1 INTRODUCTION

1.1 Background

The Government of Uzbekistan maintains an intensive groundwater (GW) monitoring system throughout the country, including the Khorezm region, one of the smallest administrative districts of the country. Continuous records are provided for both GW depth and salinity. More than 240,000 ha out of the total of 275,000 ha of irrigated land in Khorezm are under the control of a large number of staff in each district. Every year, substantial financing is directed to the maintenance and operation of a large number of monitoring wells (2300 units in 1990) from the state budget given to water management agencies. This great attention paid to GW is due to the fact that GW is one of the important components of the agricultural system in the region (Kats 1976; Nurmanov 1966).

As in other regions with similar (semi)arid climates, GW provides additional sources of water for irrigation through pumping. However, the peculiarity of GW in Khorezm is its rapid rise after irrigations and shallow position throughout the growing period from April till September, extremely slow lateral flow due to low hydraulic conductivity in the upper part of the soil and small slopes and intensive accumulation of salts (Kats 1976). Shallow saline GW and a constant capillary rise due to evaporation is one of the main mechanisms of soil salinization processes, resulting in reduced land productivity. Therefore, an intensive irrigation and drainage network is maintained to leach the salts from the soil and GW and remove them out of the area. This network is apparently not efficient, because the areas with moderately and strongly saline soils covering ca. 50% of the region did not significantly differ between 1990 and 2000 (GME report, 2001).

Despite the importance and relatively large investments into GW monitoring, data analysis is under-developed. It takes weeks, if not months, to manually draw paper maps of the GW table (or salinity) after the data have been processed. The base paper maps were prepared more than 10 years ago (personal communication with GME staff) and are extremely outdated, because the irrigation and drainage networks have undergone (re-) construction changes, new irrigated areas have appeared or been reallocated, and some lakes disappeared in the periphery of the region (Dzhabarov

1990). The readings are usually recorded on paper. The transfer of the readings to the maps is subject to errors and the controlling opportunities are reduced. Local specialists have drawn maps based on the linear interpolation between data values utilizing the interpolation method of triangulated irregular networks. Apart from many errors, these maps become rapidly outdated, as GW fluctuations are very dynamic. Computerized data processing approaches are not yet introduced aside from a data coding procedure. This restricts data analysis to a simply static comparison of the readings of previous with those of current years. The use of modern (geo)-statistical methods of analysis and mapping would allow a statistically-based identification of cause-effect relationship of the irrigation and drainage resources.

This study forms one component of a multidisciplinary research development project on the current situation in the areas of the lower Amu-Darya River reach. It is well known that enormous diversions and water use from the Amu-Darya River have caused serious environmental problems in the Aral Sea Basin, thereby deteriorating rather than improving, as was anticipated, the economic and social welfare of the people in the region (UNESCO 2000; Vlek et al. 2001). Especially the population in the regions of the lower Amu-Darya River area face acute socio-economic, environmental and particularly health problems. These problems have been attracting the increasing attention of the world research community as they have grown from a local to a global scale. The extent of the problems demands a radical solution, as the former gradual intervention has not led to any success. The research community has been tasked and mandated to investigate the situation in the lower Amu-Darya River Basin. The ZEF/UNESCO research project “Economic and Ecological Restructuring of Land and Water Use in the Khorezm Region (Uzbekistan): A Pilot Project in Development Research” affiliated with the university of Bonn, was initiated to identify economically and ecologically sustainable land and water-use strategies in Khorezm, Uzbekistan, and to encourage local scientific and technological capacity-building (Vlek et al. 2001).

Although the focus of this study is on the GW component, because of the complexity and interlinkage of GW dynamics with other factors it could not be restricted to GW analyses alone. An understanding of the GW dynamics is needed as well as basic intelligence of the efficiency of land- and water-resources use, irrigation and drainage network and the influence of the environmental factors in the region. The cause-effect relationships of the various interlinked components indicate that changes in one could immediately affect the others and thus, the whole system. Therefore, environmental factors and agricultural management practices have been analyzed concurrently to explain the changes in GW.

