Geoelectrical Study in Shewasoor Dam Site in Kirkuk/Northern Iraq

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Abstract
A geoelectrical investigation is carried out for a geological consideration in the Shewasoor dam site, which is situated 40 km northeast Kirkuk city. Symmetrical Schlumberger array were applied for fifteen electrical sounding (VES) points, with a maximum spread distance (120-200) meters. Seven vertical electric sounding (VES) points were surveyed in the main valley. Two (VES) points were taken at the area behind the dam, and two other points at the right side of the dam body. Additional four (VES) points measured at the left side within the spillway area. In order to achieve the qualitative and quantitative interpretations manual partial matching technique and (IPI2 WIN) (ID) software are used. The results show that the surface is comprise of recent silt, clay, sand and gravel sediments with trace of water. The subsurface within the valley nearby the dam body is dominanted by claystone underlined by pebbly sandstone with water table condition, while the spillway is characterize by silt and gravel sediments. The area behind the dam body subsurface is composed of silty sandstone underlined by sandy siltstone. It is concluded that the subsurface layers of the dam site are suffering from heterogeneity.

Keywords: Shewasoor dam, Kirkuk, VES technique, Schlumberg **.**

دراسة جيوكهربائية لموقع سد شيوه سور في كركوك\شمالي العراق

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الخلاصة
اجريت دراسة جيوكهربائية لموقع سد شيوه سور الواقع على بعد 40كم شمال شرق مدينة كركوك للحصول على المعلومات الهندسية باستخدام مسح المقاومية الكهربائية لنقاط جس بلغ عددها خمس عشرة نقطة واستخدم ترتيب شلمبرجر المتناظر ولمسافات النشر القصوى بين (120-200) م , للكشف عن الطبقات تحت السطحية وطبيعة التراكيب الجيولوجية .

تم مسح نقطتين في الجانب الايمن من السد للجس الكهربائي العميق وسبعة نقاط في وادي الرئيسي ونقطتين خلف السد واربعة نقاط في الجانب الايسر القريب من ممر تصريف الماء. فسرت منحنيات الكهربائية بالطرق اليدوية واستخدام البرامجيات احادية البعد لاتمام التفسير الوصفي والكمي ورسم المقاطع الجيوكهربائية الكاذبة والجيوكهربائية والجيولوجية. اظهرت نتائج التفسير ان الطبقات تحت السطحية القريبة من السد ضمن الوادي اغلبها ذات طبيعة طينية وان هذه الطبقات تليها طبقات حصوية رملية مع وجود المياه الجوفية وفي منطقة ممر التصريف تتكون من ترسبات الاطيان والحصى والرمل وفي المنطقة خلف جسد السد كانت هناك طبقات من الرمال الغرينية ومن طبقات الغرين الرملية وهناك طبقة رسوبية متكونة حديثا من

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الطين والرمل والحصى تغطي الوادي قرب السد والتي تكون رطبة احيانا. بصورة عامة تتصف هذه الطبقات بكونها غير متجانسة.

Introduction

The present research is concerning with Vertical Electric Sounding in Shewasoor dam site. The dam will be constructed to impound the seasonal surface stream flows in the main valley. The target of the study is to understanding the setting and nature of the rocks beneath the dam site to provide an engineering information for the designer and future implementation of the dam construction work.

Many researchers used geophysics as a tool to characterize the subsurface of dam sites. In Wadi Noman Makkah Al Mukarramch, Saudi Arabia [1], a DC resistivity profiling and vertical electrical sounding survey is conduct to determine the main hydrological and structural setting beneath proposed site of downstream of the Wadi. The researchers classified the alluvium, which covers the basement rocks in the studied area into two distinctive layers.

Geophysical (Vertical electromagnetic) method used for investigation of Oli River Lodge Dam in k , Nigeria[2] the geoelectrical sections along the major weir axis varies from two to four layers , the geophysical results show the eastern bank is underlain by conductive materials .

Electrical resistivity used for held an investigation along three proposed dam axes flowing Owuru wura River southwestern Nigeria [3] the resistivity profiles showed that the northern flank of the stream characterized by relativity lower resistivity values.

Electrical resistivity and seismic refraction method employed [4] at Audhaim dam site to evaluate geotechnical properties and delineate the rock units and determined some physical properties. The researcher could define the weak zone of the dam site.

Vertical electrical sounding with horizontal electric profiling used to investigate Guwair dam [5] the geoelectrical results encourage the structure features such as presence of fault at the study area.

Geological setting of the study area

The study area lies in Chamechamal – Butmah subzone (Kirkuk block) within foothill zone, which related to unstable shelf area [6]. Shewasoor dam site in situated in Chamechamal double plunge Anticline, it trends northwest- southeast. The foundation lies on Mukdadiya formation bedding plane, which is horizontal to very gentle dipping $(0 – 10)^0$ toward north west direction. Stratiraphically the exposed rocks are three formation, Injana, Mukdadiya and Bai Hassan formations. Injana formation (Miocene) is composed of thick to medium alternations deposits of siltstone, sandstone and claystone. Mukdadiya formation (Pliocence) comprises sandstones, pebbly sandstones, grey mudstones and siltstones. Bai Hassan formation. (Pliocence) formation comprises mudstones and conglomerates with some sandstones and siltstones.

