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Application of the Electrical Resistivity Method for Site Investigation in University of Anbar, Ar-Ramadi City, Western Iraq

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Abstract

The 2D resistivity imaging technique was applied in an engineering study for the investigation of subsurface weakness zones within University of Anbar, western Iraq. The survey was carried out using Dipole-dipole array with an n-factor of 6 and a-spacing values of 2 m and 5 m. The inverse models of the 2D electrical imaging clearly show the resistivity contrast between the anomalous parts of the weakness zones and the background resistivity distribution. The thickness and shape of the subsurface weakness zones were well defined from the 2D imaging using Dipole-dipole array of 2 m a-spacing. The thickness of the weakness zone ranges between 9.5 m to 11.5 m. Whereas the Dipole-dipole array with a-spacing of 5 m and n-factor of 6 allocated the geoelectrical stratigraphic layers sequence in low-accuracy of weakness zones, but deeper than the inverse model of 2 m a-spacing. This survey was made to explain the correlation between the weakness zone and the deeper layers in the study area. It points out that the deeper layers were not affected in the weakness zones. The inverse model was produced using the Standard Least-Squares Inversion Method and the Robust Inversion Model Constraints Method. The first method had a gradational boundary of the weakness zones and the second had sharper and straighter boundaries of fractures and voids within the weakness zones.

Keywords: Dipole-dipole array, Weakness Zones, Geophysical Investigation, University of Anbar, Injana Formation, Western Iraq.

تطبيقات الطريقة المقاومية الكهربائية للتحريات الموقعية في جامعة الأنبار، مدينة الرمادي، غربي العراق

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الخلاصه

تطبَّق تقنية التصوير ثنائية الأبعاد للطريقة الكهربائية في التحريات الهندسية لمناطق الضعف التحت سطحية داخل جامعة الأنبار، غربي العراق. تم اجراء المسح باستخدام ترتيب ثنائي القطب – ثنائي القطب مع عامل يبلغ (6) وبتباعد ما بين الأقطاب (2) و (5) أمتار. أشارت النتائج بوضوح أن المقاومة النوعية تتغاير ما بين الجزء الشاذ من منطقة الضعف والمحيط. تم تحديد سمك وشكل انطقة الضعف بصورة جيدة من خلال التصوير ثنائي الأبعاد باستخدام ترتيب ثنائي القطب – ثنائي القطب بتباعد مابين الاقطاب 2 متر، حيث

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يتراوح سمك منطقة الضعف بين (9.5 و11.5) متراً. في حين أن ترتيب ثنائي القطب – ثنائي القطب بتباعد (5) متر ما بين الأقطاب مع عامل يبلغ (6) أشار إلى تعاقب من الطبقات الجيوكهربائية الأرضية بدقة تفصيل واطئة لمناطق الضعف التحت سطحية وكما اعطى صورة ثنائية الأبعاد أعمق من نموذج الانعكاس بتباعد ما بين الاقطاب 2 متر. تم تطبيق المسح الجيوكهربائية لعمل مقارنة و تحديد مناطق الضعف التحت سطحية وعمقها. وقد أشارت النتائج إلى أن الطبقات العميقة لم تتأثر بمناطق الضعف. تم تفسير النتائج باستخدام طريقتين، الطريقة قلب المربعات الصغرى القياسية والطريقة الأخرى هي نموذج الانعكاس القوي. حيث أوضح التفسير في الطريقة الأولى حدوداً تدريجية لمنطقة الضعف، و تفسير الطريقة الثانية أوضح حدود مناطق الضعف بأكثر حدة وأضيق للكسور والفراغات داخل منطقة الضعف.

Introduction:

Subsurface weakness zones have become an increasing problem as new karst environments have developed. Human activities can lead to the breakdown of subsurface weakness zones that were already stable. The development in karst areas creates the increased need to detect subsurface weakness zones, as in locating buried features, cavities, pipelines, clay-filled sinkholes and buried channels. The needs also include plotting the water interface in coastal areas, locating economic deposits of sand and gravel, evaluating the quality of rock and soil masses in engineering standings, and mapping depth to bedrock for geotechnical applications such as foundation, planning, and construction [1]. The electrical resistivity method is one of these techniques that are applied in underground investigation via determining the electrical resistance. Materials are electrical in nature and their susceptibility to conduct electricity varies from one material to another. The evaluation and assessment processes are essential to detect the properties of elementary particles that compose materials. The movement of electrical charges in a medium or an electrode generates electrical current [2].

