Hydrogeological Conceptualization of Seyhan Basin With Regard To Vulnerability to Climate Change

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1. Introduction

Water resources availability and quality and climate change are interlinked. Assessments of impacts of climate change on water resources are generally documented in the literature on an approximate and sketchy basis. This is, to a great extent due to the fact that each natural hydrogeological system has its own uniqueness in terms of factors governing the occurrence and movement of water. Regarding the type of the water resources system, the effective parameters may change not only by category but also by degree. Total annual precipitation and although connected to the total precipitation more importantly the effective precipitation is the foremost leading parameter in water resources. Because, the effective precipitation is directly affected by climate change and directly affects the recharge of the water resources. Apparently, not only the reduction in precipitation but also its spatial and temporal distribution will have adverse effects on the availability and quality of the water resources. In addition to the climatic conditions, effective precipitation is controlled by the hydrogeological framework of the concerned system.

2. The Study Area

Within the framework of the ICCAP project, the Seyhan River Basin was studied with regard to the vulnerability of the available water resources systems to climate change. The basin, having an area of 23 172.8 000 km^2, was first divided into two major parts, according to the water resources types. The area downstream of the Seyhan Dam is a large coastal alluvial plain while the upstream constitutes one of the largest hydrological basins in Turkey (Figure 1.). The basin extends from the Mediterranean Sea coast in the south to the foothills of the Erciyes Mountain in Central Anatolia. Obviously, the climate prevailing over the basin varies from harsh continental type in the upstream section to mild Mediterranean type in the south. Orography together with meteorological conditions controls the extent of effectiveness of different types of climate in the basin. The plain, constituting the groundwater resources is almost flat while the upstream part is mountainous exhibiting steep topography. Hot and dry summers and temperate and rainy winters characterize the plain, while cold and snowy winters are typical in the northern-upstream part.

3. Hydrogeological Setting

Two major water resources systems exist in the Seyhan River Basin. The Seyhan Dam located at the northern edge of Adana city can be regarded as the approximate divide between the groundwater system and the surface water system. The groundwater system occurs in the alluvial plain extending from the Seyhan Dam site to the Mediterranean in the south (Fig. 1). The plain geologically is composed of alluvium deposited mainly in deltaic and fluvial environments. Clearly, the tectonic development of the country is reflected in the deposition, because the thickness of the alluvium exceeds 1000 m. in some places. The surface area of the alluvial plain is 2211.9 km^2 corresponding to about 10 % of the total area of the basin. Owing to the heterogeneity that is evident from the boreholes, the groundwater reservoir is constituted by more than one aquifer separated by less permeable layers. On the other hand, because the lithological layer covering the upper aquifer is not homogenous, the aquifer is confined in some areas. That is the groundwater system is a multilayered system partly unconfined in the north and confined in the southern part. The general hydrogeological structure is depicted on a cross-section in Fig. 2. As seen form Fig. 2, the hydrogeological behavior of the boundary between the groundwater system and the Mediterranean Sea is not clear and should be defined. The physical and chemical composition of the groundwater measured in the private boreholes reveals the existence of the multilayered groundwater system. In Fig. 3, the measured electrical conductivity values in Adana Plain are shown together with the depth of the groundwater bearing units. The EC and chemical composition of the groundwaters of different depths imply at least three hydrochemically separate units.

As stated by Ekmekçi et. al (2004) in this volume, an accurate definition of the boundary conditions of a system is essential in the study on impacts of climate change not only because the vulnerability of a groundwater system to climate change is related to the boundary conditions of the system, but also because an accurate assessment of the response of the system to any change in its components, such as recharge as long as climate change is concerned.

The surface water resources in the Seyhan River Basin originate from the runoff of the hydrologic cycle. This potential depends to great extent upon the physiographical and meteorological conditions of the basin. In addition to the type and spatial and temporal distribution of precipitation, vegetation, land-use, soil type, underlying lithology, slope, and basin characteristics such as area, shape, drainage patterns and density etc. controls the occurrence of the runoff and the storage capacity of the basin (Maidment, 1993). Geologically the upper basin comprises lithological units representing a time span from Paleozoic to Quaternary (Figure 4).

The Paleozoic is represented by carbonates and schists. Mesozoic units are made up of mainly carbonates and ophiolitic rocks while the extensive clastics, carbonates and evaporitic lithologies represent the Cenozoic units. Volcanic rocks are of Neogene age. Alluvium, morain and slope wash are of Quaternary age. The carbonate rocks that form karst aquifers constitute 6758.3 km^2 corresponding to about 30 % of the whole basin.

