GEOELECTRICAL INVESTIGATION OF SEAWATER INTRUSION IN THE COASTAL AQUIFER OF NADOR (TIPAZA, ALGERIA)

ABDELKADER BOUDERBALA [1], BOUALEM REMINI [2] & ABDELAMIR SAAED HAMOUDI [3]

1. Faculty of nature and earth sciences, University of Khemis Miliana, Ain Defla 44000, Algeria.
e-mail: bouderbala.aek@gmail.com
2. Department of Water Sciences, Blida University, Blida 9000, Algeria. e-mail: reminib@yahoo.fr
3. Department of Hydraulic, Chlef University, Chlef 2000, Algeria. e-mail: hamoudisaaed@yahoo.fr

Abstract

The Wadi Nador plain at the North of Algeria is very talented area for agricultural activities. It depends on underground water in its agricultural activities. The Plio-quaternary aquifer in this plain has suitable thickness to be used as the main water source for different purposes. Due to the presence of the main aquifer in the area in contact with the Mediterranean Sea, the fresh coastal water is contaminated towards the western direction. The present study concerns the application of surface geophysical techniques to study the spreading out of seawater intrusion.

The geoelectric study showed a variation in the electrical resistivity for two moments separated in time by more than 45 years. The fall in resistivity may be due to the seawater intrusion into the freshwater where the aquifer was strongly exploited during the period from 1980 to 1990. The resistivity surveys reveal two distinct sectors: the saturated aquifer in brackish and saltwater having resistivity values to 36-10 Ω.m, which extends nearly 1600 m inland, and the saturated aquifer in freshwater with resistivity values more to 36 Ω.m in upstream of the plain at more than 2 km.

Introduction

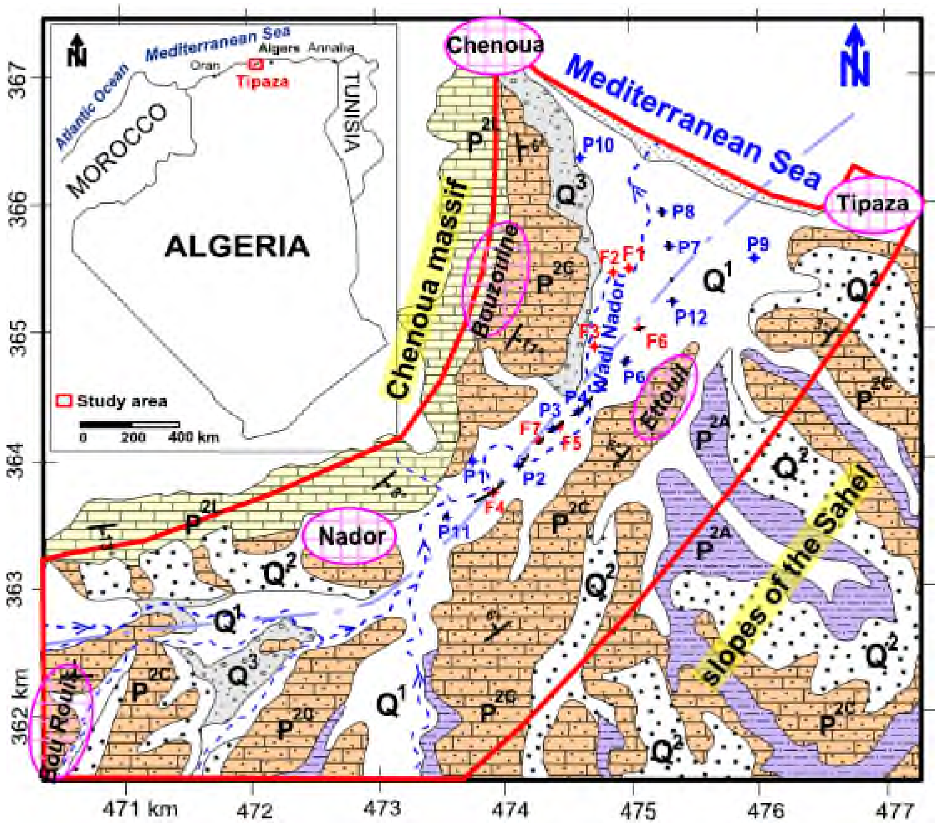
In coastal aquifers in direct contact with the sea, a state of equilibrium is created between the flow of saltwater and freshwater. When these natural conditions are altered, due to either an increase or a reduction in the flow of freshwater, the freshwater/saltwater balance shifts. Saltwater intrusion occurs when extractions of water from aquifers cause a depletion of freshwater, thus allowing saltwater to invade the land. Experience shows that once salinity increases, the process advances extremely quickly (Kirsch 2009; Kouzana et al. 2010; Bouderbala et al. 2014).