Location of the study area

Shewasoor dam site is located at Kirkuk, about 40 km northeast from the city center, and about 9.5 km northeast of Redar (Shwan) town. Its coordinates are and $(35^{o}\ 47^{-}\ 20^{=})$ N and $(44^{o}\ 33^{-}\ 40^{=})$ E figure1.

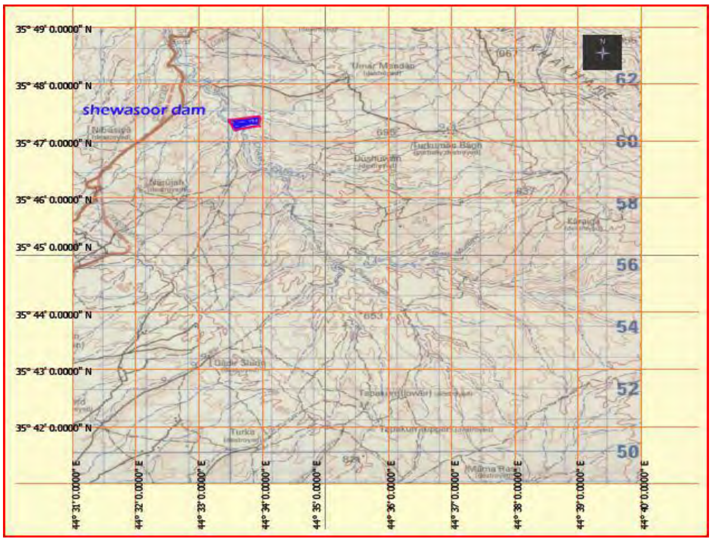

Figure 1- location and topographic map of Shewasoor dam site

Materials and methodology

The present research concerns with conducting geophysical Vertical Electrical Sounding (VES) in Shewasoor dam site figure 2 using symmetrical Schlumberger spread survey of (VES) points.

Table 1 shows the detailed about the surveyed (VES), the distance between the mid points of surveyed spread was (50) m, excluded the two points (VES_{12}) and (VES_{13}) which are (10) m.

Figure 2-Satellite image of Shewsoor dam site showing the (VES) points locations

Table 1- The (VES) points information in Shewsoor dam site.

VES point	location	Maximum spread
1,2,3,4,5,6,7	Perpendicular to the dam body axis ,within upstream area	200(m)
12,13	Right side nearby the dam body	200(m)ves3, 120(m) ves4
8,9,10,11	above the Spillway area	200(m)
14,15	Behind the dam body	200(m)

The apparent resistivity curves are interpreted using manual (Auxiliary point method) of partial curve matching which was handled by [7] of two layers Sclumberger standard curves, to proceed qualitative and quantitative interpretation for the apparent resistivity curves.

Interpretation of Vertical Electrical Sounding curves: Qualitative Interpretation of apparent resistivity of curves (VES)

- **Apparent resistivity of curve types**

The apparent resistivity curves yielded in study of the dam site survey (3-4) layers of K , KQ , HK, HA and QH types as shown in table 2.

Table 2- Apparent resistivity curve types of the study area

VES point	Apparent resistivity curve type
2,3,8,9,10,12,14,15	K
1,11,	KQ
7,13	HK
6	HA
4,5	QH

K type

This type is the most predominant one in the study area where there are eight (VES) points of this curve type. The scheme of this type is different because of, the conducted geoelectric profiles (VES points), which have been taken in different elevations and location besides the nature of the study area.

The first layer of the (VES_2, VES_3) points figure 3 refers to top soil of the valley deposits , which composed of recent clayey silt soils ,the second part shows higher apparent resistivity , it might represent dry silty claystone , the third part , with reducing resistivity value , it may be related to the gravely sand deposits with presence of moisture condition.

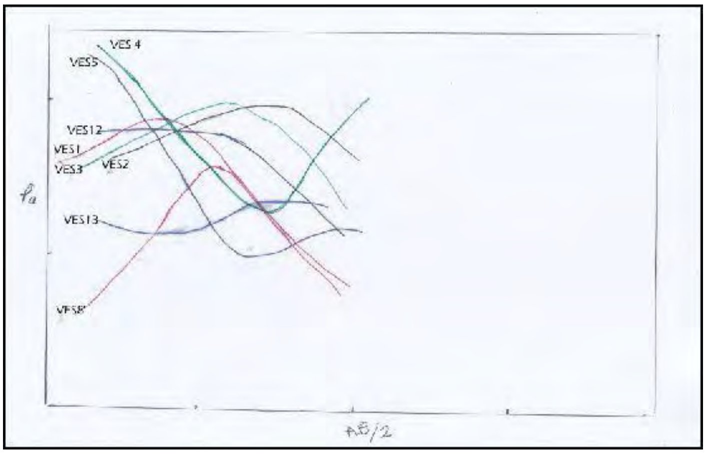

Figure 3- Manual apparent resistivity curves ($ves_{1-2-3-4-5-8,12,13}$).

