EARTH FISSURES CAUSED BY GROUNDWATER WITHDRAWAL IN SARIR SOUTH AGRICULTURAL PROJECT AREA, LIBYA

by

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ABSTRACT

Sarir South agricultural well field consists of 157 production wells constructed in double rows running east to west. Each well was designed to pump 76 l/sec to irrigate 80 hectares of winter and summer crops. Large volumes of water have been pumped from the aquifer since 1975. By 1990, water levels in the most heavily pumped areas had declined more than 6 meters. These large water-level declines have caused compaction of compressible fine-grained deposits within the aquifers.

Earth fissures were reported in the Sarir South agricultural project as early as 1982. These fissures were mainly caused by lowering of the piezometric heads due to the withdrawal of groundwater. The fissures range in width from 2.5 cm. to 100 cm. on the surface and, generally, become narrower with depth. However, the total depth is not known for any of the fissures.

Development of new cracks or fissures near the old ones has also been observed. Most of the recent fissures occur parallel and immediately adjacent to the older fissures. It appears that these fissures tend to develop into a linear fissure system in a north-south direction.

RÉSUMÉ

Le champ captant du sud de Sarir, destiné à l'irrigation, est constitué de 157 puits d'exploitation, disposés en deux rangées orientées est-ouest. Chaque puits est équipé pour pomper 76 l/sec pour irriguer 80 ha de cultures d'hiver et d'eté. Des volumes considérables d'eau ont ainsi été pompés dans l'aquifère principal depuis 1975. Depuis 1990, le niveau piézométrique dans les zones les plus sollicitées est descendu de plus de 6 m. Cet abaissement important a provoqué dans les aquifères une compaction des dépôts compressibles à grains fins.

Dès 1982, le sol de cette région s'est fissuré. Ces fissures proviennent pour la plupart de l'abaissement de la surface piézométrique sous l'effet du pompage de l'eau souterraine. Ces fissures sont larges de 2.5 à 100 cm. en surface et se rétrécissent en profondeur. Leur profondeur totale n'est pas connue.

De nouvelles fissures apparaissent au voisinage des anciennes. La plupart d'entre elles sont parallèles et adjacentes aux anciennes. Engin, les fissures tendent à former un ensemble linéaire orienté nord-sud.

INTRODUCTION

Sarir South agricultural project is one of the largest projects implemented in the southern Libyan desert. It is located approximately 600 kms southeast of Benghazi, lying between longitudes 22° 30E and latitudes 26°30' and 27° 15'N.

The well field consists of 157 production wells, each 300 m deep, which were constructed in double rows running east to west. Each row is 10 kms apart and contains 12 to 17 wells with a spacing of 2.5 kms (Figure 1). Each well is constructed to pump

76 l/sec and is fitted with a self-propelled sprinkler that spreads over 80 hectares at a variable speed in order to grow wheat and summer crops.

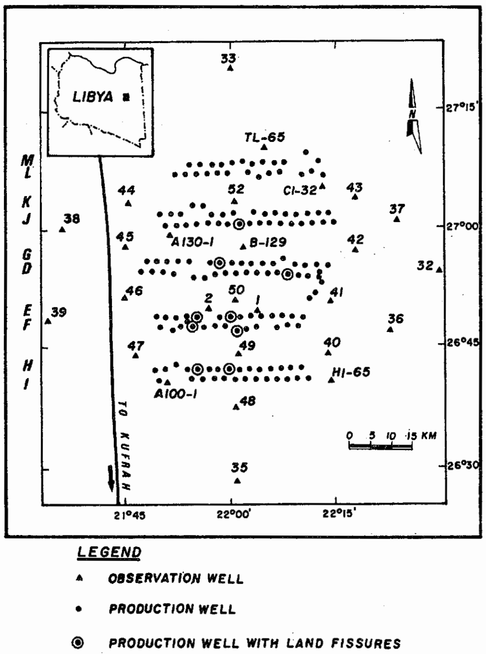

Figure 1. Location map.

