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Water level change in wells—a predictor for earthquakes?

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Abstract Regional as well as worldwide development on the subject of earthquake prediction has failed to succeed and, until now, has not provided reliable forecasting phenomena. Along the history of research, earthquake prediction was a challenging but unsuccessful task for saving life. Furthermore, development of forecasting tools is limited and there is an increasing gap between the known post-shock data and the unknown pre-shock lack of information. Numerous attempts have been made to achieve advanced warning for earthquakes. In our case the water level rise and falls in the regional confined aquifers were found to manifest themselves clearly prior to the earthquake, potentially giving a sufficient amount of time to warn the population of the coming quake. Although the results are preliminary, observations based on scars and insufficient data, it should not be ignored and more research should be carried out in order to be sure that this newly observed phenomenon is suitable.

Key words aquifers; earthquake prediction; groundwater; Israel; pumping wells

INTRODUCTION

A recent observation concerning earthquake prediction has been discovered in Israel. Three medium earthquakes that occurred along the Jordan–Dead Sea Rift Valley, recently shocked Israel and neighbouring countries. Two water wells, located quite far apart, “announced” the earthquakes about 1 h prior to the shock and about 1 h prior to the first seismographic record! A third well seemed to respond to the latest third shock during the earthquake itself, only and not before, since the data prior to the event was missing due to pumping procedures (Fig. 1).

The major tectonic element in the region is the Dead Sea–Jordan Rift Valley that is part of a NS long dislocation line—The Dead Sea Rift (a segment of the East Africa Rift System). Geologically the Rift comprises a plate boundary between a northern dent of the African Plate to the west (the Sinai–Israel sub-plate) and the Arabian plate to the east. The Dead Sea–Jordan Rift Valley, an area partly shared between Israel, the Palestinian Authority and Jordan is a hazard risk zone exposed to recent earthquakes.

However, regional as well as worldwide development on the subject of earthquake prediction failed to succeed and until now, did not exceed reliable forecasting phenomena. Numerous attempts have been made to achieve advanced warning for earthquakes. Studies have been carried out in an attempt to identify precursory signs that involve pre-shocks, geodetic changes, oil and water level changes in wells (Muir-Wood, 1993;

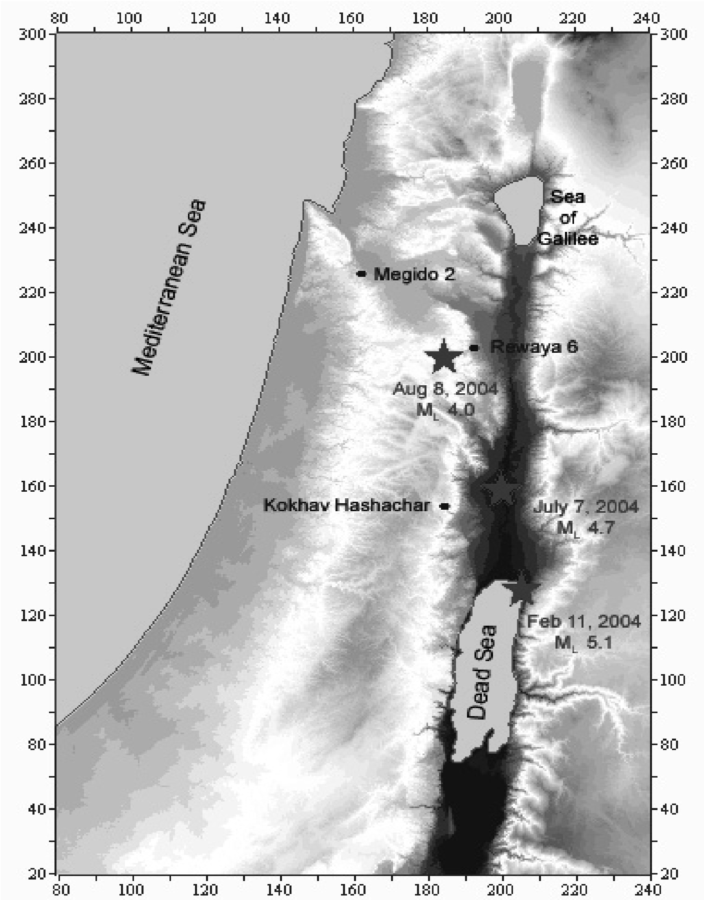

Fig. 1 Location map of the earthquake epicentres and the responding water wells along the Dead Sea–Jordan Rift Valley.