In (VES_{12}) figure 3 which is located in higher elevation in the main valley , of this type curve is some things different , the first part is refer to the top soil of silty clay , the underlined is clayey siltstone , with higher moisture content is the lower third layer.

Another scheme of this type is the curve (VES_8), (VES_9) and (VES_{10}) points' figure 4, which is different from previous scheme. The first part of these points refers to the top soil of gravely sandy silt, the increasing in the resistivity value in second part refers to sandy gravel layer in the point (VES_8), (VES_9) and (VES_{10}), and the third part of the curve represents wet gravely sandy silt deposits.

Figure 4- Manual apparent resistivity curves ($VES_{6, 7, 9, 10, 11, 14, 15}$)

(VES_{14}) and (VES_{15}) figure 4 are K type curves, the first is sandy silt soil deposits, and the middle is silty sand, the last part indicates wet sandy silty deposits.

HK type

This curve type has another scheme in (VES_7) figure 4 , which is located in the valley , the first part represents top soil of stream valley recent sand nature, the second part with decreasing value , may represent wet claystone, the third higher resistivity value might reflect claystone, the final lower part is of gravely sandstone nature with trace of wet conditions.

(VES_{13}) curve figure 3 is HK type with another relation of the resistivity values. The first part has low resistivity refers to silty clay, the second part with lower resistivity value indicates wet clayey silt deposit, the third part has relative higher resistivity value of clayey silt, then the last part of this curve represents clay deposit with trace of water.

KQ type

There are three (VES) points of this type, they spread in different locations of dam site, and have different elevations, which indicate different schemes of this type.

(VES_1) figure 3 is composed of first top clayey silt resistivity value, the second part, may be pebbly sandstone. The third part with lower resistivity, refers to claystone, the curve ending with last part of the lowest resistivity, it might be wet gravely sand or water table existence.

In (VES_{11}) figure 4, KQ type curve shows another scheme. The curve begin with high resistivity value , it indicates presence of gravely sandy silt layer , the second part has higher resistivity value , it may indicate sandy gravel , the third part also refers to sandy silty gravel deposit to the final part of this curve here , might represent gravely sandy silt .

HA type

The only one type is (VES_6) curve figure 4. It begins with low resistivity value which represents the top soil of recent deposit of clay layer. The second part, which shows relatively low value, might be wet clay deposit. The third part is in range of clay resistivity value, the final part is altering to conglomerate, it indicate by the high resistivity value.

QH type

This type represents by the two points (VES_4) and (VES_5), figure 3, the first part refers to the top soil recent sand with gravel deposits. The second with decreasing in resistivity represents clay sediment while, the third part with lower resistivity amplitude refer to gravely sandstone with trace of water content. The last part in (VES_4) indicates gravely sandstone, while in the (VES_5) it refers to claystone.

Apparent resistivity curves map

Generally the study area includes different apparent resistivity curve types figure5 ,it reveals heterogeneity in subsurface composition, despite that the vertical electrical resistivity traverses have been conducted in different topography, there are vertical and lateral variation in sequences within a short distances, which is (50) m between the (VES) points.

Figure -5 Study area satellite image showing apparent resistivity

Curve types

The main valley apparent resistivity curve types are composed of 3-4 layers, they are K, KQ, HK, QH, HA types. It shows lateral and vertical variation in the geoelectrical resistivity structure which reflects the subsurface heterogeneity produced by the dominantly, top different low and high resistivity sediments of clay, silt, sand, and gravel. The moderate resistivity of the underlined silty claystone or claystone and the bottom low resistivity indicate gravely sandstone layer. Apparent resistivity K type of 3 layer comprises the geoelectrical resistivity structure of the area behind the dam body, it indicates the top and bottom relatively low resistivity sandy silt and the intermediate high resistivity silty sandstone layer. The area above the spillway apparent resistivity curves composes of 3-4 layers of K and KQ types denote the alternatives of its components which are silt, sand , gravel and conglomerate with its own resistivity producing that geoelectrical structure, that reveals lateral variation in the north end.

Pseudosections

Pseudosections of the apparent resistivity measurements are carried out by IPI2 Win (1D) one dimension software program in qualitative interpretation [8]. The program fed with field measurements of resistivity values, and the half distance of the current electrodes (AB/2), with the potential electrodes separations (MN). The output of the software will yield a pseudosection.

Pseudo-section (P_1) is which taken along the valley perpendicular to the dam body figure 6 including the (VES) points(VES_1,VES_2,VES_3,VES_4,VES_5,VES_6,VES_7) shows a vertical and lateral apparent resistivity variation. The top layers in (VES_1) through (VES_7) in the profile reveal different apparent resistivity values, which reflect the recent deposits of stream recent silt ,sand and gravel , in the main valley where the dam body is situated , with trace of water content in this horizon (VES_6).

