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Water Quality Evaluation Modeling for the Hablehrood River under Various Hydrological Conditions

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Abstract: Rapid population growth and industrialization in central Iran has caused serious damage to many sources of fresh water. One such water source is the Hablehrood River, which is relied upon for both drinking and agricultural water throughout a large region. In recent years, pollution has increased phosphate and nitrate levels in the river, such that the river's restoration has become a prime objective of the United Nations Development Program (UNDP). For this study, a model based on the US-EPA QUAL2K model was developed in order to track changes of nitrate and phosphate concentrations under different hydrological conditions. These hydrological conditions were identified by calculating the Standard Precipitation Index (SPI) with normal distribution in four different locations along the Hablehrood River. The results from this model show significant water quality degradation during dry conditions. By using this model to predict water quality, more effective water management strategies can be developed, which can help improve water quality in the region.

Key words: Hablehrood River, hydrological conditions, nitrate and phosphate pollution, QUAL2K modeling, standard precipitation index

1. Introduction

The Hablehrood River satisfies the demand for both drinking and agricultural water in Tehran Province, and also influences the economy and prosperity of the region (Fig. 1). The river basin is located between 35°60'N, 52°12'E and 35°15'N, 53°9'E, which is divided into upper, middle, and lower sections. The areas of each section are about 1600 km^2, 900 km^2, and 700 km^2, respectively. In recent decades, rapid population growth, along with the industrial and urban development of the region, has caused a serious decline in water quality in the lower section of the river. The major pollutants are nitrate and phosphate, introduced to the river through domestic sewage, industrial wastewater, livestock contamination, and urban and agricultural runoff. As a result, restoration of the Hablehrood River has become an important objective of the Sustainable Management of Land and Water Resources Project of the UNDP [1].

In order to improve the condition of the Hablehrood River, and to protect the river from further pollution, it is important to fully understand the river's current conditions, and to have the ability to predict the river's behavior. Hydraulic conditions such as flow rate, as well as quantitative evaluations of qualitative features, are vital to this understanding [2]. Hydrological conditions also affect the quality of the Hablehrood River, which can be classified in two states: dry conditions and wet conditions, as quantified by the Standard Precipitation Index (SPI) [3]. Once the hydraulic and hydrological conditions of the river have been identified, it will be possible to model the characteristics of water pollutants based on the US-EPA's QUAL2K [4, 5] or QUAL2E [6] models.

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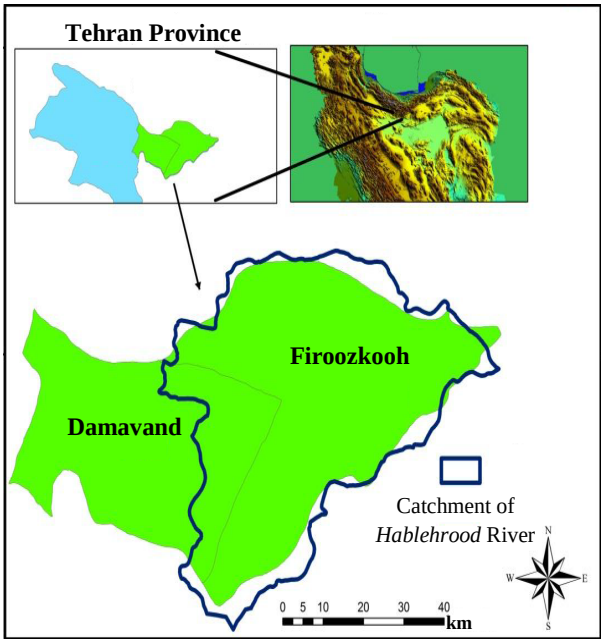
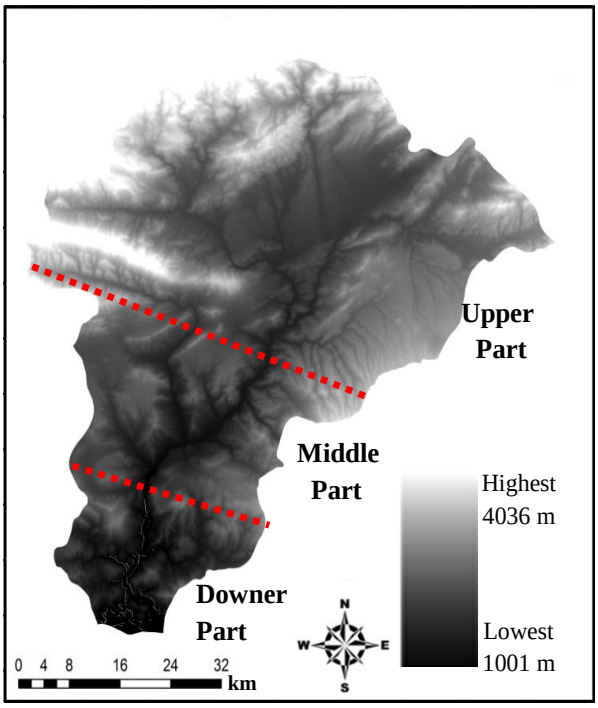


