4.10. Spatial and temporal analysis of groundwater

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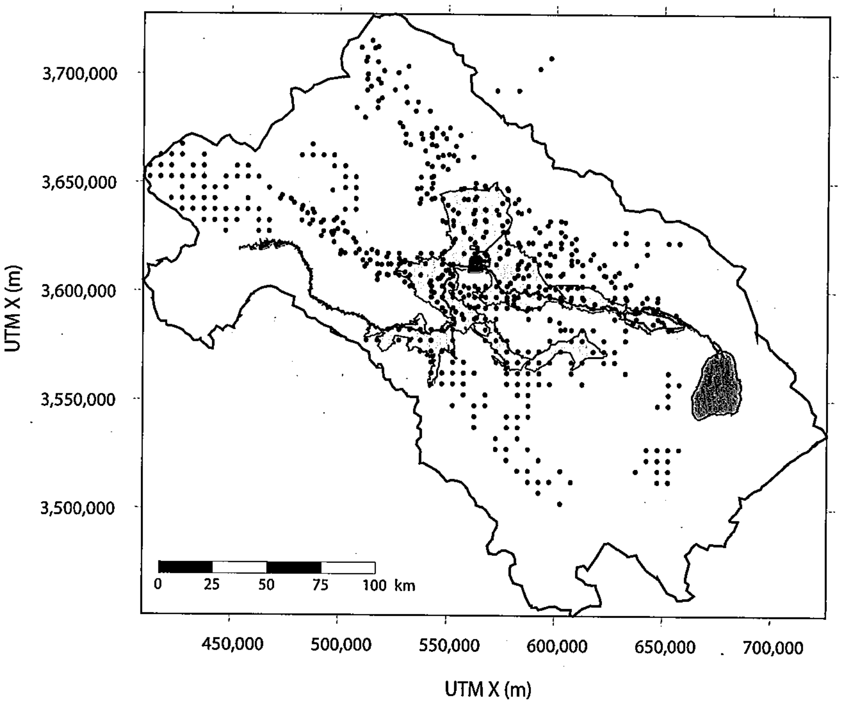
Using the data provided from the Ministry of Energy on monthly observations from 717 wells over a 10-year period, it is possible to make a number of observations on spatial and temporal changes in groundwater from 1990 up to 2000. The distribution of these observation wells and their relationship to the irrigation systems is shown in figure 4.34.

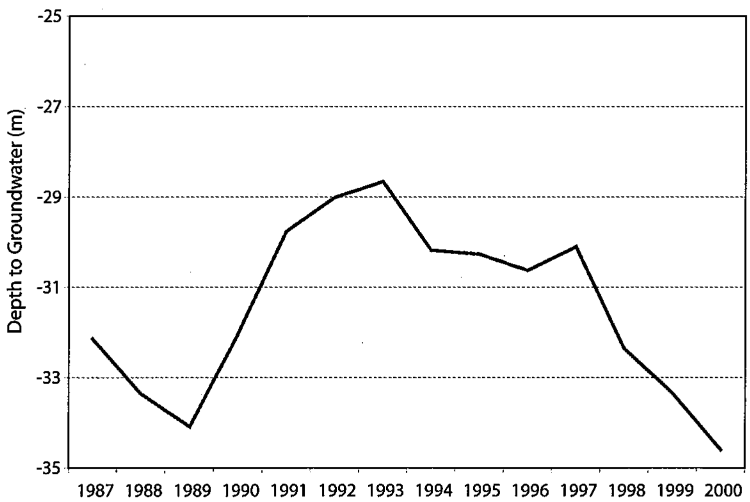
Figure 4.34. Location of groundwater observation wells and major irrigation systems, Zayandeh Rud Basin.



In water-short basins, groundwater becomes an important additional source of water to supplement surface water supplies, but it is also a vulnerable source because it is easy to deplete aquifers. Aquifer recharge may be through the natural processes of rainfall and snowmelt or through the artificial recharge from irrigation systems where water application is greater than evapotranspirative demand. These two sources of water represent the sustainable maximum yield of an aquifer, and withdrawals in excess of this total will result in declining water tables and may eventually result in long-term damage or destruction of the groundwater resource.