In the subsequent of the section, the resistivity value range indicates clayey silt or wet clayey silt, or wet gravely sandstone. While, in the lower part it shows less resistivity value indicating moisture condition of gravely sand. In the other parts of this section, the higher resistivity values interpreted as a claystone layer, (VES_5). This pseudosection also shows relative variation in the thickness in vertical and lateral directions, with water saturation condition in most of the lower end parts.

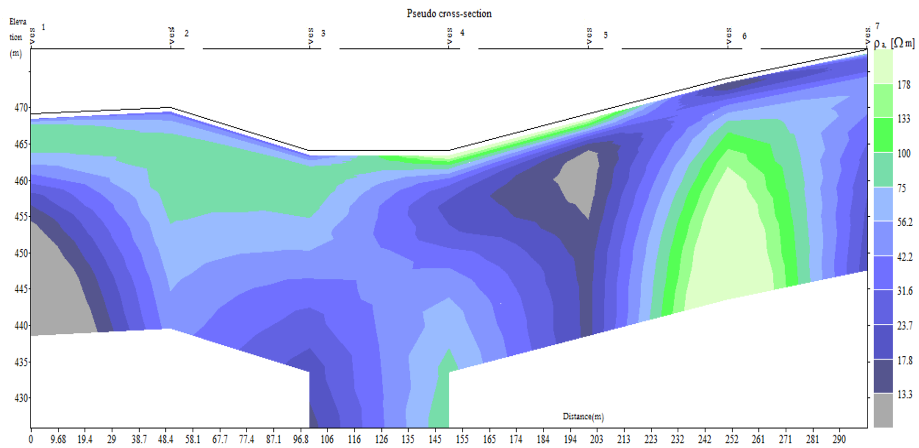

Figure 6- Pseudo-section P1 ($VES_{1, 2, 3, 4, 5, 6, 7}$)

Pseudo- section (P_2) conducted in the area above the spillway of the dam left to the dam body includes the (VES) points (VES_8, VES_9, VES_{10}, VES_{11}). The top of this section figure 7 shows top thin horizon with different apparent resistivities, but with less contrast than the previous section.

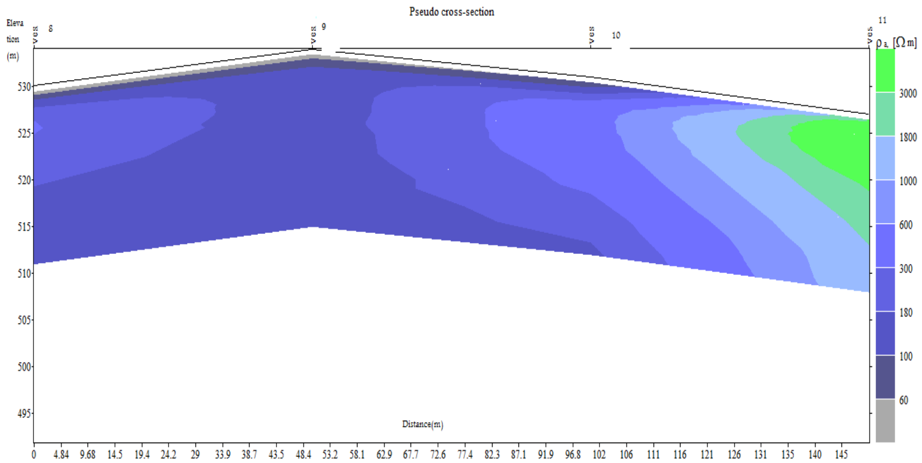

Figure 7-Pseudo-section P2 ($VES_{8, 9, 10, 11}$)

The sandy silt and gravel of resistivity value comprises the most section area in the left (VES_8, VES_9, VES_{10}), while in the right it compose of silty sandy gravel (VES_{11}). In the bottom there is variety of resistivity values, which reflect silty gravely sand ($VES_{8\&}VES_{9)}$ and sand with gravel apparent resistivities amplitude from (VES_{10}) and (VES_{11}). This section reveals the insertion of the sandy gravel (conglomerate) from the right side toward the center of lower resistivity recent sediments.

Quantitative interpretation:

Manual interpretation

The manual quantitative interpretation of the apparent resistivity curves is applied by using two layer case empirical curves, with auxiliary principal curves (K, H, Q, A) types applying partial technique, to determine the true resistivity and thickness of the subsurface layer. Figure 8 shows manual interpretation of ($VES_{1)}$ .Table 3 gives in detail the results of manual interpretation of field curves of the study area.