In the higher elevations of the basin, the precipitation falls in the form of snow. In addition to its contribution to the runoff, the importance of the snowmelt stems from the fact that karst groundwater system contributes in significant amounts to the streamflow through numerous huge karstic springs. The karstic groundwater systems (aquifers) are recharged by the snowmelt as well as rainfall. Therefore, the change in type of precipitation should change the recharge conditions of karst aquifers which in turn will alter the stream flow regime of the Seyhan River.

4. Plausible Impacts of Climate Change

Regarding the hydrogeological setting of the study area it is possible to speculate on the parameters that may be vulnerable to climate change.

As far as the groundwater system in the alluvial plain is concerned, two major factors seem to play essential role in assessing the impact of climate change: the boundary conditions of the aquifer and the mechanism of recharge. The upper boundary of the aquifer is made of pervious and impervious units in different parts. That is, in some part the aquifer is open to receive the effective precipitation directly while the precipitation onto the confined part does not infiltrate to recharge the system. The confined part will also be closed to infiltration from irrigation. As regard to the connection with the sea, although the aquifer is bounded by the sea in the south, groundwater flow into the sea does not occur all along the coastline because impervious lithologies may form barriers in some sections. Lithological variation with depth may also affect the sea water intrusion at different layers of the aquifer. Therefore, it is of vital importance to characterize the boundary conditions along the sea cost to be able to assess the effect of sea level rise expected due to the climate change.

The actual recharge of the aquifer seems to be by infiltration from direct precipitation and by seepage from the Seyhan River Basin where it flows over permeable units. However, the hydrogeological behavior of the northern boundary of the alluvium plain is not clear yet. In case of deep inflow from the upper basin to the plain, impact of climate change on the water resources in the upper basin will ultimately be also effective in the alluvium plain aquifer. This proves once again that an accurate hydrogeological conceptualization to represent the real system is essential in assessing the impact of climate change on water resources.

On the other hand, it is obvious that reduction in total precipitation will adversely affect the recharge to the aquifer. However, based on the conceptualization briefed above, even if the precipitation rate is not reduced, if the frequency and the type of precipitation is changed, recharge of the aquifers (karstic and alluvial) will be altered because the recharge will be limited to the infiltration rate of the overlying lithological units. Similarly, recharge from seepage from the Seyhan river bed will also be altered because of the expected irregularities in the flow regime of the river as a consequence of the impact of the climate change to the surface water resources in the upper basin. The adverse impact of the heavy use of the plain for agricultural production on the other hand will be more pronounced in terms of quantity and quality of the groundwater. Because, as the recharge rate is decreased and the evapo-transpiration rate is increased due to climate change, the infiltration of the return waters will be induced and the groundwater quality will be more degraded in the shallowest unconfined aquifer. The surface water resources in Seyhan River Basin are fed by three major sources: direct runoff, snowmelt and karstic springs. Owing to the areal extent and the morphology of the basin, the hydrological behavior of the basin is dependent largely on the snowmelt and the karstic discharges. Small basins that discharge direct runoff are more susceptible to the change in precipitation frequency. Large basins fed by groundwater may compensate the change in precipitation regime, limited to the capacity of the aquifer supplying groundwater to the river. Although karstic aquifers are more vulnerable to climate change than granular aquifers, in Seyhan basin, the karstic aquifer has large storage and long residence time so that it should compensate to a certain extent the change in frequency of precipitation. However, the change in precipitation type, from snow to rain will alter the flow regime of the river and will adversely affect the recharge of the karstic aquifer. Analyses suggest that the vulnerability of the surface water resources in the Seyhan River Basin related to the type of precipitation as well as the regime itself. Finally, land use and vegetation cover of the basin play an important role in the availability and quality of the surface water potential, particularly for that part originates from direct runoff.

5. Conclusions

The water resources of the Seyhan River basin are evaluated under two categories according to their existence: surface waters and groundwaters. Groundwater systems occur in two different types of aquifer. In the upper basin the carbonate rocks form extensive and high capacity karst aquifers which are fed by snowmelt as well as rainfall. Large discharge karstic springs have a significant share in contributing to the surface water resources in the upper basin. It is important to take this hydrogeological-hydrological relation into account in assessment of the impact of climate change.

The groundwater system in the alluvial plain occurs in a multilayered confined-unconfined aquifer system. The mechanism of recharge to this system still needs some clarifications in terms of whether the northern edge is pervious thereby the upper system contributes to the alluvial aquifer or the recharge is merely from direct infiltration from precipitation onto the plain and the seepage from the Seyhan River in the unconfined part. Isotope analyses are essential to clarify this question.