A number of authors applied the 2D Electrical Resistivity Investigations (ERI) technique for the investigation of engineering sites in order to discriminate subsurface structures such as cavities and sinkholes. Schoor [3] detected sinkholes using 2D electrical resistivity imaging. Metwaly and Al-Fouzan [4] applied the 2D geoelectrical resistivity tomography for subsurface cavity detection in the eastern part of Saudi Arabia. Abed [5] and Thabit and Abed [6] compared the two-dimension imaging resistivity survey and Bristow's method in detecting the accurate depth and shape of subsurface cavities located within Haditha-Hit area, western Iraq. 2D imaging resistivity surveys were conducted along four traverses in Hit area. Dipole-dipole (n-factor= 6 and 8), Wenner-schlumberger (n=8), and Pole-dipole (n=8) arrays were applied along a traverse above Um El-Githoaa cavity. One more Dipole-dipole (n=6) array was carried out along a traverse in Haditha area overhead Wadhaha-Shamut cavity. Abed and Thabit [7] detected the subsurface cavities using Pole-dipole array (Bristow's Method) in Hit Area- Western Iraq. Abed [8] used the Graphical Bristow's technique across a K-3 cave to assess the efficiency of the method to detect the dimensions of a relatively large natural cave. The data interpretation demonstrated that the cavity elongates along a West-East traverse of about 58.6 m, with an error that did not exceed 3% in depth and 2% in height. Abed and Thabit [9] conducted a 2D imaging resistivity survey across an unknown K-3 cavity located in Haditha area- Western Iraq. 2D measurements were collected along two intercrossing traverses above the cavity, each with 105 m length. The Dipole-dipole array was performed with an n-factor of 6 and a-spacing of 5 m. The K-3 cavity was well defined by the 2D imaging resistivity survey with a selected Dipole-dipole array, in comparison with the actual depth of this cavity which is equal to 11.5 m approximately.

In the present study, the 2D electrical resistivity technique is applied for detecting subsurface weakness zone and evaluating the natural-formed subsurface structures that are formed as a result of the lithological study area. We also aimed at analyzing the resolution of subsurface images under different subsurface conditions in addition to comparing the 2D inverse model using two methods for interpretation using the Standard Least-Squares Inversion and Robust Inversion Model Constraints.

Materials and Method:

Location and Geology of the Study area:

The study area is located at the University of Anbar in the south of Ar-Ramadi city, west of Iraq, between 33°24'7.13'' N (longitude) and 43°15'38.20'' E (latitude), (Figure-1). Stratigraphically, the study area is lies within the Injana Formation (Upper Fars Formation) that is comprised of gypsiferous soil, gypcrete, pale brown clay stone, pinkish pale clay stone, siltstone, and fine sandstone in a cadenced nature. The thickness of the formation in the north of Euphrates River reaches 18 m, while at the southern part of Euphrates River it has a range of 5-8 m. The lower contact of the Injana Formation is Fatha Formation [10].

The tectonic settings of the study area were sited within the Salman Zone of the Stable Shelf of the Nubian-Arabian Platform from the west and the Mesopotamian Zone (Euphrates Subzone) of the Unstable Shelf from the east [11].

