Use of Forward and inverse modeling of ERT data to detect salt bodies in Shallow Aquifer

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Abstract**—** this paper treat the high salinity degree of the Quaternary alluvial aquifer over a part of the Algerian Sahara, the goal of this study is the delineation and mapping the salt bodies in the alluvium sediments contaminating Oued Zegrir water. The use of 2D electric tomography gives important information concerning salt body's dispersion, 10 electric tomography profiles are realized in the study area, and the results confirm the presence of more than 4 salt lenses characterized by moderate electric resistivity contrast.

Key-Words**—** Alluvial Aquifer, Electric tomography, Salt bodies

I. INTRODUCTION

The Algerian Sahara desert contains the most important water aquifers, known as terminal complex and continental intercalary deep aquifer, the variability in climate changes affect directly water resources potentialities, the Mediterranean countries are the most vulnerable for water stress, the increasing in water demand for fresh water implies a global strategies for water quality preservation.

The alluvium aquifer in Algerian Sahara presents a potential resource for drinking and irrigation purpose, groundwater quality data gives important clues to the geologic history of rock and indication of ground water recharge, discharge and storage .

Variation in ground water quality depends on physical and chemical parameters influenced generally by the geological formation and pollution hazard.

The difficulties to assess hydrochemical monitoring of the ground water requires the use of rapid, non destructive and cost effective techniques, in this context the geophysical methods represents the alternative comparing to the hydrochemical analysis.

In this purpose, among the geophysical techniques, the 2D electric tomography (ERT) is widley regarded as a suitable tool to study the aquifer charachteristics and ground water salinity (Skuthan et al. 1986; Nguyen et al. 2009; Adhikary et al. 2015)

The subsurface resistivity variations can be visualized through two dimentional resistivity pseudo-section created by inverting the observed data recorded at a time sequence.

The ERT technique is an important devlopement of electric imaging for subsurfaces mapping, the detailed interpretation of 2D resistivity distribution allowed to solve complex geological-geotechnical problems such as karst investigation, bed rock mapping and hydrogeological investigation it also has the ability to asses groundwater salinity (Naidu et al.2013; Adhikary et al. 2015) and to demarcate pollution plums in the ground water (Rao et al. 2013).

The objective of this study is to asses the alluvium water quality and to determine the suitability of the aquifer for various purposes, However the use of the geophysical tools aims to delineate the locatation of the salt lenses by coupling forward modeling and the field investigation results. Consequently this study serve as reference base to evaluate the rate of changement in shallow and deep water ressources

II. Methods

The geophysical survey consists of 2D ERT profiles, the data sets were measured with ABEM terrameter (SAS1000), with 36 electrodes a total of 10 ERT profiles were conducted manually using Werner array each of the traverses was from 45 to 180m in length, the electrode separation for the data measurements is fixed to 5m over all profiles, survey techniques for measuring 2D ERT data is based on Loke and barker (1996), data acquisition principles.

III. Forward modeling

Time lapse inversion images produced under the salt body's simulation in alluvial context demonstrate the effect of seven different arrays

A two layer synthetic model for the subsurface was developed based on geologic characteristics of drilled wells and geophysical data interpretation , The top model correspond to the topographic surface and the bottom model is extended to 45m, the salt bodies are located at 2 and 4m respectively (Fig.1).

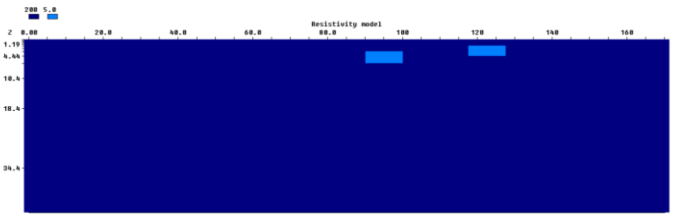

Fig 1. Synthetic model of two layers, layer with 200 Ω.m represent Alluvium sediments while layer with 5 Ω.m represents salt bodies

The tested forward modeling scenario is composed of two salt bodies with a resistivity value of 5 Ω.m; the second layer represents alluvium sediments with a resistivity value of 200 Ω.m resistivity values for both layers were chosen based on direct measuring of geological outcrops in different sites of the region