It is clear that in the Zayandeh Rud basin there is not only substantial groundwater exploitation but also a real risk that groundwater resources are under severe stress. Average data for all wells, irrespective of location in the basin, indicate a sustained decline in the

Figure 4.35. Average water table depth in irrigated areas of Zayandeh Rud, 1991-2000.



order of 0.75 m yr^{-1} (figure 4.35.), even excluding data for 1987 where there are relatively few observation points. To determine whether this risk is genuine or not, the data-set as it applies to the irrigation systems was analyzed in two main ways: analysis of longer term trends in water tables over the whole 10-year period, and an analysis of within-year changes in water-table depth.

4.10.1. Analysis of long-term changes in irrigated areas of Zayandeh Rud

To assess the extent to which there are long-term trends in water-table decline within the irrigated areas of the Zayandeh Rud basin, the data were processed to obtain the maximum water-table depth for each observation well within each hydrologic year (i.e., from October 1 to September 30). The maximum level recorded gives an indication of the extent to which the groundwater is under stress. To obtain average values, all data were kriged within ILWIS and a surface obtained for groundwater levels within the irrigation systems. The final step in the analysis was to estimate the total area within each system underlain by a particular water table depth. The results are presented in figure 4.36.

The overall trend can be observed by comparing the lowest water table depths in 1991 with 2000 and determining the difference in lowest water table over the 10-year period (figure 4.37.). It is obvious that some areas are under considerable stress while others are relatively unaffected.

Figure 4.36. Average depth to lowest water table each year in each irrigation system.