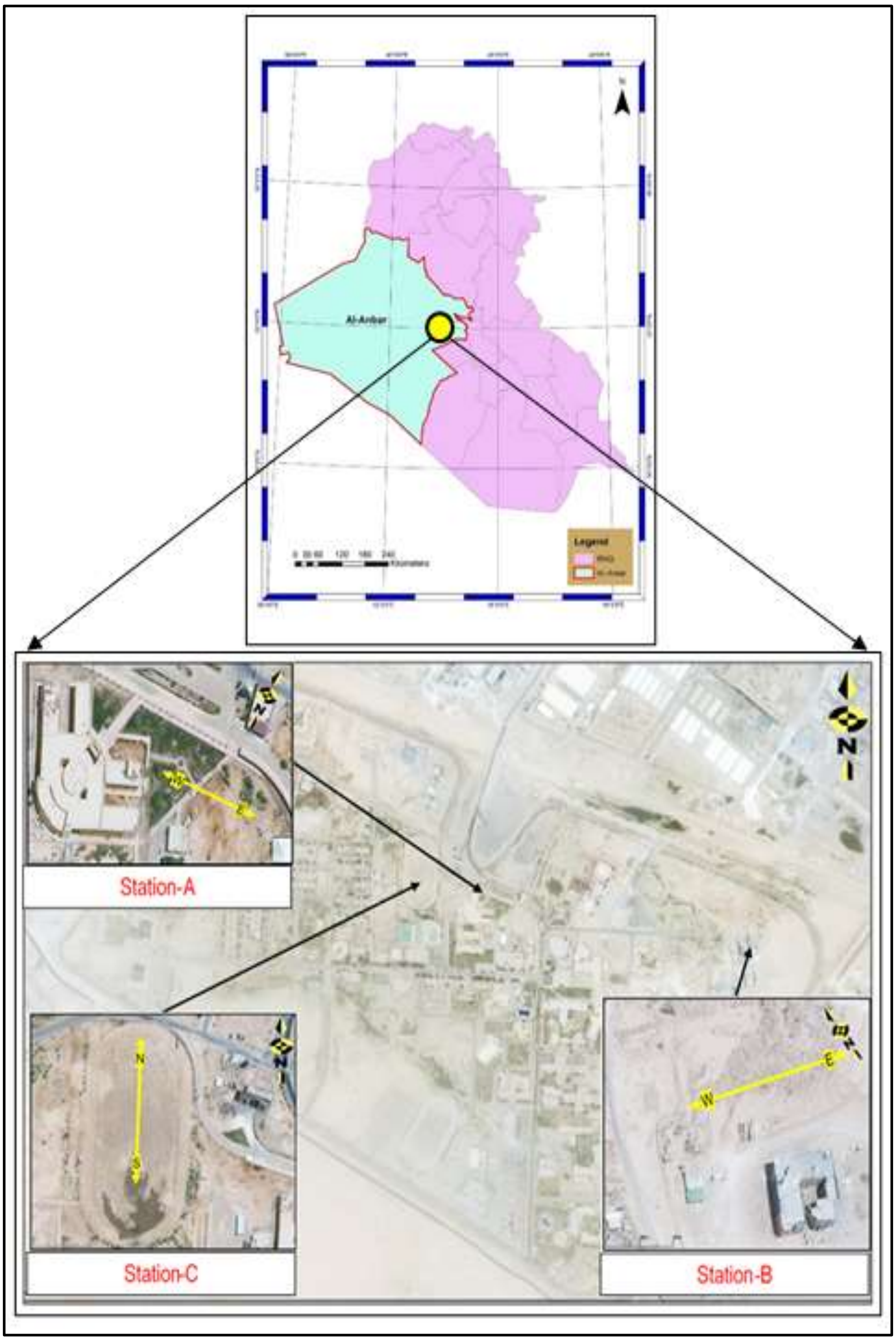

Figure1- A satellite image shows location of the study area and the three selected stations.

Data Acquisition and Processing:

A Terrameter SAS 4000 instrument was used for the 2D resistivity imaging for data acquisition along the three traverses in University of Anbar, western Iraq. The 2D survey was conducted using a Dipole-dipole array with n-factor of 6 and electrodes spacing (a-spacing) of 2 m for the first time and 5 m for a second time. We applied this array since it provides the best technique of subsurface imaging as compared to the other arrays such as Pole-dipole, Wenner-schlumberger, and Pole-pole arrays [12]. The apparent resistivity (ρa) readings were measured along each traverse are 685 readings of Dipole-dipole with a-spacing of 2 m and 138 readings with a-spacing of 5 m.

The measurements of the 2D resistivity imaging were processed and interpreted using the RES2DINV software, version 4.8.12 [13]. The ρa values were calculated using the forward modeling, while a non-linear least-square optimization technology was used for the inversion of data [14].

The inversion programs use mathematical algorithms to delineate the subsurface resistivity model that will best fit with the ρa data set.

The problems facing this method are related to the overcoming of the non-uniqueness (numerous models fit the data equally well) and the regularized Least-Squares Optimization Algorithms [15].