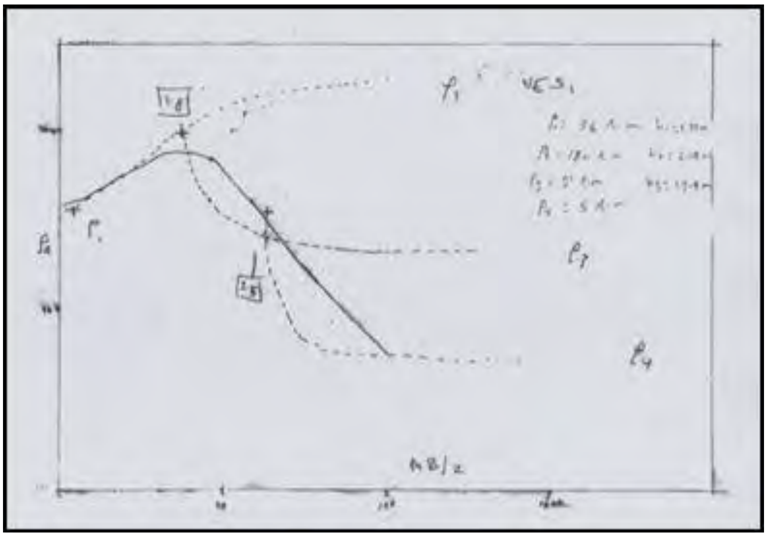

Figure 8- Manual interpretation of ($VES_{1)}$ curve.

Table 3-Manual quantitative interpretation results.

VES points	Resistivity (Ω.m)				Thickness(m)		
	ρ-1	ρ-2	ρ-3	ρ-4	h-1	h-2	h-3
1	36	180	21	5	1.22	2.19	13.9
2	34	120	25		1.9	32.3	
3	30	120	20		1.3	20.8	
4	320	65	15	310	1.4	5.6	13.8
5	260	42	10	46	1.4	3.01	32.5
6	18	7.5	25	2000	1.1	0.77	0.17
7	110	24	95	17.5	0.7	2.73	9.72
8	28	500	60		1.0	9.0	
9	42	210	160		1.45	4.7	
10	60	2100	48		1.23	3.45	
11	2200	20100	2800	750	1.0	1.7	6.9
12	64	65	22		1.81	15.2	
13	18	12	60	19	1.7	7.47	7.22
14	24	310	22		1.7	12.6	
15	50	320	30		1.4	11.2	

Computer interpretation

IPI2win one dimensional commercial software program is employed in quantitative inversion interpretation, figure 9 illustrates computer interpretation of (VES_1) .Table 4 gives in detail the results of IPI2WIN computer interpretation of field curves of the study area.

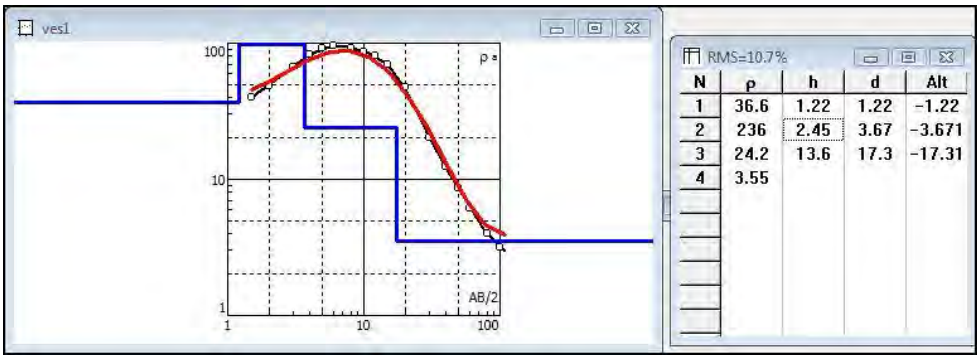

Figure 9- IPI2Win inversion interpretation of (VES_1) curve.

Table- 4 Quantitative computer interpretation results.

VES points	Resistivity (Ω.m)				Thickness(m)		
	ρ-1	ρ-2	ρ-3	ρ-4	h-1	h-2	h-3
1	36.6	236	24.4	3.55	1.22	2.19	13.9
2	35	104	10		1.9	32.3	
3	35.5	101	9.35		1.3	20.8	
4	333	52.1	15.6	592	1.4	5.6	13.8
5	275	39.3	10.8	36.4	1.4	3.01	32.5
6	13.4	7.84	20	2000	1.1	0.77	0.17
7	149	21	69.3	14.9	0.7	2.73	9.72
8	34.1	501	40.3		1.0	9.0	
9	42	197	151		1.45	4.7	
10	57.7	2417	32.4		1.23	3.45	
11	2322	21907	2632	1191	1.0	1.7	6.9
12	59.6	60.1	7.28		1.81	15.2	
13	18.7	11.8	60.6	19	1.7	7.47	7.22
14	25.1	333	12.4		1.7	12.6	
15	44.7	275	25.1		1.4	11.2	

Geoelectric and geological sections

IPI2win program has another facilities, it constructs geoelectric section, for at least two (VES) points model yield either by forward or inversion techniques. This section might be an image of the subsurface layers, which provides the individual layer true resistivity and its thickness. This section will be converted into final geological section with available information and field notes of the dam site.