The water-bearing formations of (Post-Middle and Lower Middle) Miocene sediments in the Sarir South agricultural well field consist of two main shallow and deep aquifers. The shallow aquifer is under a water-table condition and consists of unconsolidated sediments. It is separated from the deep aquifer by aconfining layer, consisting of intercalated grey clay, silty clay, siltstone and thin layers of sandstone. The thickness of confining layer is approximately 30 to 100 meters.

The deep aquifer is multi-layered and consists of unconsolidated and semi-consolidated sediments, which include light brown sand, silty sandstone and gravel intercalated with siltstone and light brown to grey clay or shale. The saturated thickness penetrated by the production wells is approximately 140 m. The transmissivity ranges from 870 to 2100 m^2/d, with an average of approximately 1500 m^2/d, and the storage coefficient ranges from 0.001 to 0.0006. The aquifer functions as a confined aquifer during short-term pumping, while leakage from the upper aquifer is observed during long-term pumping.

Pumping of groundwater in the Sarir South agricultural well field began in May 1975 with only a few production wells. In 1978, most of the wells were in production. By 1990, approximately 1654 million cm. of ground water had been pumped from the deep aquifer.

In February 1982, the first earth fissure was observed near the production well G-10. Further cracks have been observed in the vicinity of production wells J-10, E-7, E-10, F-8, F-11, D-3, H-8 and H-11. The earth fissures first appeared as narrow and shallow cracks that generally were less than 10 cm wide or as an alignment of shallow holes or sink-like depressions that are typically less than 10 cm. in diameter.

GEOLOGY

The study area is a part of the Sirte basin. Deposits range in age from Pre-Cambrian to Tertiary. The simplified geological sequence is as follows:

Tertiary deposits
Upper-Cretaceous deposits
Palaeozoic deposits
Pre-Cambrian basement rocks

The Tertiary deposits form approximately 60% of the stratigraphic sequence in the area. Thickness ranges from 1500 to 2000 m. The upper part of these deposits is the Post-Eocene sediments, which consist of thick layers of sandstone intercalated with silt, clay and thin layers of limestone. The thickness of these sediments ranges from 500 to 1000 m. The Post-Eocene section is underlain by the Eocene rocks, which consist of limestone and dolomitic limestone.

Regional geological and structural studies indicate that the trend of existing faults is towards north-northwest. The available data of earth fissures in the Sarir South agricultural project indicate that the structural activities have no control on the occurrence of earth fissures.

GROUND-WATER ABSTRACTION

The average rate of discharge from all of the production wells ranges from 60 to 90 l/sec. The maximum rate of abstraction occurs during the peak irrigation period, from October to April.

To date, approximately 1654 million cm. of water have been extracted from the Sarir South agricultural well field since pumping started in May 1975 to the end of December 1990 (Figure 2).

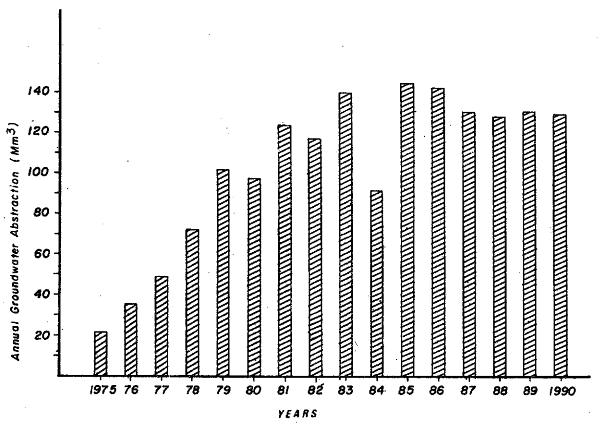

Figure 2. Annual groundwater abstraction at Sarir South well field.

WATER-LEVEL DECLINE

Ground-water extraction has caused water-level declines in wells throughout most of the project area. These changes in potentiometric surface led to many observation wells being drilled in the project area (see Figure 1).

Water levels in the production wells decline approximately 20 to 45 meters during the pumping periods. In general, since the project started in May 1975 to April 1987, the decline in water level of the deep aquifer ranged from 1 to 6 meters.

Figures 3 and 4 illustrate the decline in water level for the shallow and deep aquifers in the Sarir South well field. Figure 5 shows the hydrographs of selected piezometers.

