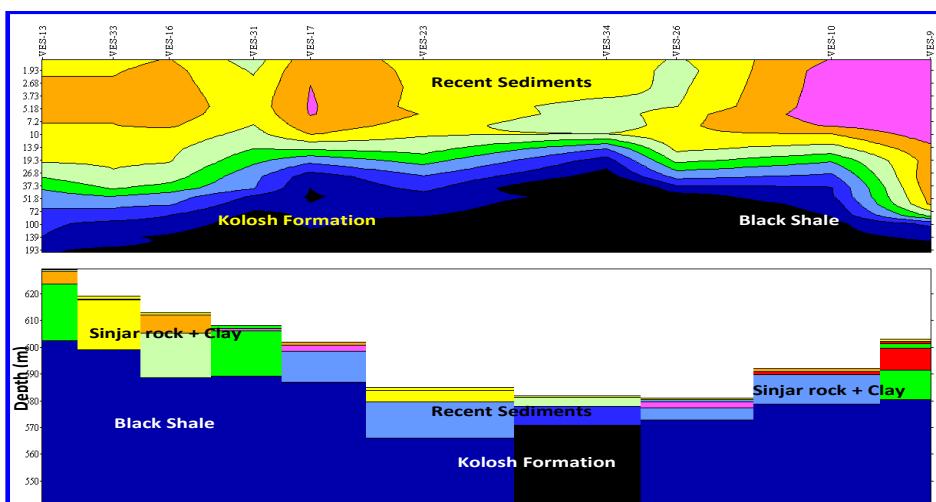
Fig.(13) Interpretation section of the Traverse-3

For the depth level of 20 m apparent iso-resistivity map of AB/2=50 m is drawn, Fig (16). Approximately, the same trend of the previous depth level maps is observed with slight change in the resistivity magnitudes. The right bank still shows high resistivity ranging from 40 to 240 Ohm.m. It refers to greater thickness of the recent deposits at this location.

The whole subsurface is composed of black Shale of the Kolosh Formation of low resistivity.

The resistivity changes through the whole area are from 7 - 240 Ohm.m, the variation of the resistivity indicates that the subsurface is characterized by more heterogeneity.

The last apparent iso-resistivity map of AB/2=100 m for approximate depth level equal to 45 m is drawn. The resistivity ranges from 7 Ohm.m at the left bank of the dam to about 25 Ohm.m at the right bank, as shown in Fig (17). The whole subsurface is covered by the

Kolosh Formation at this depth level, this formation showing more homogenous materials depend on the narrow range of the resistivity magnitude.
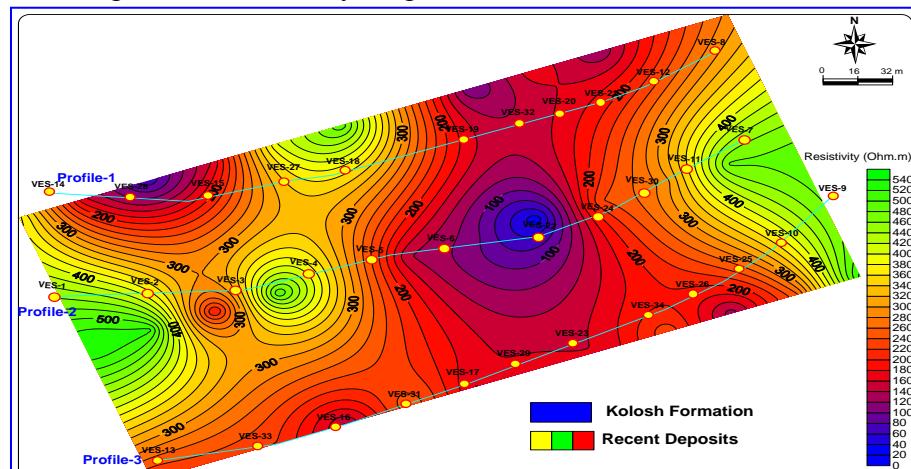