(a)



(b)

Fig. 1 Location (a) and digital elevation model (DEM) map (b) of the Hablehrood River Basin.

Several practical studies of a similar nature have been performed on other rivers. For example, Lorenzo-Lacruz et al. [7] studied the impact of climate change on headwaters and upstream regions of the Tagus River, located in central Spain. The results of the Tagus River study showed that dry conditions have had the greatest effect on water quality in the Tagus River basin since the early 1970's. Hosseini Zare & Saadati [8] studied the impact of dry conditions on water quality in the Karoon and Dez rivers, as well as the water quality in Behshahr province. Zainali & Rezaei [9] conducted their studies on the Shahre Chai River in Urmia, developing a model for pH, Biochemical Oxygen Demand (BOD), and Dissolved Oxygen (DO) based on QUAL2K. Park & Lee [10] compared several qualitative models for the Nakdong River, positing a model based on the US-EPA's QUAL2E as the most suitable.

In this study, qualitative features of the Hablehrood River were examined at both wet and dry conditions, which were determined using SPI. This data was then used to develop a QUAL2K modeling procedure to model the changes of nitrate and phosphate concentrations during four select years: two dry years and two wet years.

2. Materials and Methods

The first stage of the modeling process involved dividing the river into one-dimensional segments and identifying variables such as auxiliary branches, flow deviations, hydrological conditions, and notable changes of water quality at different points. Fig. 2 presents the segmentation of the Hablehrood River as defined by this study.

After dividing the river into segments, geographical coordinates of the segments were determined, as was the elevation, the length, and the surface area of the segment profile. Hydraulic data was gathered at this stage using of the curve fitting method. This data included flow rate, discharge, depth of water, and pollutant downstream movement.

Meteorological data was also gathered at this stage in consultation with the Islamic Republic of Iranian Meteorological Organization (IRIMO) [11]. The data included solar radiation, cloud coverage, temperature, proportional humidity, wind speed, and dew point at

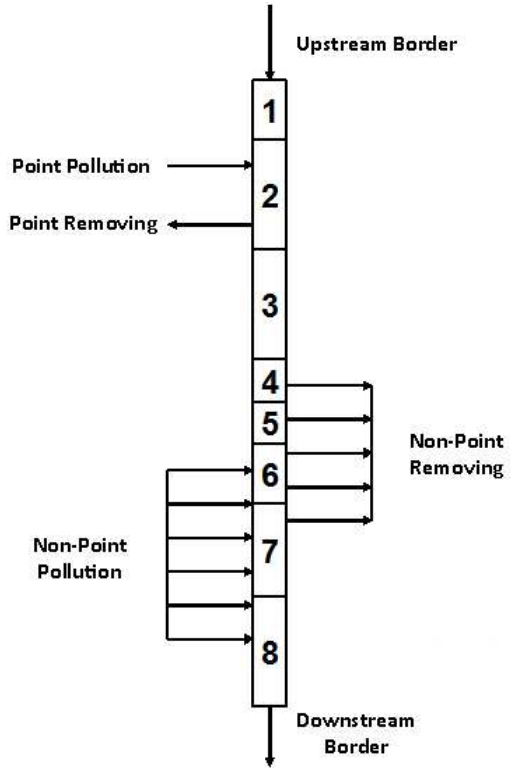


Fig. 2 Hablehrood River system segmentation and pollutant resources.