Quilly & Roellofs, 1997), geochemical changes (Silver & Wakita, 1996; King & Igarashi, 2002), changes in the ratio of P/S waves, radon emission and unusual animal behaviour (Kirschvink, 2000). To the best of our knowledge all these methods have failed to predict earthquakes. Generally the anomalies attributed to the earthquake were found to appear following the event. In our cases the water level rise and fall in the regional aquifer were found to manifest themselves clearly prior to the earthquake, potentially giving a sufficient amount of time to warn the population of the coming quake.

RESULTS

In 2004, three medium earthquakes that occurred along the Jordan–Dead Sea Rift Valley recently shocked Israel and its neighbouring countries. Two water wells, located quite far apart, gave warning of the earthquakes about 1 h prior to the shock and about 1 h earlier than the first seismographic record. The third well seemed to respond to the latest third shock during only, and not before, the earthquake itself, since the data prior to the event was missing due to pumping procedures. The three wells are pumping from confined aquifers composed of limestone and dolomite.

On 11 February 2004, at 10:15 h, an earthquake felt all over the country shook Israel and its surroundings. According to the Israeli Geophysical Institute, the seismographs recorded the earthquake at a magnitude 5.1 (M_L) and calculated the epicentre to be the northeast corner of the Dead Sea (Fig. 1).

Forty-five minutes prior to the event, the water well (Rewaya-6) located about 75 km north of the epicentre, at the southwestern margins of the Beit-Shean Valley (Fig. 1), clearly predicted the earthquake. The well that is part of the "Mekorot" water supply system in this area had been inactive since midnight. The depth to the static water level is usually around 161 m below the surface. The static level was found to be stable over a period of about 10 h until 45 min before the earthquake. At 09:30 h the static water level started to rise quickly, by the time of the shock it had risen by 4.5 m above the static water level. It continued to rise to a maximum level of 5.7 m at 10:25 h and remained at this elevation for approximately half an hour. Following this it proceeded to drop back to the static water level (Fig. 2).

A few months later, on 7 July 2004 at 17:35 h, the area of Israel and its surroundings was shaken by a magnitude 4.7 (M_L) earthquake whose epicentre was some 25 km north of the Dead Sea along the Jordan Valley (Fig. 1).

Unfortunately, the first well Rewaya-6 was active at the time of this quake. However, another water well (Kokhav Hashachar) located about 15 km southwest of the epicentre (Fig. 3) was not active several hours before the shock. The well is located in the Ein-Samiya fault strip that is a branch of the Dead Sea–Jordan Rift Valley structure. The static water level in the well is about 343 m below surface. Precisely 1 h 15 mins prior to the earthquake (at 16:15 h) the water level at the well began to fluctuate, dropped by 4 m, rose to the original level, dropped again by 3.6 m at the time of the event, rose to the original level, dropped to a maximum of 6.6 m right after the earthquake, fluctuated once again and then stabilized at the original aquifer water level (Fig. 3).

A third small earthquake of 4.0 (M_L) occurred on 8 August 2004 southwest of the Beit-Shean Valley (Fig. 1), along the continuation of the Carmel-Gilboa fault system that is also a part of the Dead Sea–Jordan Rift Valley structure. The water level in the Megido-2 that is located close to this fault, responded to the shock. As the recovery to