Recently, applications of geoelectrical survey methods have been increased for resolving various environmental and hydrogeological problems such as groundwater explorations and seawater intrusion, and proved to be successful in detecting the fresh/salt-water interface in coastal aquifers. The direct current resistivity method based on the apparent resistivity measurements along the earth's surface is the most commonly used geoelectrical methods in groundwater explorations and research of fresh/salt water limits (Bouderbala & Remini 2014; Kaya et al. 2015). This study aims to map the subsurface salinity distribution in Nador coastal aquifer due to salt water intrusion by using electrical resistivity method.

Description of the study area

Wadi Nador plain is part of a great littoral ensemble named Algiers Sahel. It is geographically located at 75 km West of Algiers (Figure 1). It is bordered on the west by the Chenoua massif, on the south and the east by the Sahel's slopes of Tellian Atlas, while it indeed faces the Mediterranean Sea on the north. The total surface area of of the plain is around 20 km2. The plain receives up to an average of 540 mm of annual precipitation.

The Plio–Quaternary aquifer of Nador is contained in the Quaternary alluvium (consisting of sand, gravel and pebble) as well as sandstones and limestones of the Astian in the Upper Pliocene age. The aquifer is confined beneath the Quaternary layer (consisting of clay and sandy silt). The aquifer's Quaternary and Pliocene horizons are in hydraulic communication. The substratum is formed mainly by marls plaisanciens of Middle Pliocene age. The water table is located at a depth of only a few metres downstream, but it lies at more than 10 m depth further upstream. Most of the recharge to this Plio–Quaternary aquifer comes from the rainfall infiltration on the outcrops of the plain. The recharge also occurs by return flow of the irrigation water. Recharge by the Wadi Nador is much reduced because its open channel flow is ephemeral, and the banks of the watercourses are clogged with clay. However, the axis of the synclinal nearly coincides with the flow trajectory of Oued Nador (Bouderbala 2015).



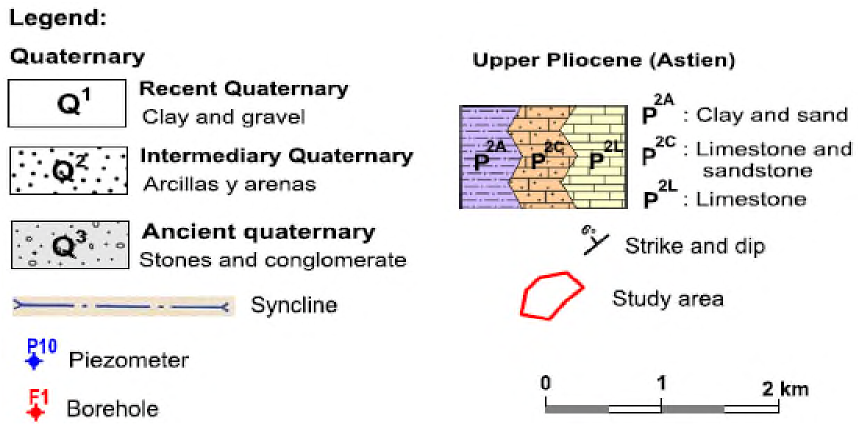


Fig. 1 Geographic and geologic location of the studied area.

Geoelectrical data acquisition and interpretation

In 1967, the study area knew a geophysical survey by the General Company of Geophysics (GCG) by the execution of 52 vertical electrical sounding (VES). In 2012, 47 VES were made in the study area using a Schlumberger array, in the subject to map the subsurface salinity distribution in this coastal aquifer. Our VES were executed in the same coordinates as the 1967 survey. The distance between the current electrodes was between AB = 600 m and AB = 800 m, and the VES sections were oriented more or less NW-SE, across the plain. The resistivimeter used was an Iris Syscal R1. Calibration of the VES was done near seven boreholes and ten piezometers. It is relevant to note that, currently, all the piezometers in this study area are clogged and have been abandoned; only three of the drinking water supply boreholes remain operational.

To track the ingress of the saltwater wedge inside the inland, 11 transverse geoelectric profiles (generally oriented E-W), were drawn. Examination of all the profiles together shows that the aquifer traces a syncline with S-N orientation, whereby the sections also indicate dips down from the eastern and western borders towards the axis of the syncline. This aquifer’s layers reach its maximum thickness of 60 m. The cross sections also show how the Plio-Quaternary aquifer is overlain by a variable layer (up to 30 m thick) of clayey sediments. Except where the aquifer formations outcrop on the east and western boundaries, these clays locally confine the aquifer.

