GEOLOGIA • 2009 • Tom 35 • Zeszyt 2/1 • 455–462

GEOPHYSICAL TECHNIQUES FOR HYDROGEOLOGICAL TARGETS IN SEMI-DESERT AREA IN SOUTHERN PART OF VIETNAM

Badania geofizyczne dla celów hydrogeologicznych w południowej części Wietnamu

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Treść: Obszar badań jest zlokalizowany w południowej części Wietnamu na obszarze wsi Hong Phong i Hoa Thang w okręgu Bac Binh w prowincji Binh Thuan, gdzie występują czerwone piaski wydm przybrzeżnych. Obszar ten należy do najbardziej suchych w Wietnamie. Wykonano pomiary oraz przetwarzanie i interpretację danych geofizycznych w celu oceny warunków hydrogeologicznych. Wykonano sondowania i profilowania geoelektryczne, sejsmiczne badania refrakcyjne, sondowania magnetycznego rezonansu jądrowego, MRS, badania elektromagnetyczne VLF oraz TEM, a także badania georadarowe dla rozpoznania struktur geologicznych. Głównym celem było rozpoznanie potencjału hydrogeologicznego. Stwierdzono występowanie dwóch warstw wodonośnych, z których druga, na głębokości 40÷90 m okazała się warstwą perspektywiczną.

Słowa kluczowe: metody geofizyczne, wody podziemne, skała wodonośna, wydmy

Key words: geophysical tools, groundwater, aquifer, sand dunes

INTRODUCTION

Binhthuan-Ninhthuan coastal area is located in the southern part of Vietnam, where extensive red-sand dunes occur with about 90 km of length and 12 km of width from Ham Tan to Phan Rang. The region is a typical semi-desert region in Vietnam. The study area (Bac Binh) is located between 11°00'00"–11°05'00" N and 108°15'00"–108°25'00" E, where a driest place is located in the centre of above mentioned semi-desert region. The aim of geophysical investigations is the appraisal of hydrogeological condition for groundwater aquifer location in this

area. The complex of geophysical tools as geoelectric resistivity measurements, electromagnetic soundings, seismic prospecting were used for location of basement and aquifers.

There are two local aquifers which were interpreted by complex of geophysical data. The shallow aquifer is limited of water table and the second aquifer is located between 40÷90 m of depth with a great potential of good quality water. The results of geophysical techniques are proved by two monitoring wells with the depths of 63 and 71 m and by two testing wells with the depths of 95 and 110 m.

OVERVIEW OF RELIEF AND GEOLOGY OF STUDY AREA

The morphology of area is mainly plain with some hills and coastal plains with variable relief from west to east (Fig. 1). The geological units of the study area are mainly Pleistocene sediments, consisting of marine-aeolian, alluvial-marine and marine sediments. Underlying Quaternary and Neogene sediments are hard rocks of igneous and metamorphic origins like dacite-ryodacite with very low permeability which can't be considered as likely aquifers (Thoa *et al.* 2006).

Fig. 1. Location of study area and geophysical measurements by profiles

Fig. 1. Obszar badań w południowej części Wietnamu oraz położenie profili pomiarowych

GEOPHYSICAL INVESTIGATIONS

There are two seasons of a year in semi-desert area: dry season and rainy season. Due to very dry sand at the surface of the study area the best of geoelectric data should be collected during the rainy season (from July to October). Then, there is useful time for geoelectric measurements because contact between electrodes and rock formation is good. The best time for collecting seismic and electromagnetic data is in dry season (Nguyen & Le Ngoc 2007). Following geophysical techniques were used for investigation of hydrogeological structure of the study area including methods:

a) vertical electrical sounding (VES) with Schlumberger configuration array (current electrodes AB=1000 m and potential electrodes MN=100 m (maximum)), electrical profiling with AB=400 m and step 60 m (Pham *et al.* 1994). Geoelectric measurements were made by Terrameter SAS 4000,
b) seismic refraction survey along 8200 m line, each spread of 115 m length with 5 m spacing between geophones and with 5 shot points located inside and outside of the spread, made by Terraloc Mk6 (Fagin 1991, Giang *et al.* 2006).

The electromagnetic methods as well as magnetic resonance sounding (MRS) (Girard *et al.* 2005), transient electromagnetic sounding (TEM), very low frequency (VLF), ground penetrating radar (GPR) are used with modern instruments for local geological structure investigation and assessment of groundwater potential of study area.

