Mapping shallow groundwater aquifer by performing high-resolution seismic reflection technique in Wadi Nisah

Ibraheem Hafiz
KACST
Riyadh, Saudi Arabia
ihafiz@kacst.edu.sa

Elkhedr Ibrahim
KSU
Riyadh, Saudi Arabia
eibrahim@ksu.edu.sa

Abdullah Al Amri
KSU
Riyadh, Saudi Arabia
amsamri@ksu.edu.sa

SUMMARY

This study was carried out in Wadi Nisah to the south-west of Riyadh, Saudi Arabia, at latitude of 24° 14' 28 N and longitude of 46° 29' 59 E. The main purpose of this study is to investigate the depth of the shallow groundwater aquifer and the geological structures that could affect the ground water bearing layer in the area. For this purpose, the high-resolution seismic reflection technique was performed along Six 2D seismic lines and geophone spacing of one meter. The constructed seismic sections revealed that the depth of the water bearing formation lies in the range of 100m to about 240m and normal faulting affect the surface of this formation. The interpreted water-bearing formation is correlated with Biyadh Formation as confirmed by the drilled near water wells. The output of this research proved that the high resolution seismic reflection technique can be an effective method for determining water bearing layer depth in such arid area.

INTRODUCTION

The Wadi Nisah is considered one of the most important wadis in the Riyadh area that hosts the annual rain water in large quantities and is characterized by its fertile land, which makes it suitable for agricultural development. The main purpose of this study isto investigate shallow aquifer depth in the Wadi Nisah, and mapp the subsurface structure that could affect this aquifer using high resolution seismic reflection method.

The boundaries of Wadi Nisah extends from the east of Al-kharj and Dharma to the west, while from the north is Wadi Hanifa, and from the south is the Blajan and Alayn. The edges of the Wadi start at height between 800 - 1000 meters above sea level near the west end of the Tuwaiq Mountains and extend towards the east a distance of up to 100 km to the area near Al-Kharj. Due to the geologic importance of Wadi Nisah, many geological studies have been conducted in this area. Abo Al-kheer (1985) concluded that Wadi Nisah is considered a low graben structure due to an old tectonic movement occurred in the Eocene time or shortly after. Denis et al. (1991) indicates that the drainage pattern, especially Wadi Nisah in south Riyadh has a great influence on the groundwater occurrences in area, where wadi Nisha is considered the longest drainage wadi in the area where it extends to about 75 km in the nearly east – west direction until it reaches the Durma drainage system.

Tectonically, Nisah Wadi is bounded by faulting system the form and shape the wadi course as structure grabens. Vaslet et al., 1991, stated that Wadi Nisah is part of the Central Arabian Graben and Trough System that extends in the east-west direction with about 90 km long and 2.0 to 3.7 km wide representing Nisah graben. Mashael Al Saud (1996) concluded that the Wadi Nisah Basin is considered one of graben Fault wadis that bounded by parallel Faults and this geological and structural environment of Wadi Nisah area is reflected on the patterns of surface water drainage network of the basin. Alghamdi (2007) concluded that the Faults of Wadi Nisah originating mainly from basement rocks resulting to graben structures that resulted in reservation of the Formation Yamamah and Buwaib from weathering. In addition, he added that the displacement vertical of fault reached 400 m. The thickness of sediments in Wadi Nisah gradually increases towards the central axis of the wadi to reach the maximum thickness of about 200 m. Wolfart and sogrea (1961 and 1968) studied the water bearing formations (especially Quaternary and Biyadah Formations) and delineated the groundwater level and the geological and petrophysical parameters that could affect the accumulation of the groundwater in Wadi Nisah. Power et al. (1966) studied the system of slot in Wadi Nisah and suggested that the slot may be caused by the Arabian arc system. The Wadi Nisah slot is considered a refractive slot and surrounded by a number of vertical faults affected the area from the north to south with dip angle between 60 to 70 degrees and the faults displacement reaches 100m to 300m.

Al-Kadhi and Hancock (1980) stated that the surface sediments thickness in Wadi Nisah is around 200m and this is confirmed by well log data.