Fig. (14) Iso resistivity map of AB/2=10 m.
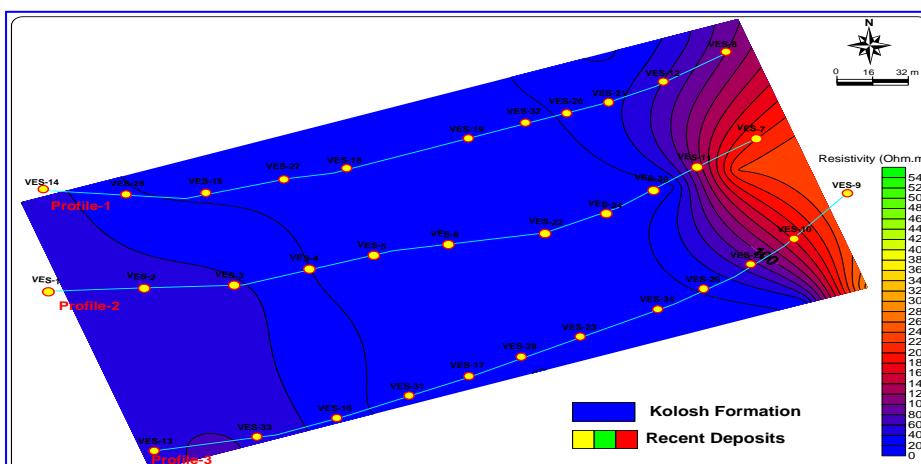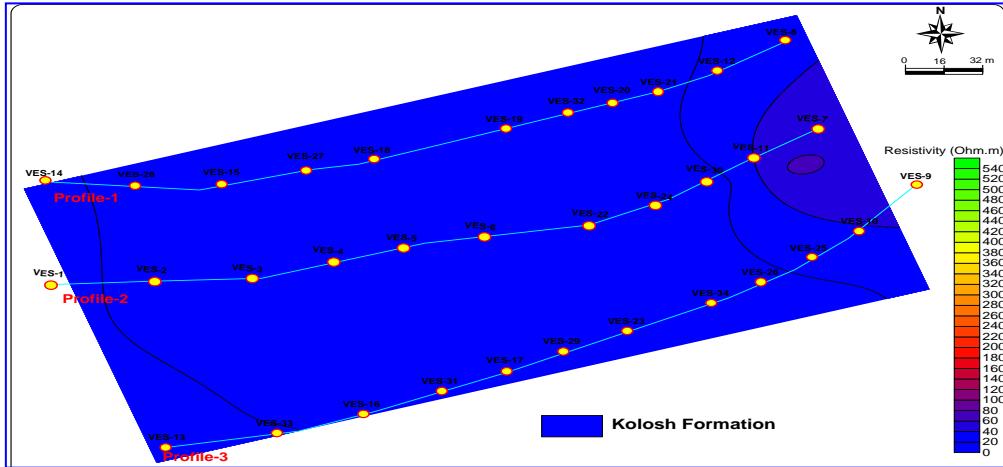
**Fig.(16) Iso resistivity map of AB/2=50 m.**
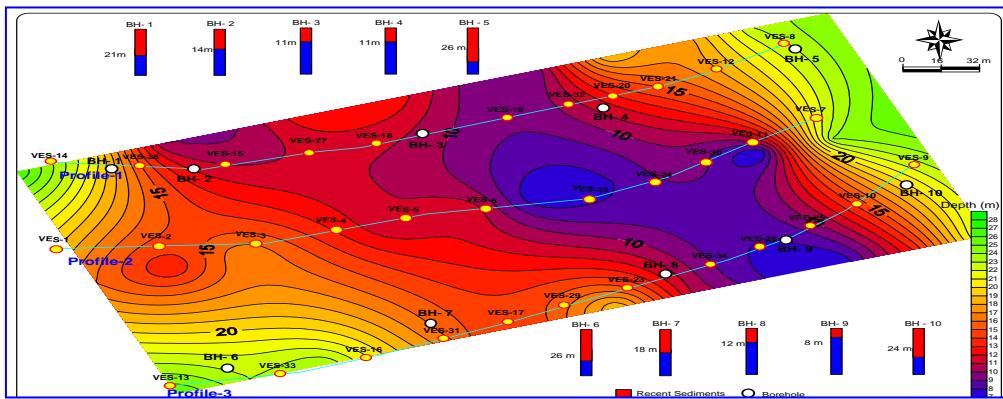
Fig.(17) Iso resistivity map of AB/2=100 m.

Depth map to the surface of Kolosh Formation

A depth map to the surface of Kolosh Formation has been drawn depend on the depths obtained from 1D interpretation of the VES points as shown in Fig. (18). Maximum depths of the Formation are recorded beneath the right and left Abutments of the dam which exceeds 20 m. This depth is gradually decreases toward the location of the stream beneath the VES points 19, 22 and 26. The investigated depths around these locations approach to 8 m.