Results and discussion:

The 2D inverse results of the Dipole-dipole array of the traverses located above the subsurface weakness zones clearly indicated the resistivity contrast between the anomalous of the weakness zones and the background (Figure-2). The 2D inverse model produced using the using the Standard Least-Squares Inversion and Robust Inversion Model Constraints.

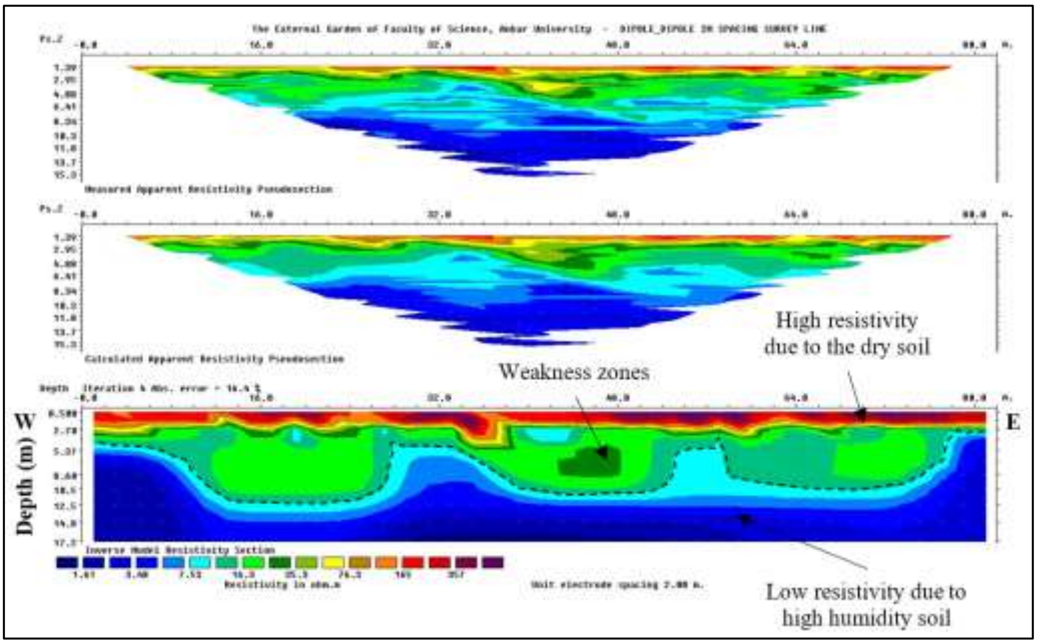

Figure 2- Measured, calculated pseudosections and inverse model of Dipole-dipole array resistivity section along travers-A (Standard Least-Squares Inversion Method).

The comparison between the two methods demonstrated that the inverse model produced by The Robust Model Method has sharper and straighter boundaries of the weakness zones than that obtained by the Least-Square Inversion Method Figures-(3, 4, and 5). The inverse model is the true image that is used for interpretation. The two inverse methods showed the range of thickness of the weakness zone was between 9.5 m and 11.5 m.

The RMS error indicates how well the calculated pseudosection is fitted to the measured pseudosection. Consequently, it is preferable to reduce this error as much as possible. However, this is not true in some situations, especially if there is a high surrounding noise. The noise is regularly more common with electrodes array, such as Dipole-dipole array, that has a large geometric factor and therefore, very small readings between the two potential electrodes [1].