Geoelectric section (P_1) figure10 is conducted for the vertical electric sounding ($VES_{1,2,3,4,5,6,7}$) points , along the valley , perpendicular to the dam body that could be categorized in three horizon or more . The first horizon represents the top layer of the stream valley deposits , which consists of silt , sand

and gravel , it is often composed of one or two of these deposits, their resistivity values range(7.5-333) ohm .m and thickness between (1.3)m and (2.5)m .

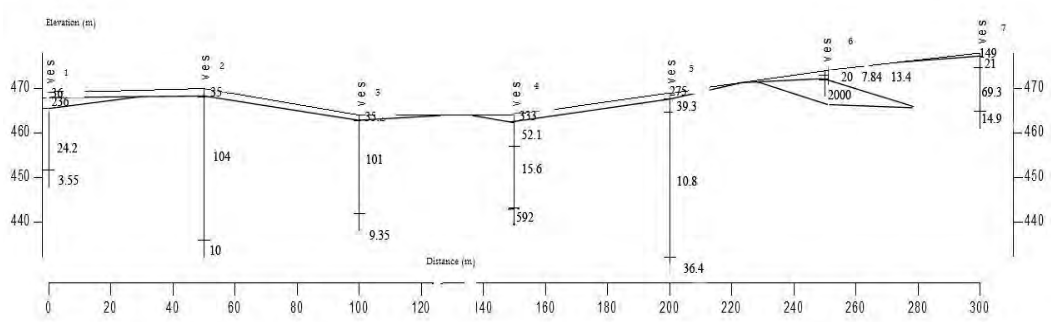

Figure-10 Geoelectric section (P1) (VES$_{1, 2, 3, 4, 5, 6, 7}$).

The second horizon, is mostly composed of silty claystone, sandy gravel deposits, its thickness varies between (9.7- 32) m, its true resistivity value ranges (10.8-104) ohm.m. There is a thin horizon of conglomerate in (VES$_6$) which has (2000) ohm.m resistivity, which might not permeable (dry lens) indicates the unable of the current to penetrate more in deeper horizon in order to determine its thickness.

The lower horizon in this section represents mostly gravely sandstone and claystone (VES$_5$), the resistivity is between (3.5-592) ohm.m, and water saturation reduce the gravely sandstone resistivities. In order to construct geological section conform this geoelectric section, the available borehole log (BH$_8$) which conducted in dam site is used. It is located nearby the point (VES$_7$) to discriminate the horizons in the geoelectric section into geological layers figure 11, as the (BH$_8$) shows [9]. The top layer of recent deposits is sand and gravel with silt follows by silty claystone , the lower layer is composed of gravely sandstone in depth of (17-25) m , this layer ends with claystone down to (30)m.