1.2 Objectives

The main objective of this study is to analyze the long-run sustainability of irrigated agriculture in Khorezm through an analysis of the spatial and temporal changes of GW table and salinity. The following specific objectives/research questions were defined to achieve the main goal of this study:

- To estimate seasonal and long-run temporal and spatial groundwater table and salinity,
- To identify the areas of potential risk from shallow saline groundwater,
- To estimate the accuracy of different interpolation methods in delineating areas with high groundwater table and salinity,
- To establish the factors influencing the spatial and temporal distribution of GW table and salinity, and
- To identify areas characterized by rapid temporal changes in GW salinity (hotspots).

The following are the research questions:

1) To characterize the ameliorative conditions in the region through an analysis of the level and salinity of GW,
2) To analyze the causes for temporal changes in GW table and its salinity,
3) To analyze the causes for the spatial changes in GW table and its salinity,
4) To determine potentially unsustainable irrigated areas based on established patterns of the GW table/salinity dynamics, and
5) To recommend proper management actions in the potentially non-sustainable irrigated areas.

1.3 Outline of the study

Following this introduction, Chapter 2 describes the general aspects and current knowledge of GW flow and salinity dynamics, their peculiarities in Khorezm and existing methods of (geo)-statistical analyses and interpolation methods. The area description and materials and methods are explained in Chapter 3. Data collection and methods used in the analysis are briefly discussed. The area description includes the geographic location, as well as the predominant features of the climate, soils, geology and hydrogeology, irrigation and drainage network and crops grown. Chapters 4 and 5 contain the results of the spatio-temporal analyses of GW table and salinity in Khorezm. The general discussion is given in Chapter 6. Finally in Chapter 7, recommendations for necessary actions to improve agricultural management practices in the Khorezm region are presented.

2 LITERATURE REVIEW

2.1 Characteristics of groundwater with emphasis on (semi-)arid zones

Studies of different aspects of hydrological processes are a special concern of research in the scientific community. Many problems related to water resources exist such as proper allocation of scarce water among competing users, agriculture and environment, its over-exploitation, lack of freshwater and point- and non-point source deterioration of quality. Solving them requires understanding of the processes and improved knowledge of relations among watershed components like rivers, irrigation and GW, hydrology and topography, climate, vegetation, and soil parameters, analysis of their interactions and prediction of possible adverse changes (Wilson et al. 2000).

Groundwater studies have received wide attention, as 97% of the freshwater worldwide is stored underground (UNEP 1996). Groundwater plays an important role as a source for drinking water and for irrigation purposes. In most arid areas where precipitation is low, GW is the only source of water. With population growth, over-exploitation and pollution of GW resources is becoming an increasingly evolving process, which requires urgent intervention and protection.

GW is defined as subsurface water storage. The dynamics of GW depend to a great extent on climate, geology and topography (UNEP 1996; Sophocleous 2002), which are considered as the three main factors in the hydrologic landscape that control subsurface water flow (Sanford 2001). In arid/semiarid climates, natural GW changes occur mainly due to evaporation from the soil surface and transpiration by vegetation, while precipitation and upslope flow determine recharge. In irrigated areas, where the rate and/or spatiotemporal distribution of precipitation are frequently inadequate for farming, recharge occurs mainly through irrigation.

In arid/semiarid regions, GW influences the soil formation processes, moisture and solute transport dynamics and is one of the important factors ameliorating soil conditions (Kats 1976). Irrigation changes the surface and subsurface hydrology causing GW table fluctuation (Bos 1996) and mobilizes salts that are naturally present in the rock and soil (Ghassemi et al. 1995; Hillel 1998, 2000). Rising GW eventually comes close to the soil root zone (ca. top 1 meter), which, with improper management, may lead to waterlogging and salinization through capillary rise (FAO 1996 a; Bos 1996;