METHOD AND RESULTS

The high resolution seismic reflection method is used during the data acquisition and the field crew consisting of three units:

1. The source unite responsible for positioning and activating the surface-energy sources.
2. The jug hustlers who lay out the cables, place the geophones in their proper locations, and connect them to the cables, and subsequently pick up the geophones and cables.
3. The recording unit that does the actual recording of the signal.

The studied area approximately marked on the map with the surveyed seismic lines, defined by the starting and ending points show in (Figure 1).

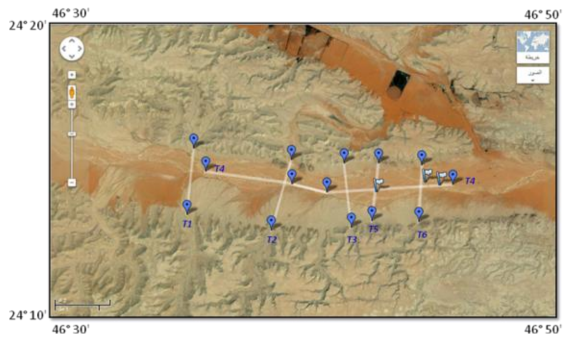


Figure 1 : The studied area in Wadi Nisah with the surveyed seismic lines defined by the starting and ending points .

The geometry configuration used for seismic reflection survey is shown under (Table 1). The geophone spread consists of 48 receivers spaced 10m apart. The 16 channel seismic cable is indicated by A, B and C. Data were recorded for a series of 16 shots located mid-way between geophones 16 and 17,…., 31 and 32, as indicated by stars. Cable A was then moved in front of B and C and the process repeated three more times.

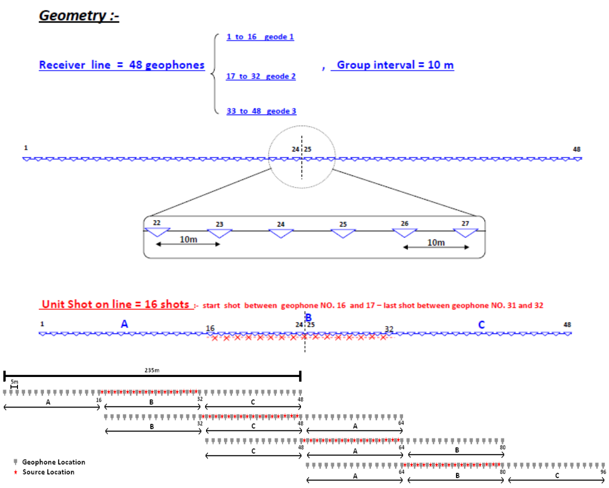


Figure 2 : Diagram of geophone array and shot locations used during the acquisition of seismic CMP line.

Table 1 : Line parameters

SPREAD	
Type	Mid Spread Shooting
Number of trace	48 traces
Receiver interval	10 m
Source interval	10 m
Skid	5m
Offset	1m
Near Offset	5 m
Max. Offset	325 m
Nominal CDP Fold	32 Fold
SOURCE	
Type	Weight Drop
No. of Weight Drop	One
RECEIVER	
Type	Geophone Flat base
Model	GS – 20 DH
Response	365 ohm , 40 Hz , 0.70 Damping
INSTRUMENTS	
Type	Geometrics , Strata Visor NZ
Sampling interval	0.5 ms
Gain constant	36 dB
Record length	2000 ms
Filter	Out

Seismic lines T1 – T6 are tied by Line T4 in order to confirm the structure and match the interpreted reflectors. A good structural image of the subsurface is visible from the seismic sections and it’s easy for the interpreter to mark the present structure and integrate it with well data. Despite this good image, one seismic line doesn’t show a better continuity and clear picture of subsurface in some locations that’s maybe because of energy penetration or energy attenuation that referred to the presence of loose sand and/or low acoustic impedance.

Line T1: Through this line the subsurface geology was mapped using seismic reflection survey with a total Line length of about 2400m (Figures 3). The seismic section along this line (T1) and the interpreted horizons show fault gaps. The effect of the faulting across this line was obvious in the discontinuity in the horizon surface. This fault structure affects the water bearing formation depth that was found at variable depths, ranging from 120m to 250m. The drilled water wells in the area assured the presence of the water bearing formation at the same interpreted depth.