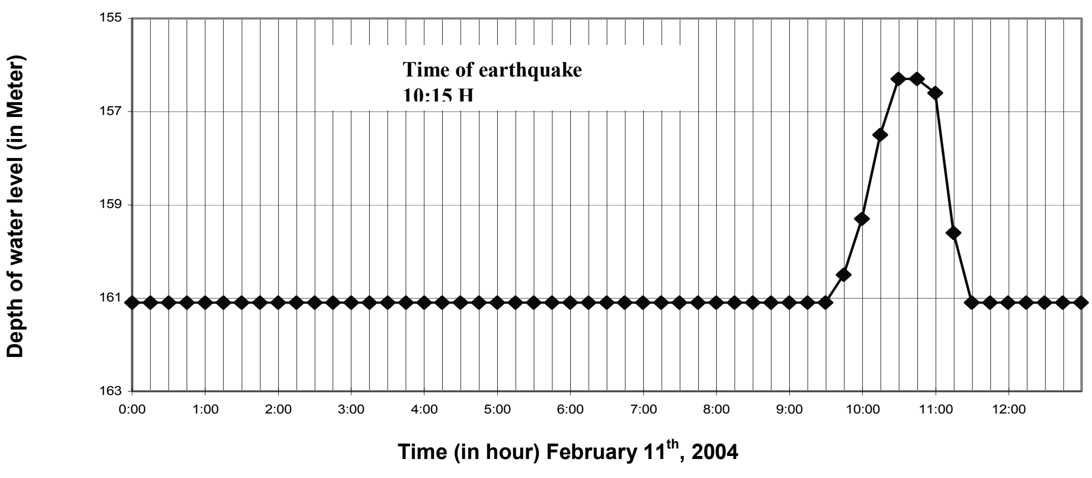

Fig. 2 The Rewaya 6 water level data before, during and after the earthquake.

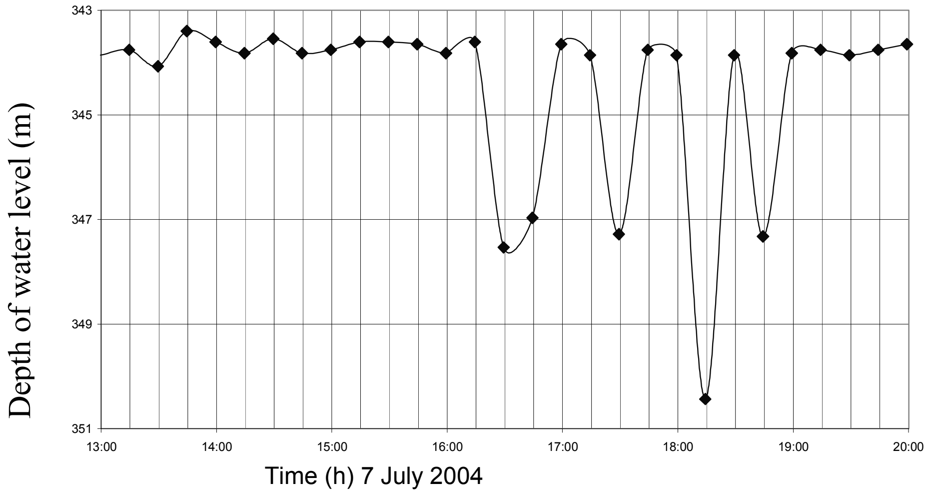

Fig. 3 The Kokhav Hashachar water level data before, during and after the earthquake.