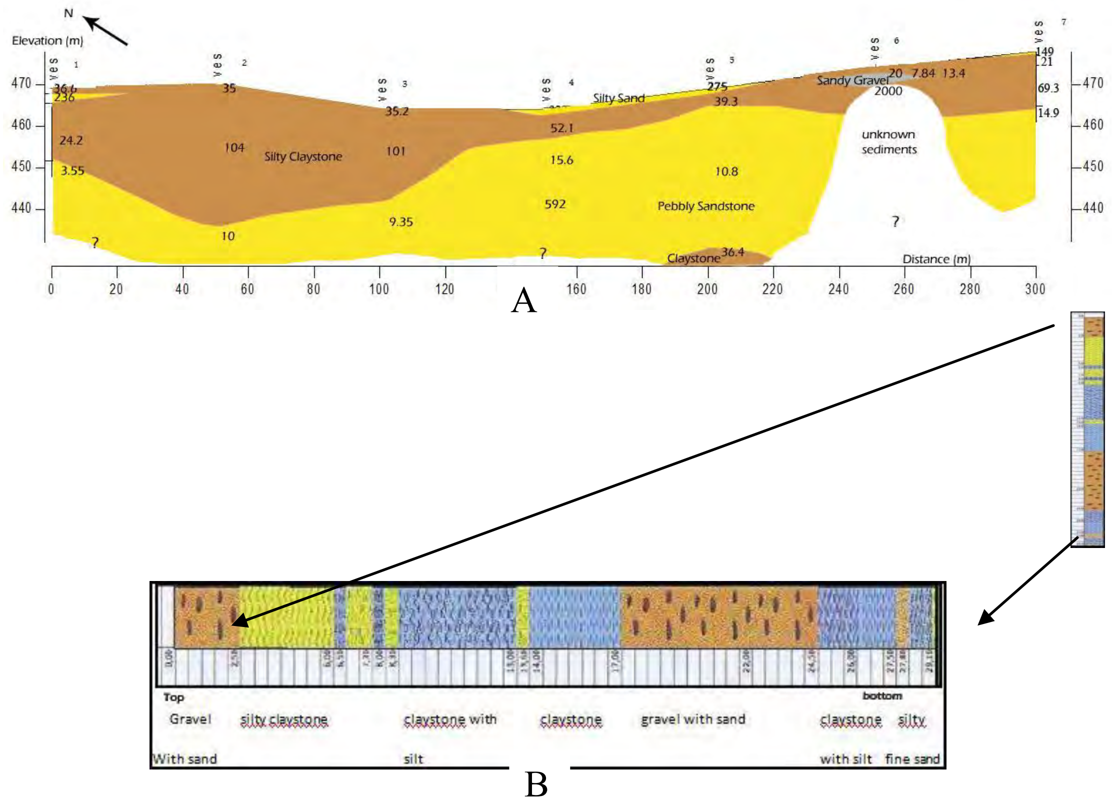

Figure- 11 A-geological section (P1) (VES$_{1, 2, 3, 4, 5, 6, 7}$) B-borehole log (B.H8).

Geoelectric section (P_2) figure12 is composed of (VES_8) (VES_9) (VES_{10}) and (VES_{11}) has taken above the spillway construction. It characterizes three horizons and shows heterogeneity in the lithology. The first horizon is composed of gravely sandy siltstone mostly ($VES_{8,\ 9,\ 10}$) but it is conglomerate in (VES_{11}), its thickness is between (1-1.46) m and true resistivity between (34-2200) ohm.m. The second horizon composed of sandy silty gravel (VES_8 & VES_9) and conglomerate in (VES_{10}) and (VES_{11}) , this horizon thickness is between (3.3-9)m and true resistivity (210-21907) ohm.m. The third horizon composed of silty sandy conglomerate in (VES_8),(VES_9) and(VES_{10}), and conglomerate in (VES_{11}), the true resistivity ranges between (32.4-1191) ohm.m .

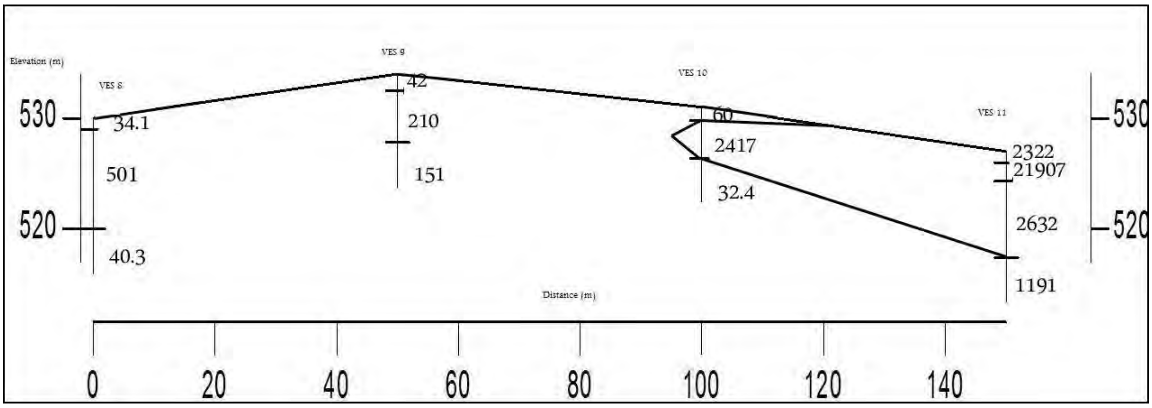

Figure-12 Geoelectric section (P2) ($VES_{8,\ 9,\ 10,\ 11}$).

Photo1 is an outcrop of the subsurface layers beneath the electric sounding (VES_{11}) and (VES_{10}), the upper layer composes of gravely sandy silt, the underlined layer is conglomerate with frequent lenses of sandstone, and this section helps to translate the yielded resistivity values into defined geological layer as shown in figure13.

Photo -1 Outcrop of the area beneath (VES_{11}) and (VES_{10})

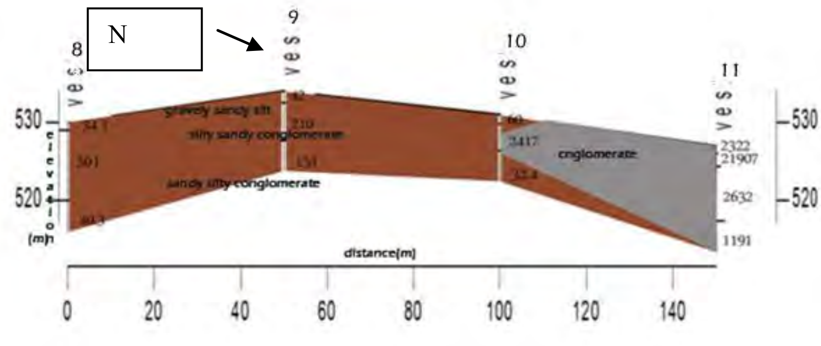

Figure13- Geological section (P2)($VES_{8,9,10,11}$).