The comparison that made between the transverse resistances maps of 1967 and 2012 (Figure 2), revealed a transverse resistance exceeding 1500 Ωm^2 for the year 1967, between the profiles A and F. In this coastal sector where four drillings were established: F1 (C′4), F2 (D5), F3 (F4), and F6 (E3). In this sector, the thickness of the Plio-Quaternary aquifer exceeds 55 m in some places and it is characterized by good interstitial and fissure permeability.

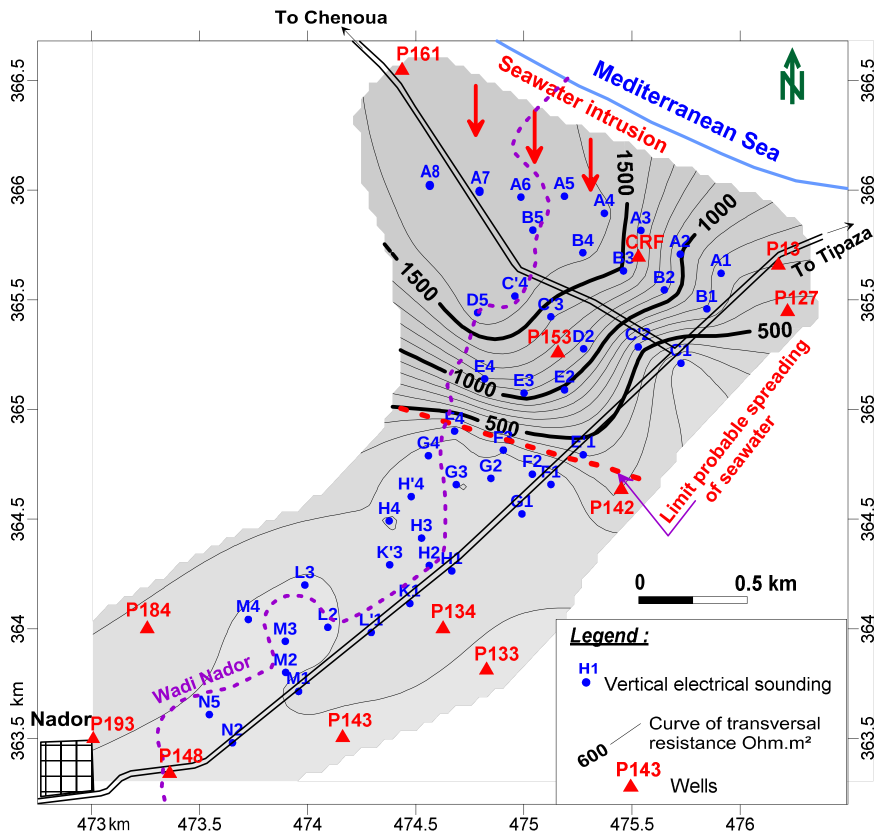


Fig. 2 Map of difference of transverse resistance.

Between the Nador city and cross-section G, the aquifer formation is quite thin; where the transverse resistance shows a remarkable decrease of 500 Ωm². while the map of the difference in transverse resistance values between 1967 and 2012 shows that the greatest values are observed in downstream end of the plain where the electrical conductivity of groundwater exceed 2500 µS/cm. The map shows how the difference in transverse resistance decreases with distance from the coast, as the proportion of saltwater in the freshwater becomes smaller and smaller. By cross-section F, no mixing is identified; in this way, we can locate the ingress of saltwater to a distance of about 1600 m inland.

Conclusion

The results of a geoelectrical study which was achieved to delineate the seawater–freshwater interface in the coastal area of Nador, by using the variation of resistivity in the time. The recent geophysical prospection carried out in 2012, based on 47 vertical electric soundings, was compared to the ancient geophysical prospection survey made in 1967.

The low resistivity observed close to the coast observed in the recent prospection, is related to the contamination of the aquifer by probable seawater intrusion are gradually decrease with distance inland.

The map of the difference in transverse resistance between the 1967s survey and the 2012s one, allowed to determine the extent of saltwater intrusion inland, approximately 1600 m into the Plio-Quaternary aquifer. Thus, the geophysical method can be considered a fast and efficient way to determine the extent of seawater intrusion inland and locate the most mineralized sectors. This technique is appropriate for monitoring the coastal aquifers and to mitigate lack of information from other sources.

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