On the study area we carried out 126 VES stations by 12 profiles. A pragmatic approach was used for VES data interpretation. The values of resistivities or thicknesses of every layer of the model can be modified instantaneously by various steps in defined ranges. This procedure allows the interpreter to see directly on the screen the influence of each layer and to use his geological knowledge in order to choose the most suitable model for the hydrogeological problem. The aquifer of ground water is located by resistivity from VES interpretation with the depths to top of water table changing from 35 to 60 m. Ground water in the aquifers is fresh water because the values of resistivity calculated by geoelectrical data are ranged about 20 Ω.m.

The 8200 m of seismic refraction profiles were carried out by 4 sections (segments) (Giang *et al.* 2006). In this paper we present typical one section T1 which was located approximate direction SW-NE in the study area. The time-distance curve and section of seismic refraction is presented in figure 2. The depth of basement (bedrock) and the thickness of the sand deposits and aquifer are determined by seismic refracted interpretation. The geological formation from surface to bedrock consists of 4 layers on the basis of seismic velocities. There are identified four layers: first one is a surface layer with seismic velocity from 400÷800 m/sec and thickness from a few to 20 m, second layer is a subsurface layer with seismic velocity from 800÷1500 m/sec and average thickness from 30÷40 m, third layer is also a subsurface layer with seismic velocity from 1500÷2800 m/sec and average thickness 50÷60 m, and the fourth one is a basement layer or bedrock with seismic velocity over 3000 m/sec and the depth on the range 60÷140 m from the surface.

The Magnetic Resonance Sounding (MRS) with Numis Plus instrument and the Transient Electromagnetic Sounding (TEM) with Protem 57 instrument were used for collecting data on T0, T1 and TEM profiles (Fig. 1). A geophysical datum always consists of two num-

bers – the measurement itself (signal) and the uncertainty of the measurement (noise). The electromagnetic background noise originates from various sources which may be from the power supply and the related man-made electrical installations or from lightning. The test measurements were used on the study area for reducing the noise and increasing the signal for choosing optimum configuration (Bernard 2006). Datasets were processed and interpreted by modeling program for investigation of hydrogeological condition of studying area, as well as layering structure and aquifers.

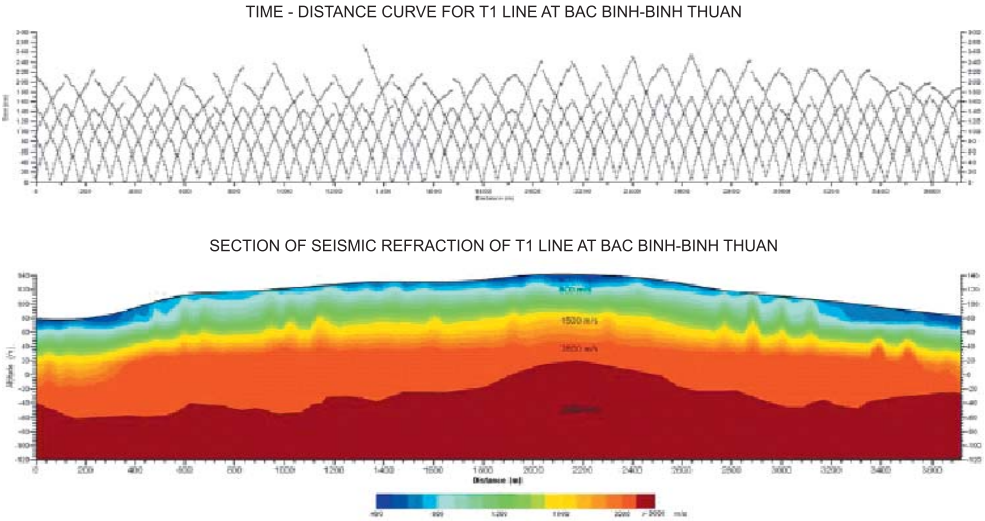

Fig. 2. Section of seismic refraction of T1 line at Bac Binh (The values within the section present the velocity in m/s)

Fig. 2. Zmiany prędkości fali sprężystej na sekcji refrakcyjnejwzdłuż linii T1

There are two aquifers of groundwater (Figs 4 and 5). The shallow aquifer is located from 20÷40 m of depth with poor groundwater and the second aquifer is located from 60÷90 m of depth with potential groundwater. The complex geophysical interpretation of electromagnetic data shows that the MRS and TEM are good correlation tools for location and assessment of aquifer on sand dune area (Nguyen & Le Ngoc 2007). The results of electromagnetic data are the basis to propose new sites of drilling wells for hydrogeological targets.