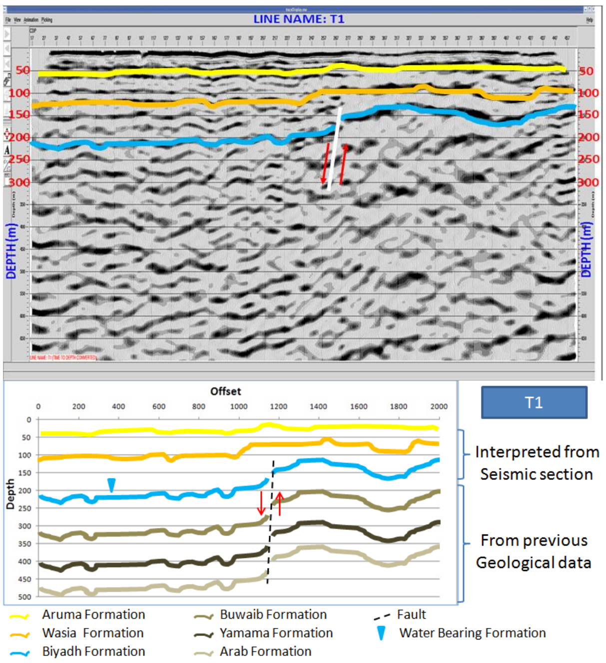


Figure 3: Time migrated section (depth scale) of T1 (Top) and the interpreted formations (bottom).

Line T2: This line extends to a total length of 2560m and the interpretation result shows the presence of water bearing formation at depths ranging from 100 to 150m. The discontinuity of this formation could reflect the presence of faulting affected this formation as shown in (Figure 4). It is worth to note that the seismic line (T2) crosses the seismic line T4 and ties with it and the results from both seismic lines came consistent. In addition, the structure that deduced from the line (T2) is almost similar to that came from line T1 which gives us enough confidence in T2 result as well.

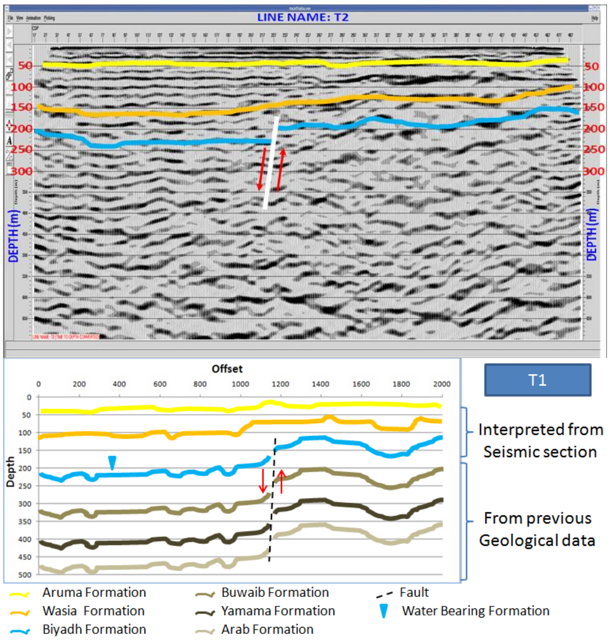
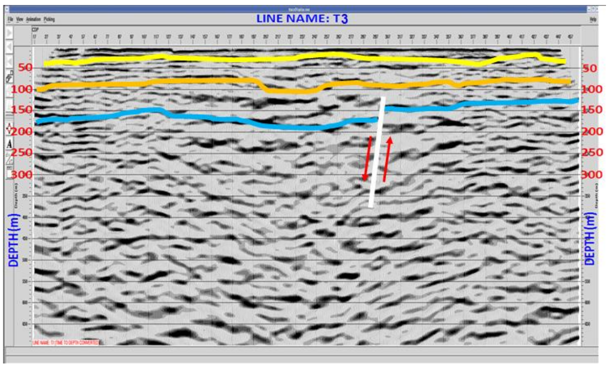


Figure 4: Time migrated section (depth scale) of T2 (Top) and the interpreted formations (bottom).