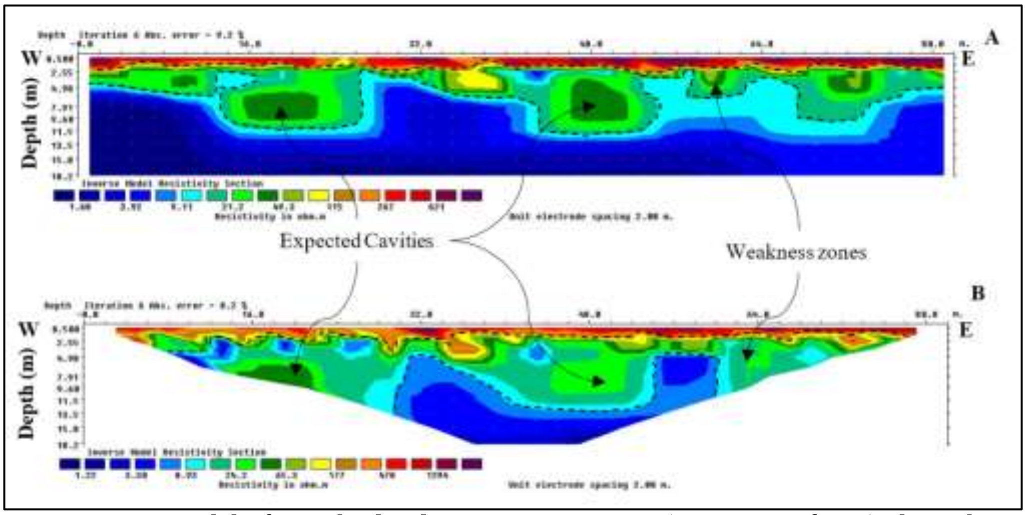

Figure 3- 2D Inverse model of Dipole-dipole resistivity section (a-spacing of 2 m) along the travers-A: **A-** Standard Least-Squares Inversion Method. **B-** Robust Inversion Model Constrain Method.

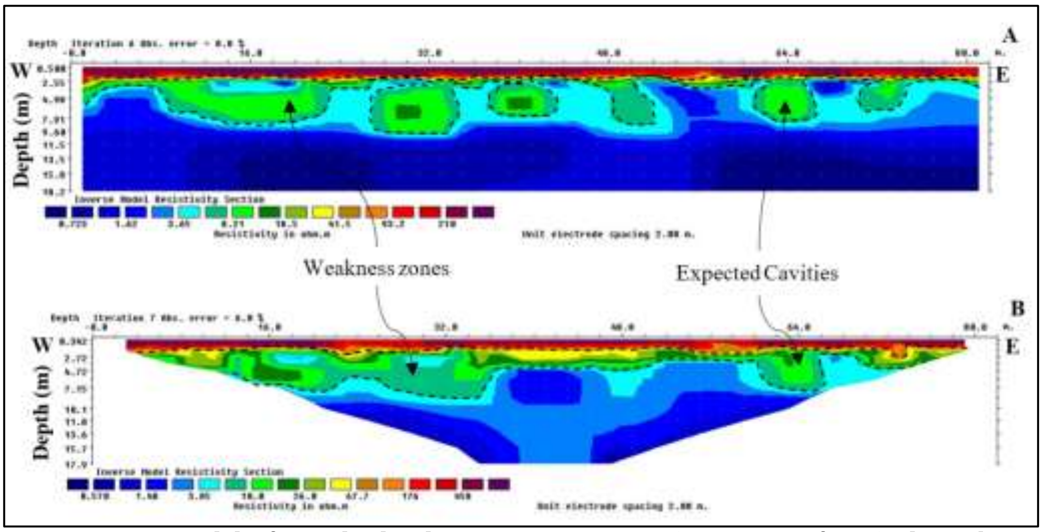

Figure 4- 2D Inverse model of Dipole-dipole resistivity section (a-spacing of 2 m) along the traverse-B: **A-** Standard Least-Squares Inversion Method. **B-** Robust Inversion Model Constrain Method.