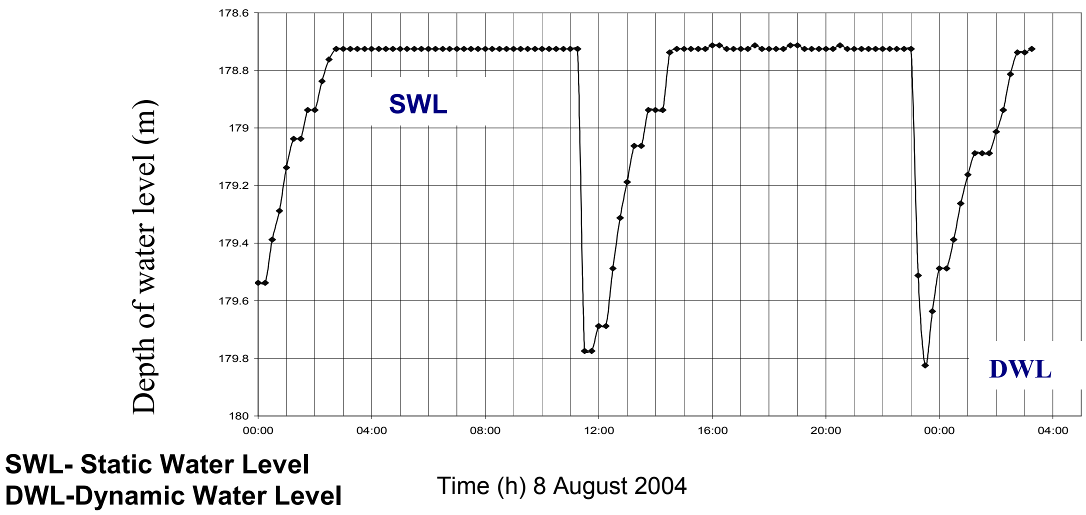

Fig. 4 The Megido 2 water level data before, during and after the earthquake.

the static water level (after the pumping stopped) was achieved only 1 h 15 mins prior to the shock (Fig. 4) and the measurement resolution was in 15-min intervals, we could not come out with clear-cut conclusions. During and after the shock the water level undulated in a few centimetres for 1 h 30 mins as shown on the graphic wavelength response in Fig. 4. Unfortunately due to pumping management a crucial data was missed (Fig. 4).

It is important to mention that these wells are part of a large measurement network that was established by "Mekorot", as part of a system to monitor the static and dynamic water level in their pumping wells. The equipment currently measures water level at precisely 15-min intervals. For earthquake prediction it is important to get the measurements in shorter intervals (few minutes only).

CONCLUSION

Numerous attempts have been made to achieve advanced warning for earthquakes. Studies have been carried out in an attempt to identify precursory signs that involve pre-shocks, geodetic changes, oil and water level changes in wells, geochemical changes, changes in the ratio of P/S waves, radon emission and unusual animal behaviour. To the best of our knowledge all these methods have failed to predict earthquakes. Generally the anomalies attributed to the earthquake were found to appear following the event. In our cases the water level rise and fall in the regional confined aquifer were found to manifest themselves clearly prior to the earthquake, potentially giving a sufficient amount of time to warn the population of the coming quake.

What conditions qualified these three wells to be appropriate as sensors or tools for earthquake prediction? The answer is probably complex and partly beyond our current knowledge. It appears to be a combination of many factors, some known to the authors and other still to be investigated. According to the regional data, the following conditions are of prime importance for prediction success:

- The well should be dedicated to observation only and not connected to a pumping system, and should be equipped with a monitoring device for automatic measurement of water level and/or pressure head.
- The monitoring wells should be located at an appropriate distant from any other pumping wells in order to avoid artificial influence on the static water level.
- The location of the wells is probably crucial for its response. Close proximity to active tectonic features is necessary. In this case the location of the wells is closely associated with major rift faults.
- The aquifer should be a consolidated and karstic one. It also should be under confined condition where the water is derived from elastic reactions of the whole system. In such aquifers the permeability is high and the storativity is low, which "transmit" the flow (and the signal) faster than in unconsolidated aquifers.

REFERENCES

King, C.Y., Azuma,S., Ohno, M., Asai, Y., He., P., Kitagawa, Y., Igarashi, G. & Wakita, H. (2000) In search of earthquake precursors in the water level data of 16 closely clustered wells at Tono, Japan. *Geophysics J.* **143**, 469–477.

Kirschvink, J. & Bull. L. (2000) Earthquake prediction by animals: evolution and sensory perception *Seismology Soc. America* **90**, 312–323.

Muir-Wood, R.(1993) Hydrogeological of earthquake strain. *J. Geophys. Res.* **98**, 22 035–22 068.

Quilly, E. G. & Roellofs, E. A. (1997) Water level changes in response to the 20 December 1994 earthquake near Parkfield California. *Seismological Soc. Am.* **87**, 310–317.

Silver, P. G. & Wakita, H. A.(1996) A search for earthquake precursors. *Science* **273**, 77–78.

Yechieli, Y. & Bein, A. (2002) Response of groundwater systems in the Dead Sea Rift Valley to the Nuweiba earthquake: changes in head, water chemistry and near-surface effects. *J. Geophys. Res.* **107**(B12), 2332–2342.