Line T3: This seismic line extends to a length of about 2400m and the interpretation results indicate that the variation of the depth to the top surface of the water bearing formation ranges between 130m and 200m (Figures 5). This discontinuity in interpreted reflector could be referred to normal faulting affected thwater-bearing formation. T3 crosses line T4, and reflectors of both are matching each other.



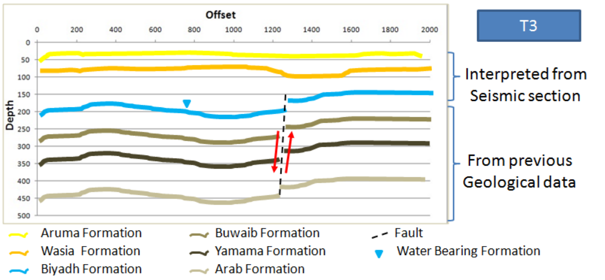


Figure 5: Time migrated section (depth scale) of T3 (Top) and the interpreted formations (bottom).

Line T4: This seismic line is considered the longest surveyed line that covered the study area with a total length of 9280m. The analysis of the seismic data across this line shows the presence of water bearing formation at depths ranging from 80 to 200m. The change in the depth and the discontinuity of this formation could reflect the presence of faulting affected this formation as shown in the (Figure 6). It is worth to mention that this line tied the seismic lines T2, T3, T5, and T6 and the interpreted depths to the reflectors are consistent in all sections, which gives enough confidence of the subsurface structural interpretation.

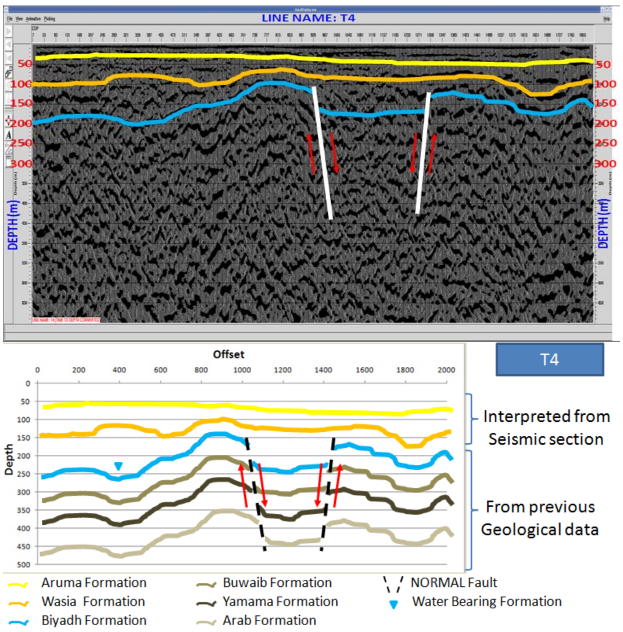


Figure 6: Time migrated section (depth scale) of T4 (Top) and the interpreted formations (bottom).

Line T5: This seismic line extends to the length of 2080m. Across this line, the depth to the water bearing formation is noticeably varying between 120m and 220m. T5 tied line T4, and the interpretation results show a good matching between the two seismic lines which gives more confidence in the interpretation of both seismic lines that come consistent with the well data from the drilled well no. 5-R-155 as shown in (Figure 7).

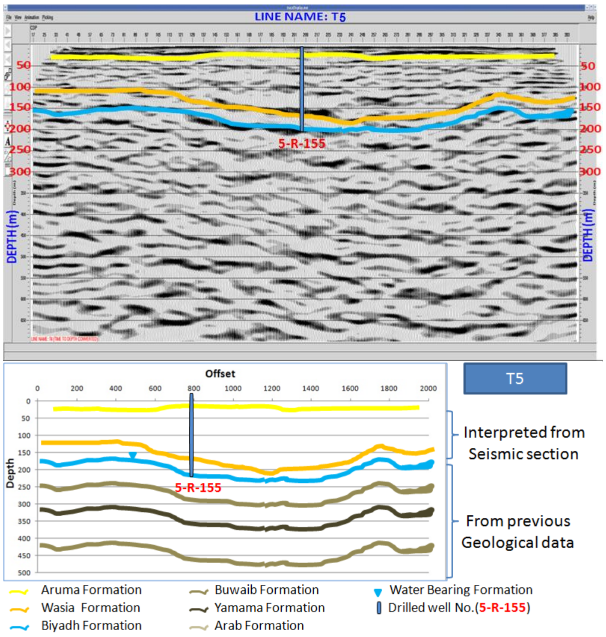


Figure 7: Time migrated section (depth scale) of T5 (Top) and the interpreted formations (bottom).