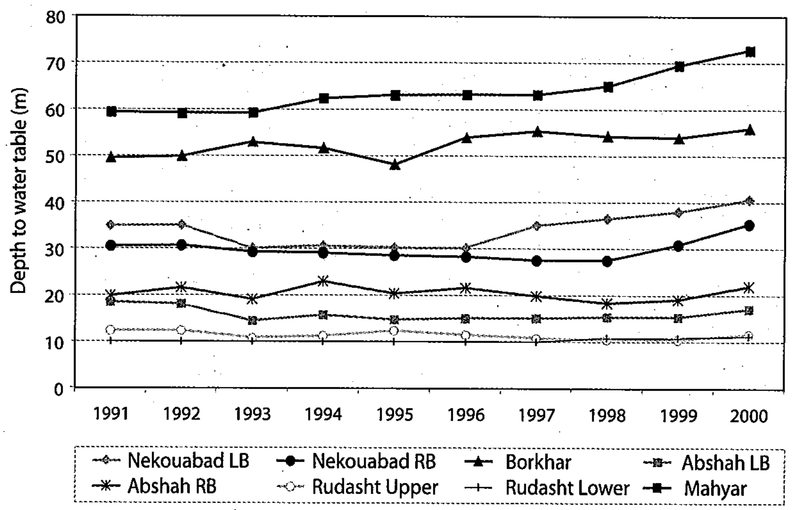
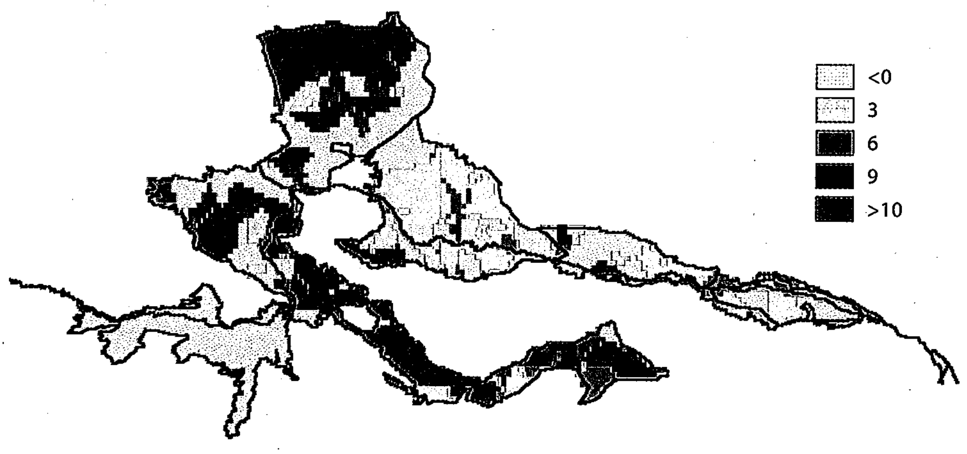
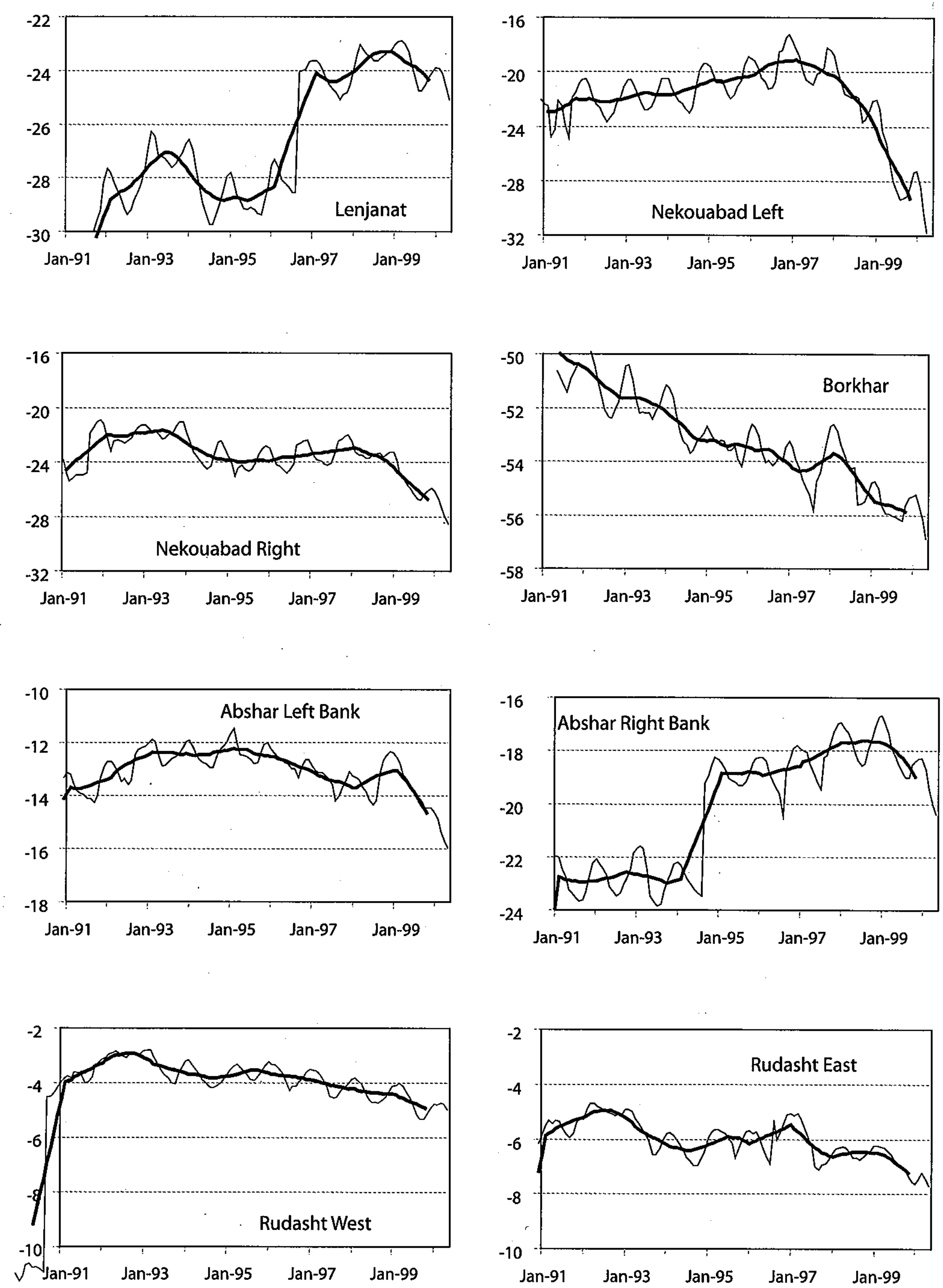