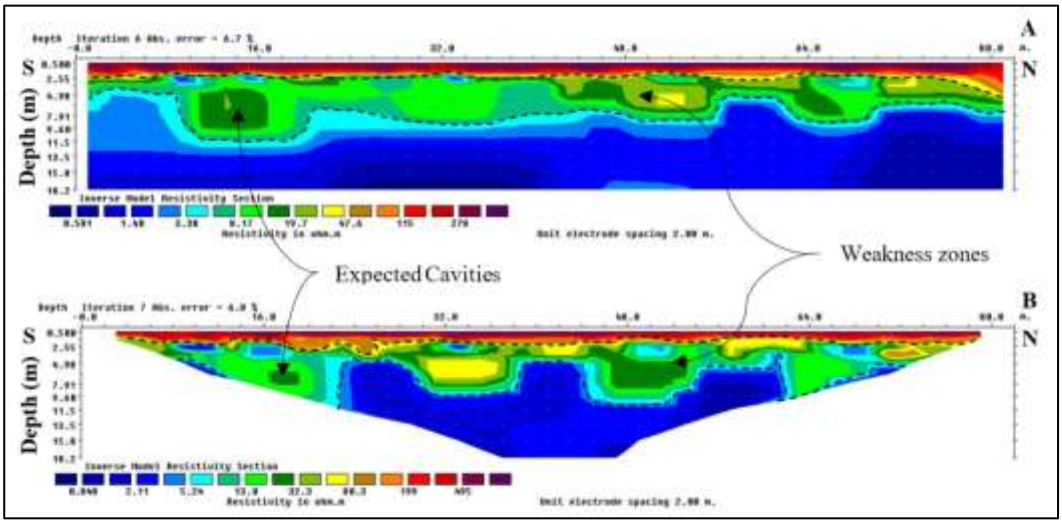

Figure 5- 2D Inverse model of Dipole-dipole resistivity section (a-spacing of 2 m) along the traverse-C: **A-** Standard Least-Squares Inversion Method. B- Robust Inversion Model Constrain Method.

Figures-(6, 7 and 8) show the sequence of geoelectrical stratigraphic layers of the study area which has a low accuracy of weakness zone, but deeper depth of investigation than the 2D inverse model with a-spacing of 2 m. This survey was carried out for the purpose of correlate between the weakness zones and the deeper layers.

It points out that the deeper layers were not affected in the weakness zones. The near surface groundwater actions (water tables equal to 3.25 m in the study area according to BH-CDS-1 well) caused the weakness zones by solutions in the soil gypsum beds.

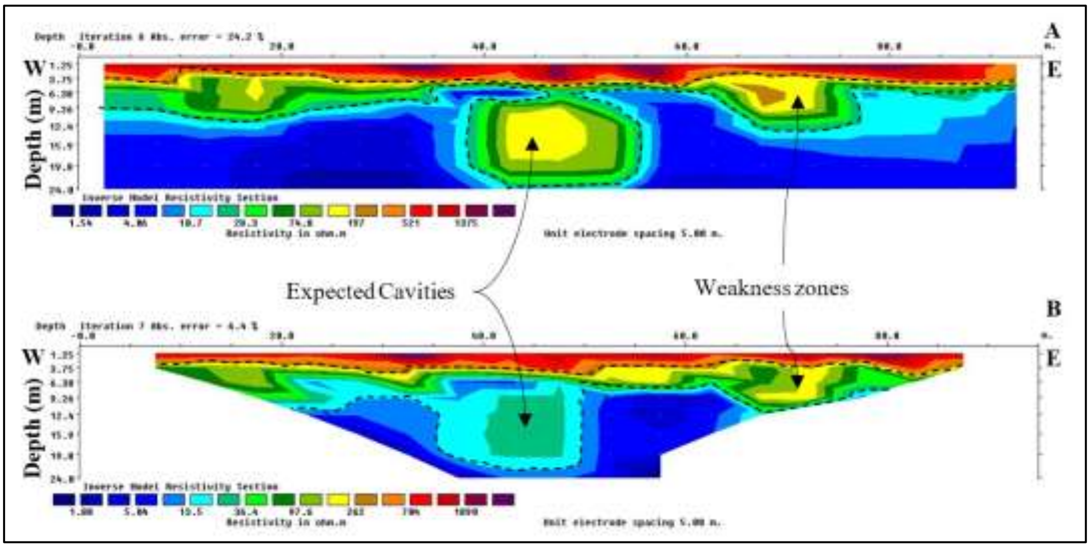

Figure 6- 2D Inverse model of Dipole-dipole resistivity section (a-spacing of 5 m) along the traverse-A: **A-** Standard Least-Squares Inversion Method. **B-** Robust Inversion Model Constrain Method.