Line T6: Through this seismic line with a total length of about 2080m, the groundwater aquifer is mapped as shown in (Figure 8) with depth confirmed by the drilled water well (well no. 5-R-151). It is worth to note that this seismic line (T6) was tied with the seismic line (T4) and the results from both seismic line came consistent and the interpreted reflectors match each other which give confidence to the results.

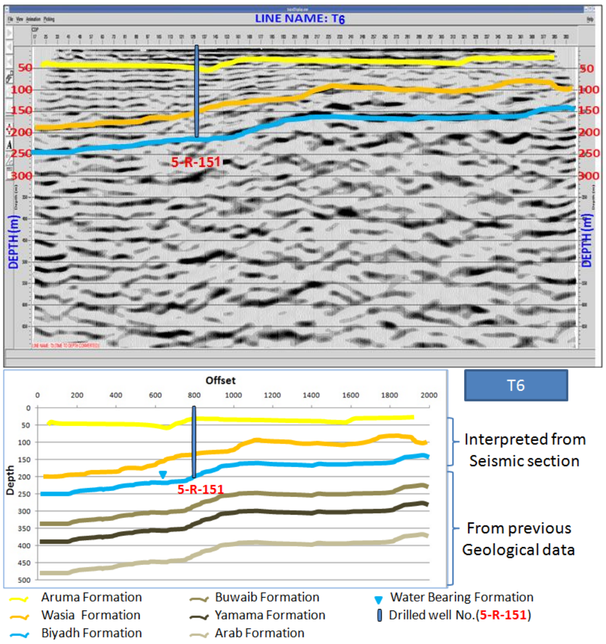


Figure 8: Time migrated section (depth scale) of T6 (Top) and the interpreted formations (bottom).

CONCLUSIONS

Aquifers can occur at various depths from one location to another. Therefore, an investigation of the aquifer depth in the Wadi Nisah was undertaken as the first objective of this thesis, and the results show that the depth of the aquifer range of 100m to about 240m, ad the detected aquifer is Biyadh Formation as confirmed by the drilled water wells. Secondly, the subsurface structure of the area under study was inspected in order to show faulting that could affect the water bearing layer in the studied area. Consequently, the water bearing layer shows a low frequency relative to the overlying sedimentary layers in all seismic lines that could give enough confidence in the results and the interpreted subsurface structure.

.

ACKNOWLEDGMENTS

I would like to express my thanks and gratitude to KACST for providing the field and data acquisition facilities.

REFERENCES

Al-Kadhi, A. and Hancock, P. L., 1980, Structure of the Durma-Nisah segment of the Central Arabian graben system: Saudi Arabian Directorate General of Mineral Resources, 16-40.

Andre, C.G., 1984, Orbital multispectral thermal infrared data,

Denis, V., Mohammed S. Al-Muallem, Sami S. Maddah, Jean -Michel Brosse, Jackie F., Jean-Paul B., and Yves- Michel Le N., 1991, Explanatory Notes To The Geologic Map of The Ar-Riyadh Quadrangle: Sheet 24 I, Kingdom of Saudi Arabia.

Power, R. and Ramirez, L., 1966, Geology of the Arabian Peninsula: Sedimentary Geology of Saudi Arabia : Geological Survey Professional Paper 540.

Vaslet, D., J.-M. Brosse, J.-P. Breton, J. Manivit, P. Le Strat, J. Fourniguet and H. Shorbaji , 1988, Explanatory Notes to the Geologic Map of the Shaqra Quadrangle: Sheet 25H, Kingdom of Saudi Arabia. Ministry of Petroleum and Mineral Resources, Saudi Arabia

Wolfart R., 1961, Geological – Hydrogeologic Research for the Utilization of Groundwater in the Wadi Nisah Area: A Supplement to the water Supply of Al Riyadh, Saudi Arabia.