A curve of magnetic resonance sounding and its model after interpretation for point 10 of the profile T1 in study Bac Binh area is presented in figure 3. The interpretation of the MRS section indicate that there is aquifer with thickness 25÷30 m. The result of TEM investigation shows 4 layers, among those is aquifer oas the third layer.

All geophysical data were collected, processed and interpreted for investigation of hydrogeological condition of studying area. The aim of the complex geophysical interpretation is the appraisal of hydrogeological potential for groundwater augmenting by delineating the subsurface distribution of groundwater in this area. In addition, the relationships between the surface/subsurface layer's parameters were proposed and we show the results seem be useful in identifying new sites that are suitable for groundwater monitoring and exploitation.

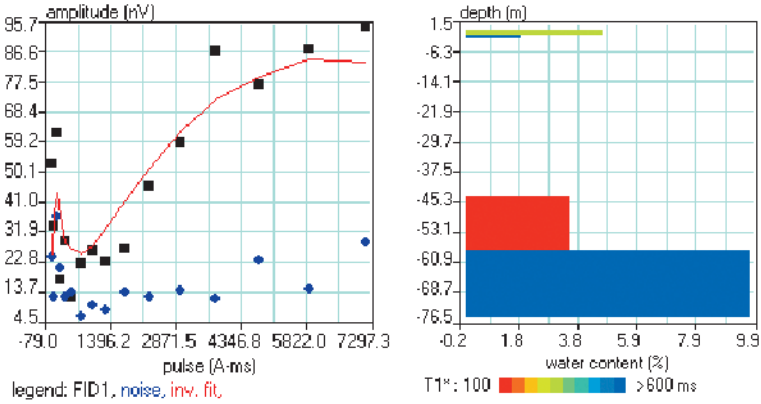

Fig. 3. Result of interpretation of MRS at point 10 – profile T1 in Bac Binh area

Fig. 3. Wynik interpretacji sondowania magnetycznego rezonansu jądrowego w punkcie 10 na profilu T1 na obszarze Bac Binh

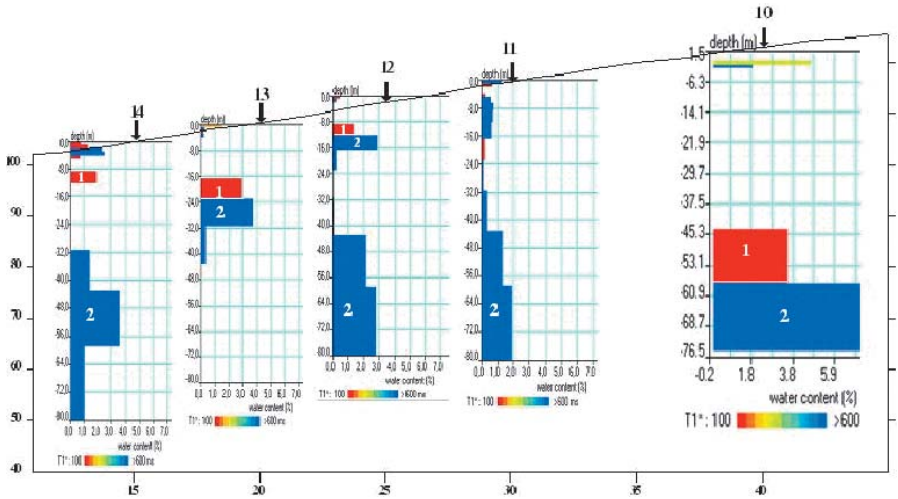

Fig. 4. Results of interpretation for profile T1 by Magnetic Resonance Sounding data in Bac Binh area (1 – fine sand layer, 2 – coarse sand layer)

Fig. 4. Wyniki interpretacji sondowań magnetycznego rezonansu jądrowego na obszarze Bac Binh (1 – warstwa piasków drobnoziarnistych, 2 – warstwa piasków różnoziarnistych)

The distribution of basement (bedrock) for study area by complex geophysical interpretation is presented in figure 6. The results of geophysical interpretation for study area are proved by two monitoring wells with the depths of 63 and 71 m and by two testing wells with the depths of 95 and 110 m.

Aquifer test began on 27 May 2005 and ended on 5 November 2005. Total time duration of pumping is 6.5 months (162 days). During this time, an amount of 33 598.8 m^3 of groundwater was abstracted.