Several boreholes were drilled within the investigated area based on the recommendation of the study. Ten boreholes were plotted on the depth map of the Kolosh Formation, Fig. (18), one important point concluded is that the interpretation of 1D sounding points gives depths smaller

than the actual depths recorded from the boreholes at location of both abutments of the dam where the dip of the beds is ranging from 40 to 70 degree. Consequently more

reliable depths are obtained in the trough of the valley in areas surrounding VES 19, 22 and 26 where the dip of the beds is around 15 degrees. The conclusion is that however the amount of dip is increase the interpretation of 1D sounding gives depths smaller than the actual depth of investigation.
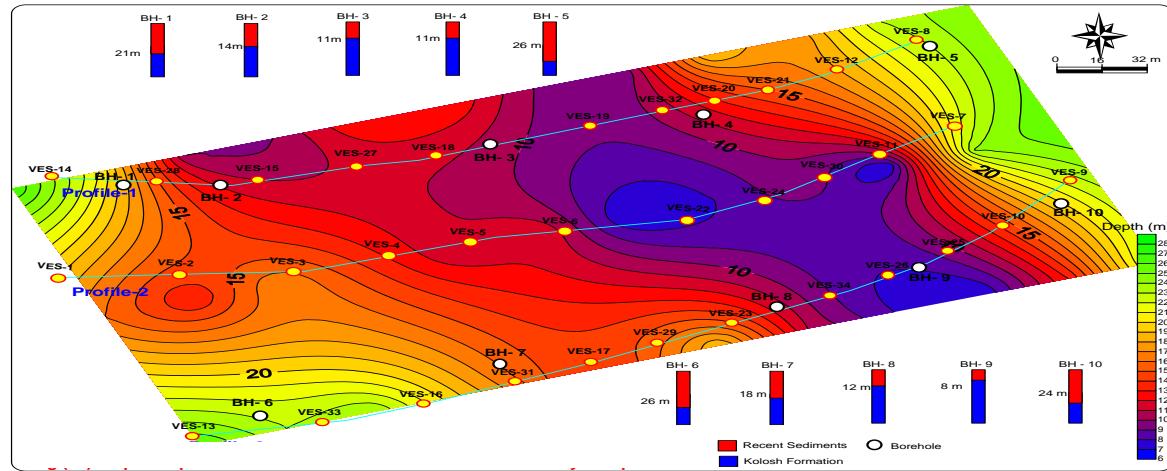

Fig.(18) Depth map of the Kolosh Formation based on 1D resistivity interpretation

Resistivity Tomography

2D model interpretation was performed using the last new version of software package "RES2DINV" version 3.54.53. It performs smoothness-constrained inversion using finite difference forward modeling and Quasi-Newton techniques [12]. An important factor in the inversion process of 2D imaging data is the quality of the field data. Good quality data usually show a smooth variation of apparent resistivity values in the pseudosection. All the soundings give very good quality. Therefore little appearance of irregularity and spots that shows high or low resistivities than surrounding has been seen in the pseudosections.

The bad data points are removed from the data set to avoid their effect in the process of inversion. These data are exterminated by the aid of plotting the data in profile from that helps to highlight the bad datum points and remove them from the data set.

Resistivity Tomography of Profile- 1:

It is run normal to the valley on an irregular area; it has length of about 355 m. Very good data quality is obtained, as shown in Fig (19). The inverse section of the sounding shows appearance

of two distinguish zone or layer, the first is a thin layer of wide range of resistivity ranging from 4 to 150 Ohm.m. The wide range of resistivity is due to its components that composed of clay and different sizes of Sinjar limestone rock fragments.

This layer has thickness ranging from 7 m beneath the stream area to about 25 m at right and left banks. The second zone which is representing by blue color is Kolosh formation of very low resistivity range; it is appeared at depths ranging from 7 to 25 m. no cavity and faults have been detected through this section.

The boreholes No.1 to 5 are plotted on the inverse section. The depths to the surface of the Kolosh Formation are exactly coinciding with the depths obtained from interpretation of 2D resistivity tomography.