Wenner Alpha (W-α), Pole-Pole (PP), Dipole-Dipole (DD), Wenner Beta (W-β), Wenner Gamma (W-γ), Pole-Dipole (PD), and Wenner-Schlumberger (WS) arrays are frequently the most used for resistivity imaging

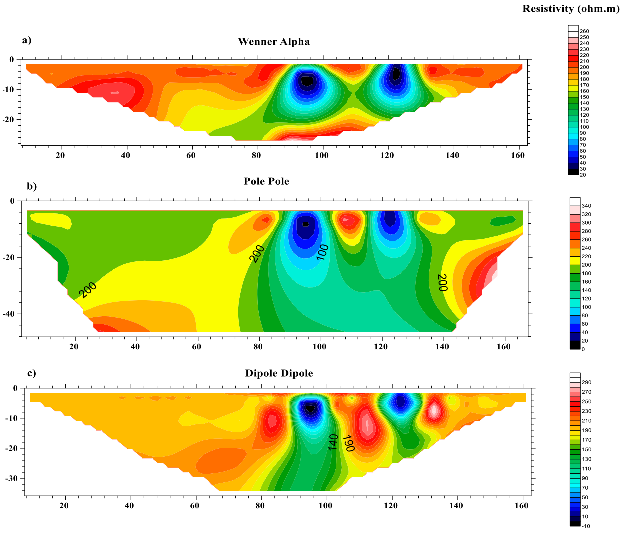

Fig.2 synthetic model of two layers, layer with 200 Ω.m represent Alluvium sediments while layer with 5 Ω.m represents salt bodies

The DD array is better than PP and DP delineating the salt bodies, this can be attributed to the high sensitivity of DD array to lateral variation in resistivity (Identifying vertical structures) than to the vertical contrasts (Identifying Horizontal structures)

The W-α, W-β, W-γ are sensitive to to vertical variation in resistivity (Identifying Horizontal structures) than to the Horizontal contrasts (Identifying Vertical structures) and W-S Array is a compromise between DD and Wenner array this gives high sensitivity to identify horizontal and vertical structures. The results shows important reduction of inversion artifacts noise except for the W- γ, the Wenner (α, β, γ) and Schlumberger are single channel that makes one potential measurement in the mid point of the array, this generate a small number of data points and lacks of high gradient in the measured potentialities. the mean artifacts values is similar to the synthetic model values (difference between 5-20 %) and the edge contours are more clear than the used arrays.

Generally the time acquisition factor is an important criteria choosing between resistivity arrays, additionally to the delineation of the salt bodies and ability to minimize inversion artifacts, from the given results the W-α, W-S arrays gives the best results using the configuration shown in Table 5 wich will be tested in real condition in the study area

IV. Application to real data

The inversion is done using two schemes, namely a normal scheme (L2 norm, with smooth last square constraint) and robust schemes (L1 norm with smooth constrain), only the best solutions are exposed in this work. Most ERT profiles had been processed using standard last square inversion

A. Profil Palm 1 and Palm 2

The profiles 1 and 2 are presented together to map the possible extension of salt bodies in the lower part of the study area, the high salinity degree in the near wells (P19, P20, P21, P22, P23, P23) confirm this probability, both profile 1 and 2 is oriented NW-SE direction and is 175m length with 5m electrode spacing

Figure a, b displays resistivity pseudo section from the standard and robust inversion with smoothness constrain for the Wenner alpha array

Generally the first layer is a hard surface characterized by high resistivity values (500-800 Ohm.m) the second layer represent the alluvium aquifer with low resistivity values due to high salinity water in the formation, salt bodies are very low electric resistivity (2-7 Ohm.m) located at the X, Z position respectively 20 m,4m for the salt body 1, 100 m,4m for the salt body 2, 124 m,2m for the salt body 3 and 152 m,5m for the salt body 4. The dry sandstone in the study area have a electric resistivity values of 90-140 Ohm.m the salt water infiltration through fractures change considerably the resistivity values of the bedrock the sandstone bed rock located at 12-14m depth with moderate resistivity values 30-70 Ohm.m.

Figure B displays the least square inversion results for Palm 2 profile, the shallow high resistivity layer appears to be thick compared to palm1 profile, the second layer resistivity is 13-25 Ohm.m represents alluvial aquifer with less salinity degree than palm1 profile, the bed rock is located at 14m with a resistivity values of 35-90 Ohm.m.