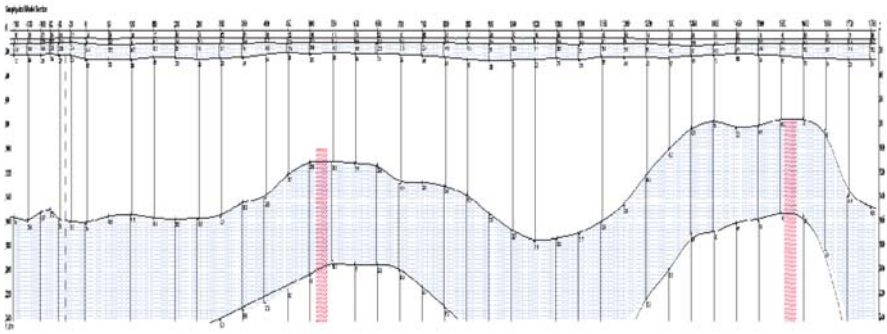

Fig. 5. Section of geological structure of profile TEM (0÷1750 m) by transient EM sounding data (two shadowed layers indicate aquifers)

Fig. 5. Przekrój geologiczny wzdłuż profilu TEM (0÷1750 m); sondowania elektromagnetyczne (dwie szare warstwy oznaczają dwa poziomy wodonośne)

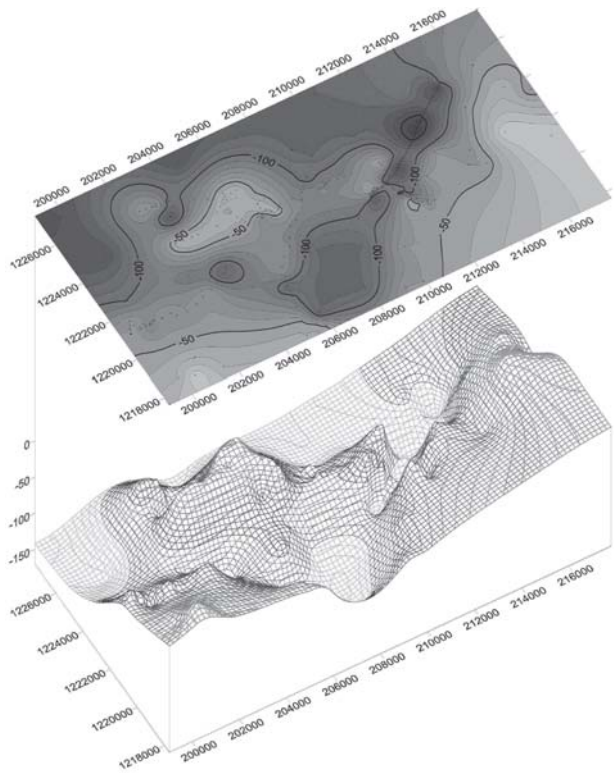

Fig. 6. The structure map of basement (bedrock) for study area on the basis of complex geophysical data

Fig. 6. Mapa strukturalna podłoża na obszarze badań wykonana na podstawie wyników kompleksowych badań geofizycznych

CONCLUSIONS

The complex of geophysical techniques are used successfully for hydrogeological targets on semi-desert area – Bac Binh in southern part of Vietnam, where the shallow geological formation consists of two parts – overburden and bedrock. The depth of bedrock in Bac Binh area is in range from 60 to 150 m in general, but around mounts is in range from 15 to 20 m. There are 4 layers of geological structure in the study area: the surface layer is dry sand and the second and third layers are corresponding to aquifer. The interfaces of layers are determined by contrast of seismic velocity values. The velocity value for basement (bedrock) is over 3000 m/s and for overburden is in range from 400 to 1500 m/sec. The depth to bedrock is distributed from 60 to 140 m. The third layer is corresponding to saturated or semi-saturated sands. This aquifer is distributed not over area and the depth to top of aquifer is from 25 to 70 m and to bottom is from 80 to 100 m.

The hydrogeological potential for groundwater augmenting is based on geophysical interpretation by delineating the subsurface distribution of groundwater in this area. In addition to this result, the relationships between the surface/subsurface layer's parameters were proposed and were shown to be useful in identifying new sites that are suitable for groundwater monitoring and exploitation.

Acknowledgments: This work is supported by project DTDL 2004/07 and by co-operation project: "Application of geophysical and geological methods into engineering and environmental tasks" between Vietnam Academy of Science and Technology-VAST and AGH University of Science and Technology in the years 2006–2009.

Praca była prezentowana na VII Konferencji Naukowo-Technicznej pt. „Geofizyka w geologii, górnictwie i ochronie środowiska" organizowanej z okazji jubileuszu 90-lecia AGH na WGGiOŚ.

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