Resistivity Tomography of Profile- 2:

Also this section shows two distinct zones, Fig (20), the first is high resistive soil cover has depth ranging from 24 m below the electrode 1 at the western part of the area to about 7 m below the electrode 52 at the eastern part of the area. This layer show wide range of resistivity from 20 to 180 Ohm.m, it is composed of clay and limestone rock fragments of Sinjar Formation.

layers of low resistivity has been identified composed of shale, silt and marl which return to Kolosh Formation has thickness extend to the maximum depth of investigation which is about 60 m. No faults and weak zones have been detected through this section. Also the boreholes No.5 to 10 are plotted on the inverse section. The depths to the surface of the Kolosh Formation are exactly coinciding with the depths obtained from interpretation of 2D resistivity tomography.
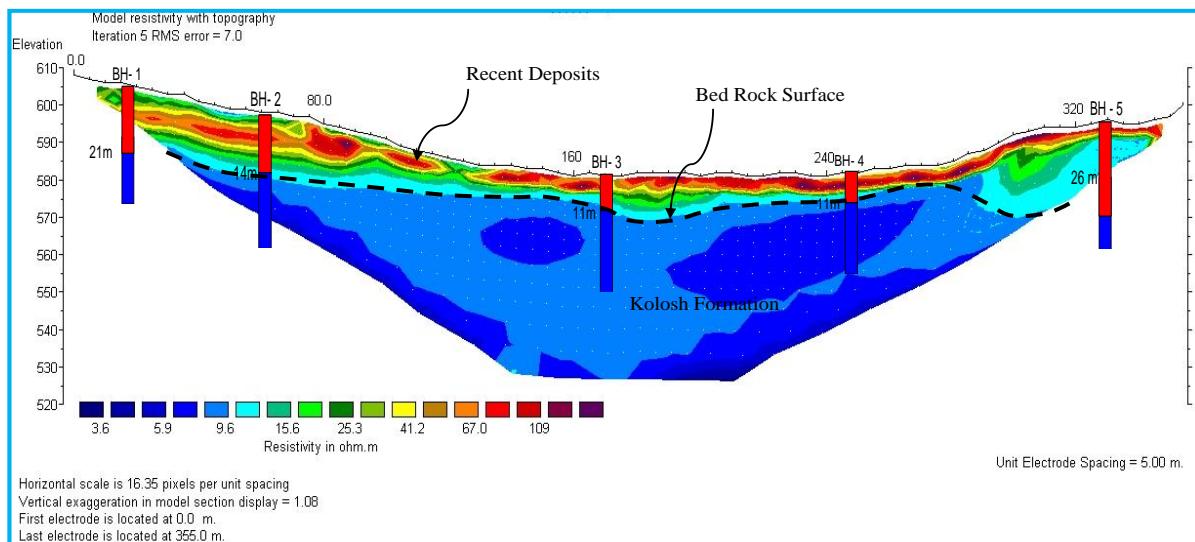
Fig.(20) Inverse section of the 2D Profile-2 with topography correction

Conclusions

1D Vertical Electrical Sounding and 2D resistivity tomography of the proposed dam reveals the followings conclusions:

1. A recent sediments has thickness ranging from 7 to 25 m is detected; it is mainly composed of clay with rock fragments of Sinjar Formation. In addition boulders of different sizes at the trough of the valley had been recorded. The thickness of these sediments is increased toward the north and north-eastern part of the area.

2. The recent sediments underlain by Low resistive layers of impermeable Kolosh Formation. It is mainly composed of Shale, Silt and marl. This layer extends to maximum depth of investigation which is about 90 m.

3. The thickness of the recent deposits in both right and left hand banks is ranging from 15 to 25 m. While the thickness is decreases toward the trough of the valley and it is approach to 7 m.

4. No cavity and no faults have been detected beneath the area under consideration.

5. Interpretation of 1D sounding points gives depths smaller than the actual depths recorded from the boreholes at location of both abutments of the dam where the dip of

the beds is ranging from 40 to 70 degrees. Consequently more reliable depths are obtained in the trough of the valley in areas surrounding VES 19, 22 and 26 where the

dip of the beds is around 15 degrees. The conclusion is that however the amount of dip is increase the interpretation of 1D sounding gives depths smaller than the actual depth of investigation while 2D resistivity tomography results are not affected by amount of dip.

6. The range of resistivity obtained by 2D tomography for Kolosh Formation (between 4 to 7 Ohm.m) is most reliable than slightly higher range obtained by 1D Sounding for the same Formation (between 8 to 18 Ohm.m). Most studies were carried out in the area and its surrounding show the range of about (5 to 7 Ohm.)

7. Lateral change of Lithology is more clearly appears within 2D inverse sections, correspondently 1D sounding ineffective to detect lateral change or facies change within the same geological Formation.

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