It is believed that the water-level declines caused compaction of fine-grained sediments (silt and clay) within the aquifer. Consequently, a significant amount of land subsidence has produced extensive areas of earth fissures.

The extent of earth fissure area and cone of depression reflect the relation between the two. The centers of drawdown and occurrence of earth fissures indicate a correlation with ground water exploitation.

EARTH FISSURES

Earth fissures in the Sarir South well field were first observed near production well G-10 in February 1982 by the Sarir production project's hydrogeologist. It was reported that the cracks initially

appeared as a tiny sand crater and joined later to form a crack. The cracks appeared narrow and shallow, approximately 1 to 2 cm wide and 3 to 5 cm deep, aligned in arcuate fashion approximately 1.2 kms north of G.10.

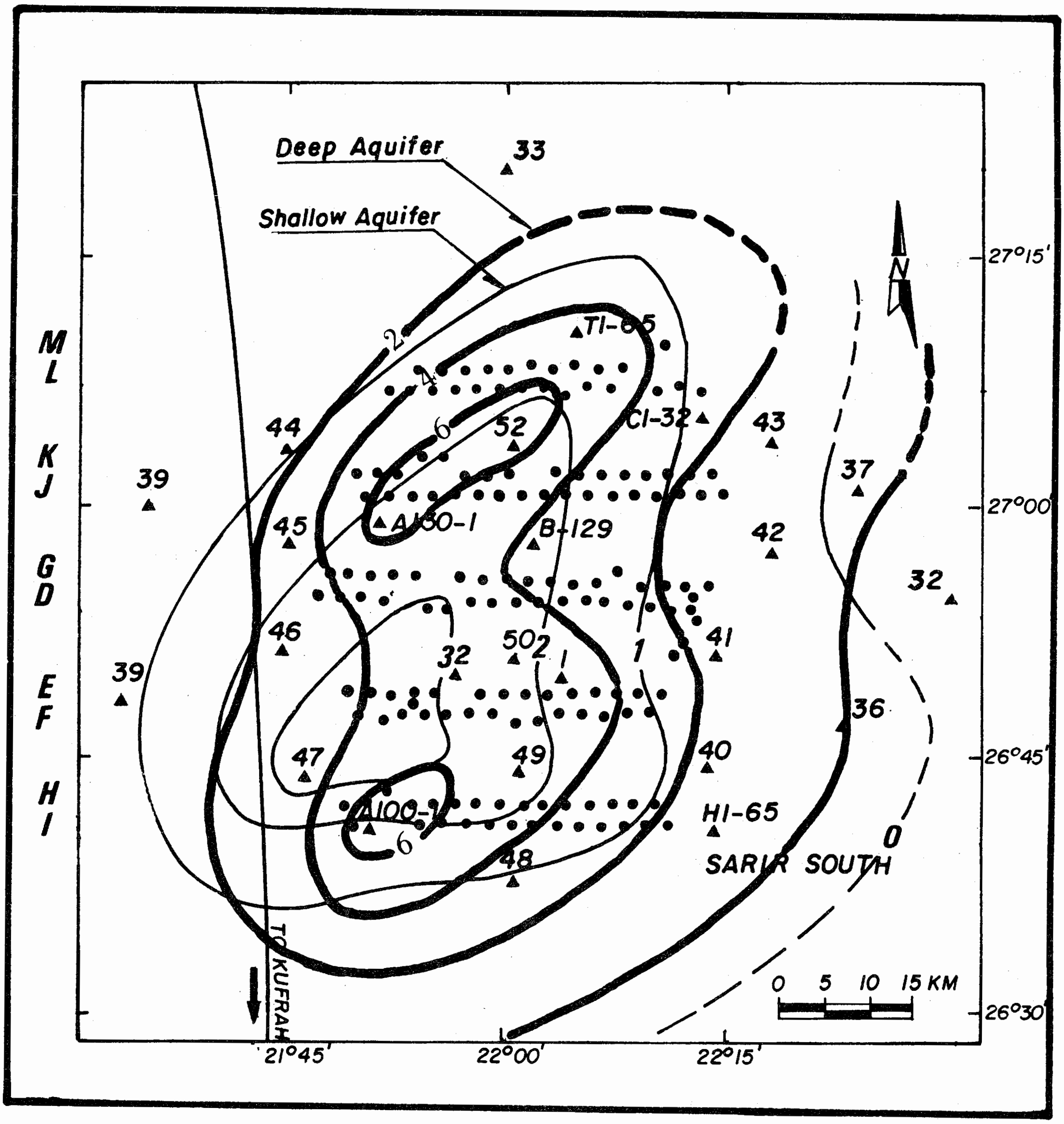

Figure 3. Decline in water level in meters from start of pumping to April 1982.

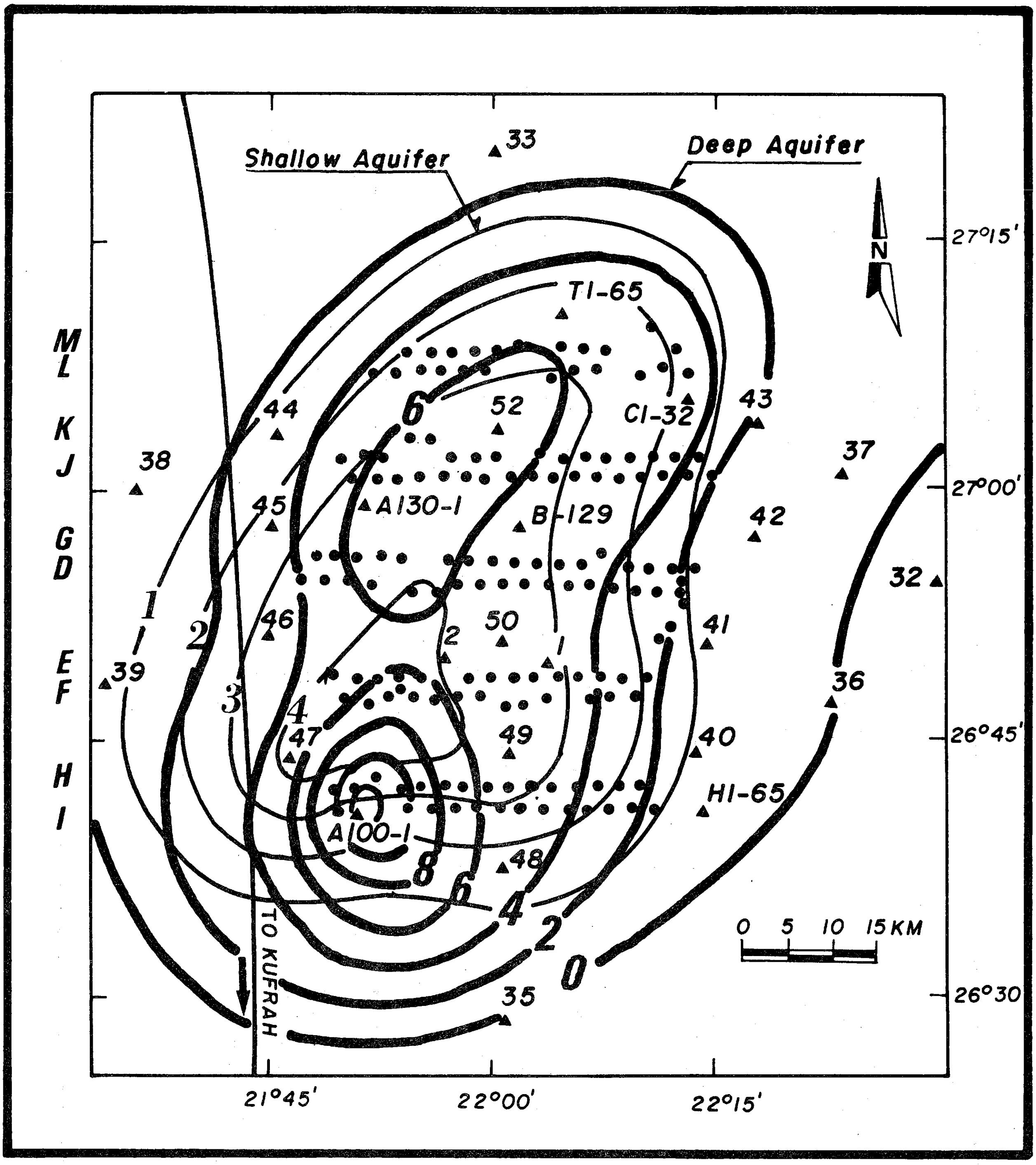

Figure 4. Decline in water level in meters from start of pumping to April 1987.