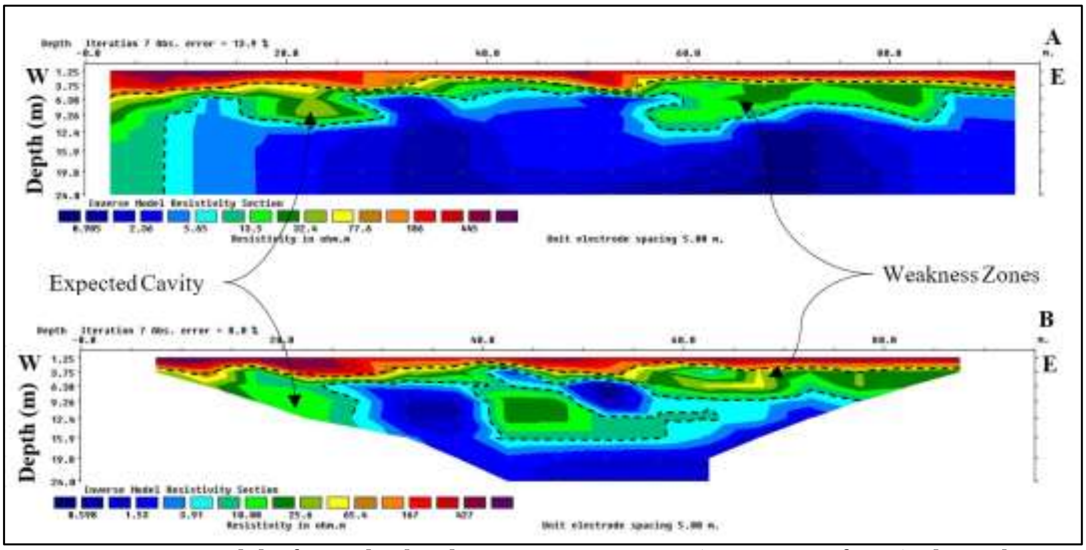

Figure 7- 2D Inverse model of Dipole-dipole resistivity section (a-spacing of 5 m) along the traverse-B: **A-** Standard Least-Squares Inversion Method. **B-** Robust Inversion Model. Constrain Method.

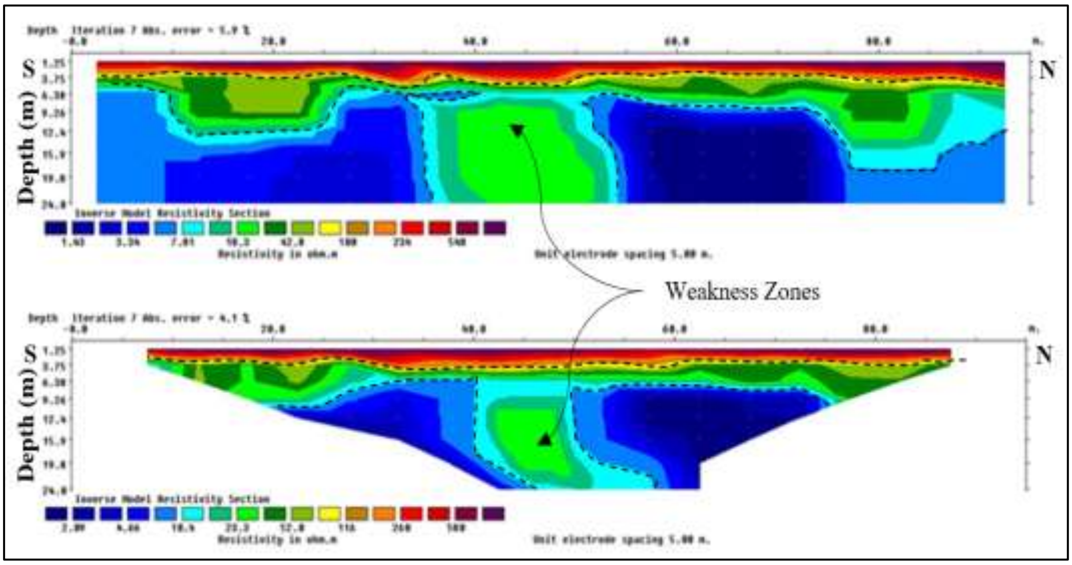

Figure 8- 2D Inverse model of Dipole-dipole resistivity section (a-spacing of 5 m) along the traverse-C: **A-** Standard Least-Squares Inversion Method. **B-** Robust Inversion Model Constrain Method.

Conclusions:

The inverse models of 2D imaging Dipole-dipole array with an n-factor of 6 and a-spacing of 2 m and 5 m clearly confirmed the resistivity contrast between the anomalous part of weakness zones and the background. The thickness and shape of the weakness zones were well defined from the 2D imaging with the Dipole-dipole array of a-spacing equal to 2 m, with a thickness range of 9.5 m to 11.5 m.