Geoelectric section (P_5) that is conduct behind the dam body comprises (VES_{14}) and (VES_{15}). The top is soil composed of sandy silt its thickness is between (1.4-1.7) m, its resistivity is between (25-44) ohm.m. The second horizon is composed of silty sandstone; its thickness ranges (11-12) m and true resistivity between (275-333) ohm.m. The third horizon is wet sandy siltstone, its resistivity is between (12-25) ohm.m, figure 14 represents the geoelectric models and geological sections.

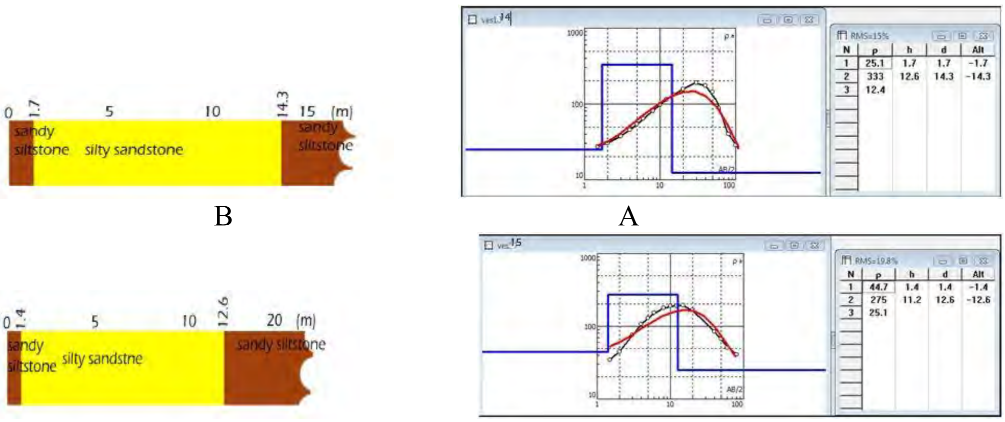

Figure14- Geoelectric models (A) and geological sections (B) (P5) (VES14,15).

Geoelectric section (P_6) has taken nearby right to the dam body figure15 adjacent to divergent tunnel. It comprises of (VES_{12}) and (VES_{13}) points. The first horizon presents in the (VES_{13}) is composed of top soil wet silty clay of two sub-layers deposits with thickness (1.7) m and (7.47) m and true resistivity (18) ohm.m and (12)ohm.m. The second horizon is composed of clayey siltstone of thickness (7.22) m and has true resistivity (60) ohm.m. The third horizon in t represents clayey siltstone with trace of water, its resistivity is (19) ohm.m. The top layer of (VES_{12}) is clayey siltstone of (15) m thickness and (64.5)ohm.m. true resistivity,the second layer is wet clayey siltstone its true resistivity is (22)ohm.m.

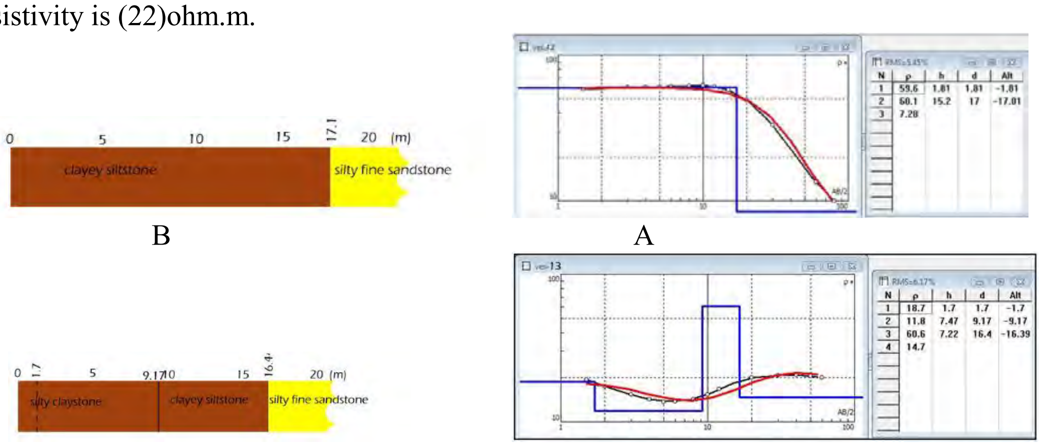

Figure15- Geoelectric models (A) and geological sections **(B)** (P6) ($VES_{12,\ 13}$).

Conclusions

1-Recent surface deposits cover the nearby area of the dam body with a bout (2-3) m thickness of silt and clay with gravel sediments.

2-The subsurface layers in the dam site within the valley are dominantly composed of clayey siltstone with thin layers of sandstone followed by pebbly sandstone, which is subsequences by claystone in some lower parts, while the area above spillway subsurface layers are dominated by gravely silty sand and sandy gravels. The area behind the dam body, top layer is sandy silt followed by silty sandstone, and underlined by sand siltstone.

3- Moisture condition presents near the body dam subsurface with more saturated and water table (4.5-32) m. in depth.

4-Generally, the dam site surface and subsurface are suffered from heterogeneity.

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