Detailed analyses of these parameters and their effects on the availability and quality of the water resources in Seyhan River Basin will be achieved after completing the mathematical models of the water resources systems separately. The hydrogeological framework of the systems should be considered as bases for the mathematical models.

6. References

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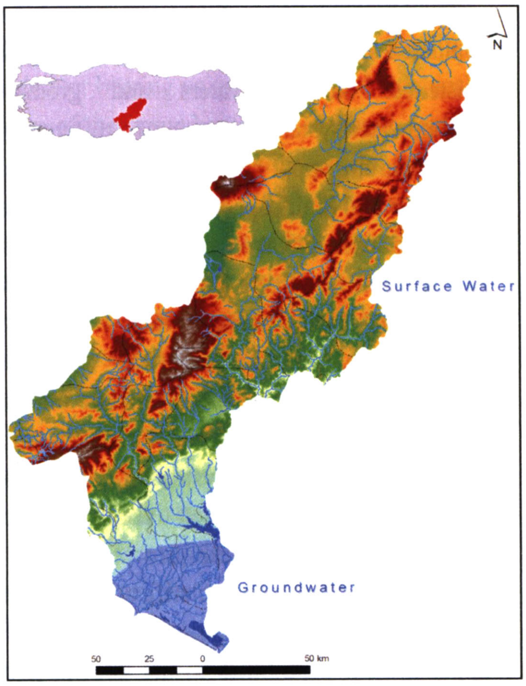

Figure 1. Location and division of the water resources by type in Seyhan River Basin

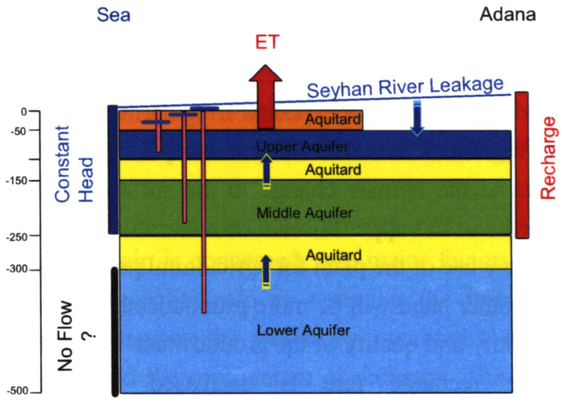

Figure 2. Simplified geological cross-section of the Adana Plain conceptualizing the hydrogeological structure

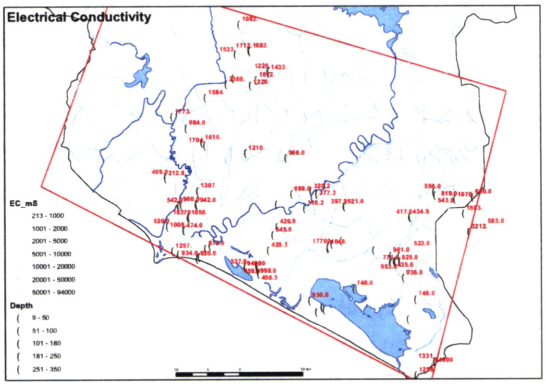

Figure 3. The electrical conductivity distribution of the groundwater in Adana Plain

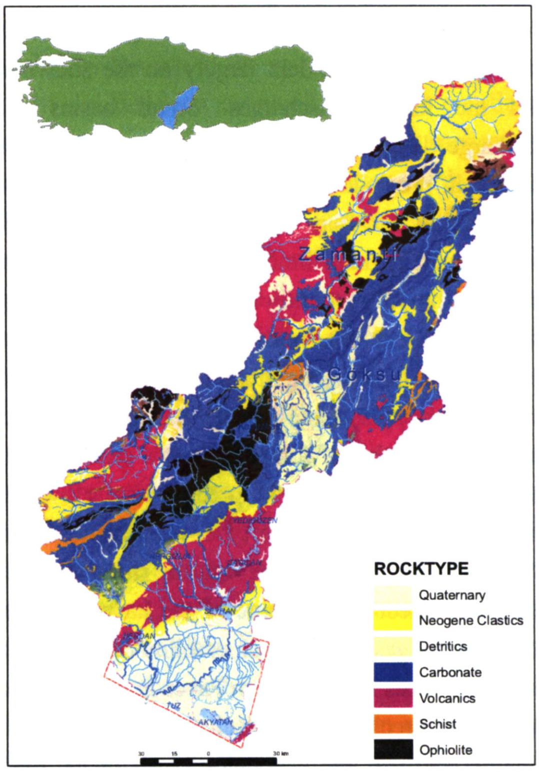

Figure 4. Simplified Geological Map of the Seyhan River Basin