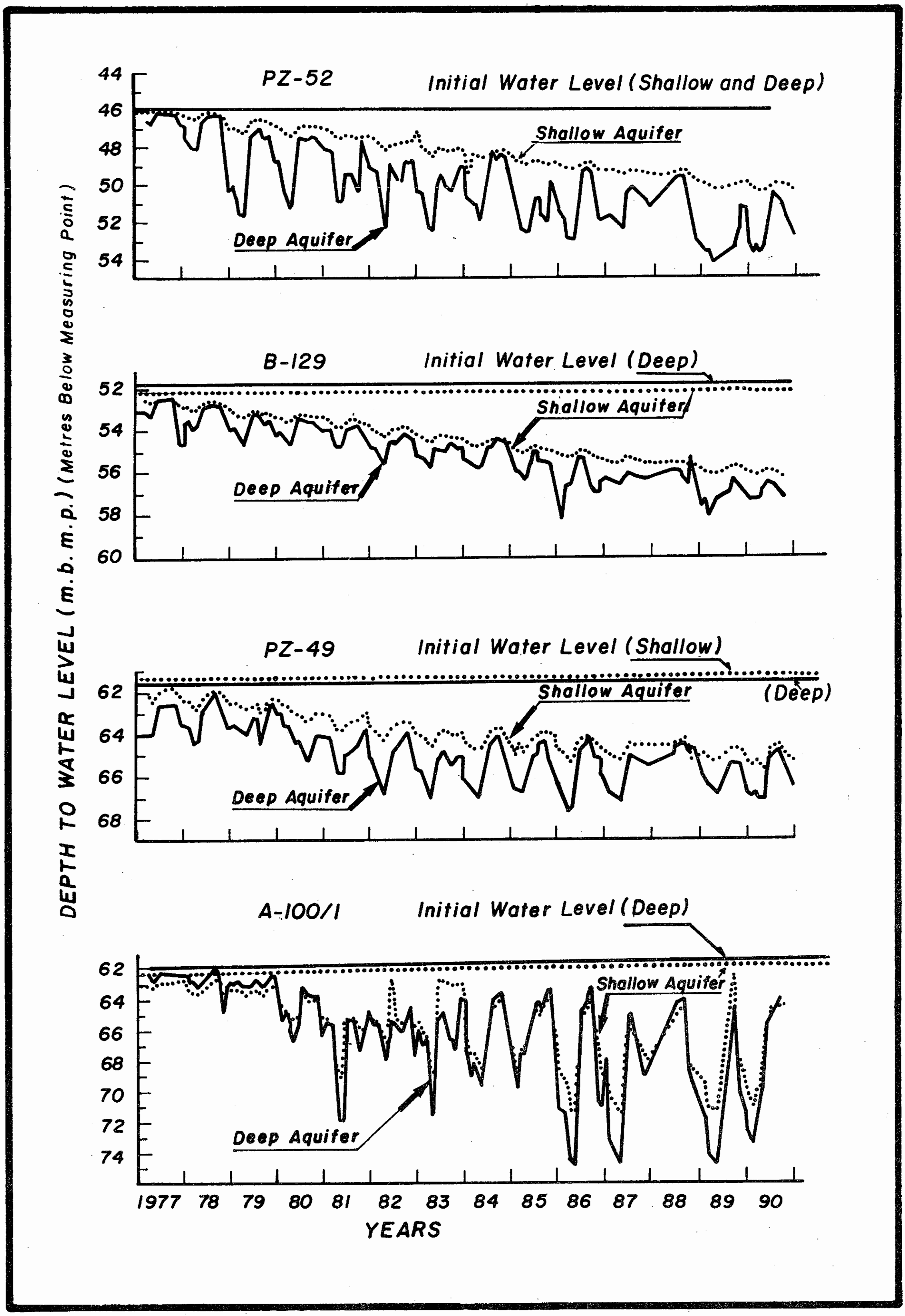

Figure 5. Hydrographs of selected piezometers.