the following weather stations in the Hablehrood River region: Firoozkooh (35°45'N, 52°44'E), Namrood (35°32'N, 52°38'E), Zarin Dasht (35°24'N, 52°32'E) and Bonekooh (35°18'N, 52°25'E). Fig. 3 shows the

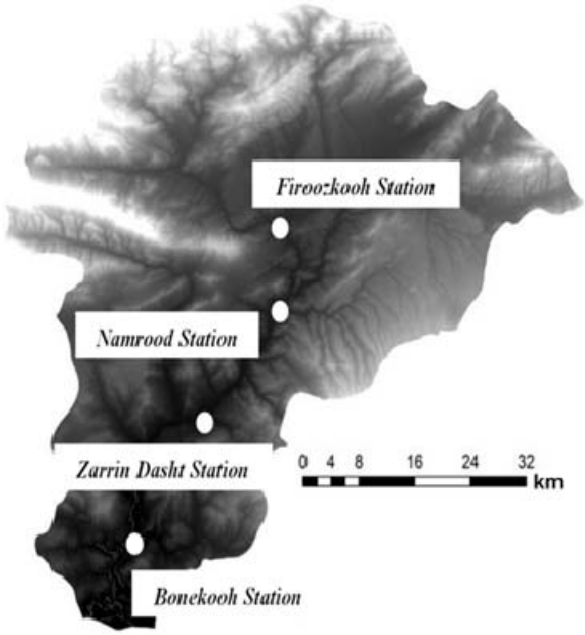


Fig. 3 Location of weather stations at Hablehrood River Basin.

location of these stations. In order to determine historical periods of wet and dry conditions, a normal SPI distribution was calculated based on rainfall data from each station for a period of 35 years, from 1980-2015 [12].

Qualitative and geometric data of pollutants along the river were also considered when modeling phosphate and nitrate concentrations based on QUAL2K. Consideration of phosphate and nitrate is because the source of most pollutants is residential wastewater and agricultural runoffs.

3. Results and Discussions

3.1 Hydrological Conditions

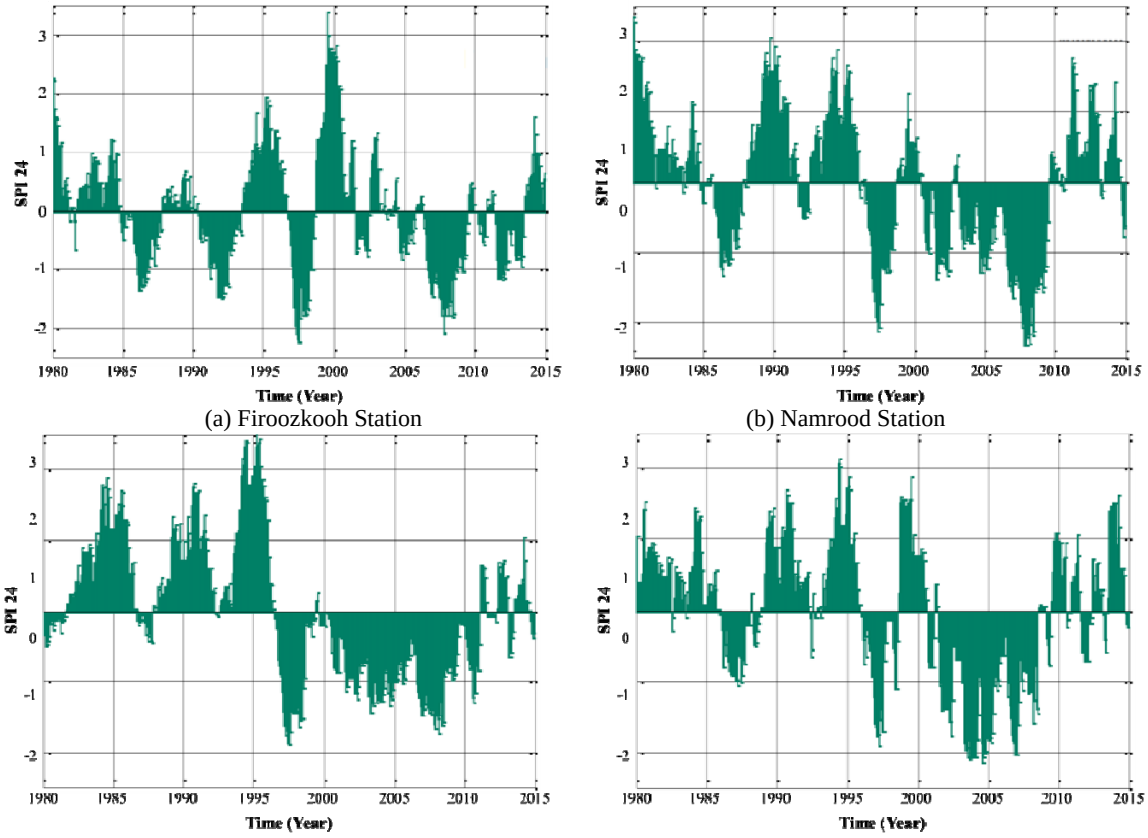
Fig. 4 shows the results of SPI based on meteorological data from 1980-2015. This data was used to evaluate the long term effects of dry and wet periods on the Hablehrood River.