The fractures density, the degree of alteration and the quality of the matrices cementing the sandstone are the main factors controlling the changes in resistivity values, in the study area the sandstone matrices is clayey in the northern part while is gypseous in the lower part in the accumulation basin.

B. Profile Palm 3

Oriented to N135° with total length of 165m, the first layer with high resistivity values 35-300 Ohm.m the layer is less thick (1.5m -2m) in the western part of the profile and thick in its eastern and central part (4m) this layer is crossed by a vertical heterogeneity representing a filled sinkhole (16m in width) or a fractured zone with moderate resistivity values.

The alluvial aquifer is characterized by electric resistivity values ranges between 10-35 Ohm.m crossed vertically by the same layer until 18m depth, salt bodies are very low electric resistivity (0.3-5 Ohm.m) located at the X, Z position respectively 20 m, 3m for the salt body 1, 50 m, 4m for the salt body 2 and 100 m, 8-18m for the salt body 3, The sandstone layer is located at 20m depth with resistivity values of 25-40 Ohm.m**.**

C. Profile Palm 5

The profile 5 is located in the Eastern part of the study area and oriented to the NW direction, the electrodes spacing is 7.5m and the total length is 245m, the maximum investigated depth is 38.4m from the top to the profile bottom three layers appears:

Discontinued and compacted layer with moderate electric resistivity values (25-60 Ohm.m) extended from the surface to 4-5m depth.

The second layer represent the alluvial aquifer of Guerrara characterized by low resistivity (5-10 Ohm.m) due to the dissolved salts and the water flow direction , the aquifer is thick in the Central part of the profile and thin in the East-West parts.

D. Profile Palm 6

The profile 6 presents the same geologic structure as the precedent; the alluvial aquifer is characterized by a mean electric resistivity between 2.5-10 Ohm.m without the presence of salt bodies in the geologic formation, the resistivity values indicated the presence of salinity source located in the northern part of the study area, the sandstone bedrock is at more than 20m depth inclined from the NW to SE.

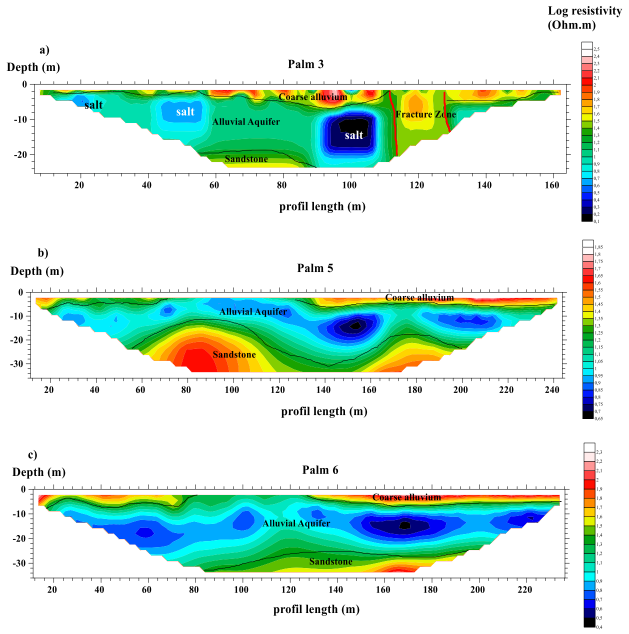

Fig.21 synthetic model of two layers, layer with 200 Ω.m represent Alluvium sediments while layer with 5 Ω.m represents salt bodies

V. Conclusion

The forward modeling approach is used in this work to examine the arrays geometry to delineate artifacts resulting from salt bodies in aquifer sediments, the tested model gives different responses using standard last square inversion algorithm, and the contrast between the two layers is identified in all the tested arrays but with different degrees of precision.

The results of the simulation shoes that the Wenner α and Wenner-Schlumberger arrays are better suited imaging evaporate heterogeneity in alluvial sediments, more arrays are tested for instance DD array producing artifacts and gives important artifact values in addition to the time data acquisition ,PP and PD arrays gives poor results and are not used in 2D electric tomography imaging.

Additional work is needed to evaluate the contrast in resistivity in different condition with non conventional arrays such the extended Dipole-Dipole or modified Pole-Dipole or gradient arrays.

Many resistivity contrast are identified in the aquifer alluvium showing the presence of evaporated material contaminating the surface water resources and influencing the suitability for Domestic, irrigation and industrial purpose;

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