By March 1983, further fissures had been observed in the vicinity of production wells E-7, E-10, F-8, F-11 and D-3. In 1985, other fissures were observed near production well J-10. New fissures were also observed in October 1987 around the periphery of production wells H-8 and H-11.

Most of the earth fissures occur at a distance of 40 to 150 meters beyond the edges of the crop areas. The fissures appear to be simple tensional breaks with no vertical or lateral offset and range from a few meters to more than one kilometer in length.

Development of new fissures near the old fissures has also been observed. Most of the recent fissures occur parallel and adjacent to the old fissures. Gradually, the old fissures were filled by the loose sand at the surface until they finally disappeared.

The fissures are concentrated in the area where the greatest amount of water-level decline is observed. They occur on the periphery of the cone of depression where the drawdown exceeds 6 meters. Moreover, these fissures tend to develop into a linear fissure system extending in a north-south direction. The observed earth fissures could be the surface expression of basin subsidence caused by water-level declines due to the ground-water withdrawal.

Prediction of occurrence of new earth fissures on the basis of water-level decline appears to be possible. Figure 6 shows the areas where land subsidence and fissures are expected to develop, due to lowering of water level, as a result of large-scale ground-water extraction.

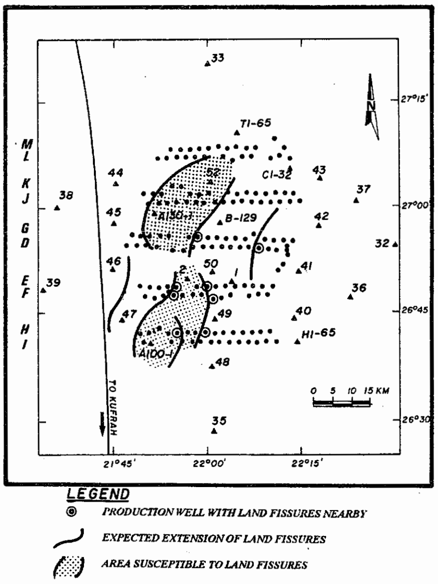

Figure 6. Map of areas where land subsidence and fissures are expected to occur.

CONCLUSIONS AND RECOMMENDATIONS

1. The earth fissures have occurred in the Sarir South area as a result of aquifer compaction from declines in groundwater levels. This is apparent from the concentration of the earth fissures in the area with the greatest amount of water level decline. Most of these fissures are simple tensional breaks formed along the edge of an advancing subsidence front caused by water level decline due to groundwater extraction. Development of new fissures parallel and adjacent to the older ones has been detected. The old fissures were gradually filled by loose sand at the surface and finally disappeared.

2. Throughout the monitoring of water-level fluctuations in existing piezometers, the maximum decline in water level occurs during March and April, and the minimum decline of water level occurs during August and September. Hydrographs of selected piezometers show a periodic fluctuation every year. The rise and fall of the piezometric head may cause the expansion, rebound, consolidation and compaction of the aquifer material.

3. Continued ground-water depletion will result in continued land subsidence. Enlargement and extraction of existing earth fissures and formation of new fissures can be expected.

4. Earth fissures should be mapped in detail by using large-scaleaerial photographs or land-sat images. These photographs would provide valuable information about the location, nature, orientation and development of the earth fissures.

5. A benchmark net should be designed to cover the areas subject to fissuring or expected to be subsiding.

6 Compaction recorders (extensometers) should be installed in the area expected to be subsiding. Compaction of aquifer material can be estimated from core tests. The tests should include consolidation characteristics, physical and hydrologic properties and petrographic analysis.

7. The relations between water-level change, aquifer compaction and land subsidence or earth-fissure occurrence should be monitored and measured.

8. Groundwater pumpage should be managed so that the occurrence of land subsidence or fissures is minimized.

ACKNOWLEDGMENTS

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