Figure 4.37. Change in depth to water table, 1991-2000 in meters.



The recharge of groundwater, either from the Zayandeh Rud or from irrigation systems, is quite apparent. Only a few areas close to the river show water table declines of more than 10m over the 10-year period, but areas away from the river show substantial decline, notably in Mahyar, Nekouabad Left and Right Banks, and in Borkhar. In Abshar and Rudasht, however, overall declines are much less due to the naturally high water table in the flatter part of the basin before the river reaches Gavkhouni swamp. A change of over 1m per year implies that at least 100mm of water has been extracted each year in excess of natural recharge.

Figure 4.38. Groundwater trends for the main irrigation systems obtained from gridded data.



Note: Nekouabad graphs have a range of 16m on the y-axis, all others are 8m.

The actual trends for eight different irrigated areas in the basin can be seen in figure 4.38. Borkhar shows a steep and steady decline through the past 10 years of up to 1.0 meter per year, no doubt due to high rates of pumping for irrigation, while the two Rudasht systems show a slower decline because pumping is reduced due to groundwater salinity. The two Nekouabad systems and Abshar Left Bank show a rise during the first part of the 1990s followed by a decline, which is particularly marked from 1997 onwards as the effects of the drought begin to be felt. Lenjanat and Abshar Right Bank show a somewhat anomalous trend in that there is a substantial rise in the water table during the 1990s and little overall decline during the drought period.

This trend in Lenjanat is analyzed separately in section 4.11 but appears related to recharge from the Zayandeh Rud itself. In other locations, the flow in the river is so low for much of the year that groundwater recharge is negligible.

4.10.2. Analysis of within-year changes in water table levels in irrigated areas

The annual variation in water table from high to low conditions during the year also gives an indication of the stress under which the groundwater resource is being placed. For the year 2000, a severe drought year, the difference between January and June is quite dramatic. The average depth to the water table over the whole of the Nekouabad Left Bank system is illustrated in figure 4.39.

Figure 4.39. Average water table depth, Nekouabad Left Bank, Jan-June 2000.

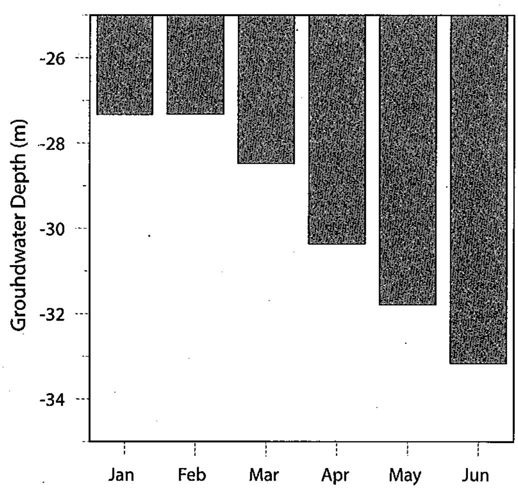


Figure 4.40. Change in depth to water table (m) in irrigated areas of Zayandeh Rud, January and June 2000.

Figure 4.40 shows the difference in depth to water tables in January and June 2000. The depletion of the water table in western Nekouabad Left Bank is obvious, with a combination of declines of up to 10 meters in only 6 months. This rate of abstraction, presumably for agriculture, drinking water and industrial uses, is far in excess of the annual recharge. Given that the water table in part of this area is more than 50m deep, we can be very sure that groundwater is being mined and will be difficult to recharge.