The Dipole-dipole array with a-spacing of 5 m delineated the geoelectrical stratigraphic sequence layers in a low-resolution of the weakness zone, but deeper depth of investigation than the 2D inverse model with a-spacing of 2 m. The Dipole-dipole array with a-spacing of 5 m was carried out to correlate the weakness zones and the deeper layers, it is found out that the deeper layers were not affected in the weakness zones. The 2D inverse models were produced using the two inverse methods; the Standard Least-Squares Inversion Method and the Robust Inversion Model Constrain. The first inverse method was a gradational boundary of the weakness zones and the second inverse method was a sharper and straighter boundary of weakness zones. Both inverse methods can provide the subsurface image but the results of the robust inverse method were more accurate.

References

1. Loke, M. H. **2018**. Tutorial: *2-D and 3D Electrical Imaging Surveys*, Malaysia. http://www.geotomosoft.com/
2. Reitz, R. J. and Milford, J. F. **1967**. *Foundations of Electromagnetic Theory* 2nd edition. Published by Addison-Wesley. ISBN-13: 978-0201063318.
3. Schoor, V. M. **2002**. Detection of Sinkholes Using 2D Electrical Resistivity Imaging. *Journal of Applied Geophysics*, **50**: 393 – 399.
4. Metwaly, M. and Al-Fouzan, F. **2013**. Application Of 2-D Geoelectrical Resistivity Tomography for Subsurface Cavity Detection in The Eastern Part of Saudi Arabia. *Geoscience Frontiers, China University of Geosciences (Beijing).* **3**(4): 469- 476. https://doi.org/ 10.1016/ J. GSF .2012.12.005
5. Abed, A. M. **2013**. *Comparison between 2D Imaging Survey and Traditional Electrode Arrays in Delineating Subsurface Cavities in Haditha-Hit Area (W-Iraq).* Unpublished Ph.D. Thesis University of Baghdad, College of Science, Department of Geology, Baghdad, Iraq.
6. Thabit, J. M. and Abed, A. M. **2014.** Detection of Subsurface Cavities by Using Pole-dipole Array (Bristow's Method)/Hit Area-Western Iraq, *Iraqi Journal of Science*. **55**(2A): 444-453.
7. Abed, A. M. and Thabit, J. M. **2016**. Delineation of K-3 Cavity Using 2D Imaging Resistivity Technique in Haditha Area (Western Iraq), *Iraqi Journal of Science*. **57**(1A): 209-217.
8. Abed, A. M. **2015**. Evaluation of Pole-dipole Technique (Bristow's method) to Detect the Dimension of K-3 Cave in Haditha area -west Iraq- Case study, *Kirkuk van University Journal-Scientific Studies (KUJSS).* **10**(3): 108-121.

9. Abed, A. M. and Thabit, J. M. **2016**. Delineation of K-3 Cavity Using 2D Imaging Resistivity Technique in Haditha Area (Western Iraq), *Iraqi Journal of Science*. **57**(1A): 209-217.
10. Saffa, F. A. **2007**. Tectonic and Structural Evolution of Iraqi Western Desert, *Bulletin of geology and mining*, **12**(1): 29-50.
11. Jassim, S. Z. and Goff, J. **2006**.*Geology of Iraq*. Dolin, Prague and Moravian Museum, Brno.341p
12. Nyquist, J. E., Pcake, J. S. and Roth, J. S. **2007**. Comparison of An Optimized Resistivity Array with Dipole-dipole Sounding in Karst Terrain. *Geophysics* **72**(4): 139-144. https://doi.org/ 10. 1190/1.2732994
13. Geotomo Software RES2DINV version 4.8.12 *Software program of 2D resistivity and IP inversion program.* **2018**. https://www.geotomosoft.com/downloads.php
14. Loke, M. H. **2000**. Tutorial: *2-D and 3-D Electrical Imaging Surveys*, Malaysia.
15. Loke, M. H. and Barker, R. D. **1995**. Least-Squares Deconvolution of Apparent Resistivity Pseudosections. *Geophysics*, **60**(6): 1682-1690. https://doi.org/10.1190/1.1443900