These results indicate that 1995 and 2000 should be considered wet years, and 1997 and 2007 should be considered dry years. With these years and conditions identified, it is possible to compare nitrate and phosphate concentrations under different hydrological conditions.

3.2 QUAL2K Modeling for Qualitative Features

Figs. 5 and 6 show the changes of nitrate and phosphate levels in the Hablehrood River under different hydrological conditions, as predicted by the QUAL2K based model.

The results predict a similar change in the concentration levels of both nitrate and phosphate as the downstream distance increases. Pollutant concentration is highest upstream due to large amounts of wastewater introduced near Firoozkooh. This high concentration decreases suddenly due to a large amount of unpolluted water introduced from a tributary near the Namrood Station, as shows in Fig. 3. As the water proceeds further downstream, pollutant concentration increases due to the introduction of wastewater from farms and villages.



(a) Firoozkooh Station (b) Namrood Station

(c) Zarrin Dasht Station (d) Bonkooh Station

Fig. 4 Standardized precipitation index (SPI) for (a) firoozkooh, (b) namrood, (c) zarrin dasht and (d) bonkooh weather stations.

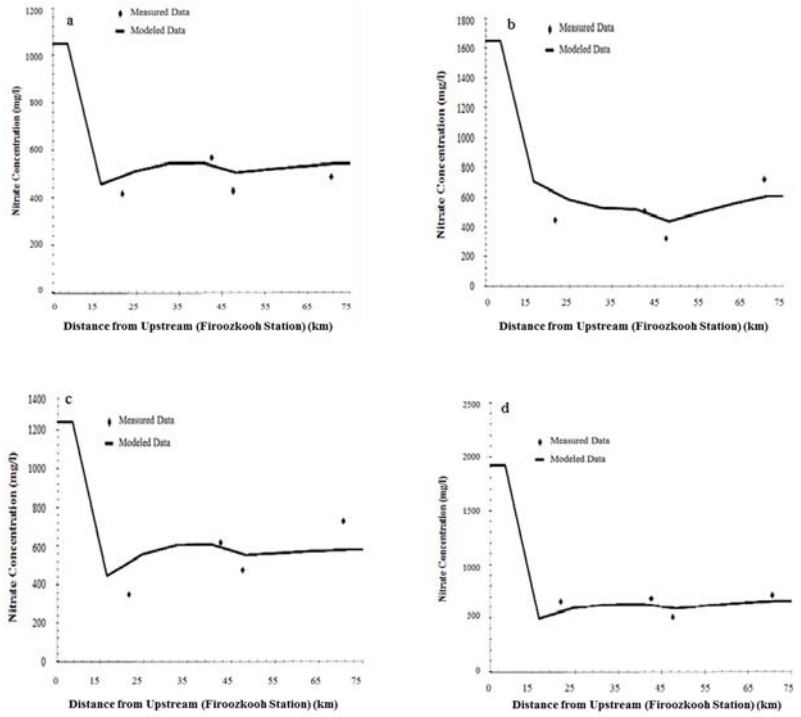


Fig. 5 Results of nitrate concentration modelling in wet years (a) 1995 and (b) 2000 and dry years (c) 1997 and (d) 2007.

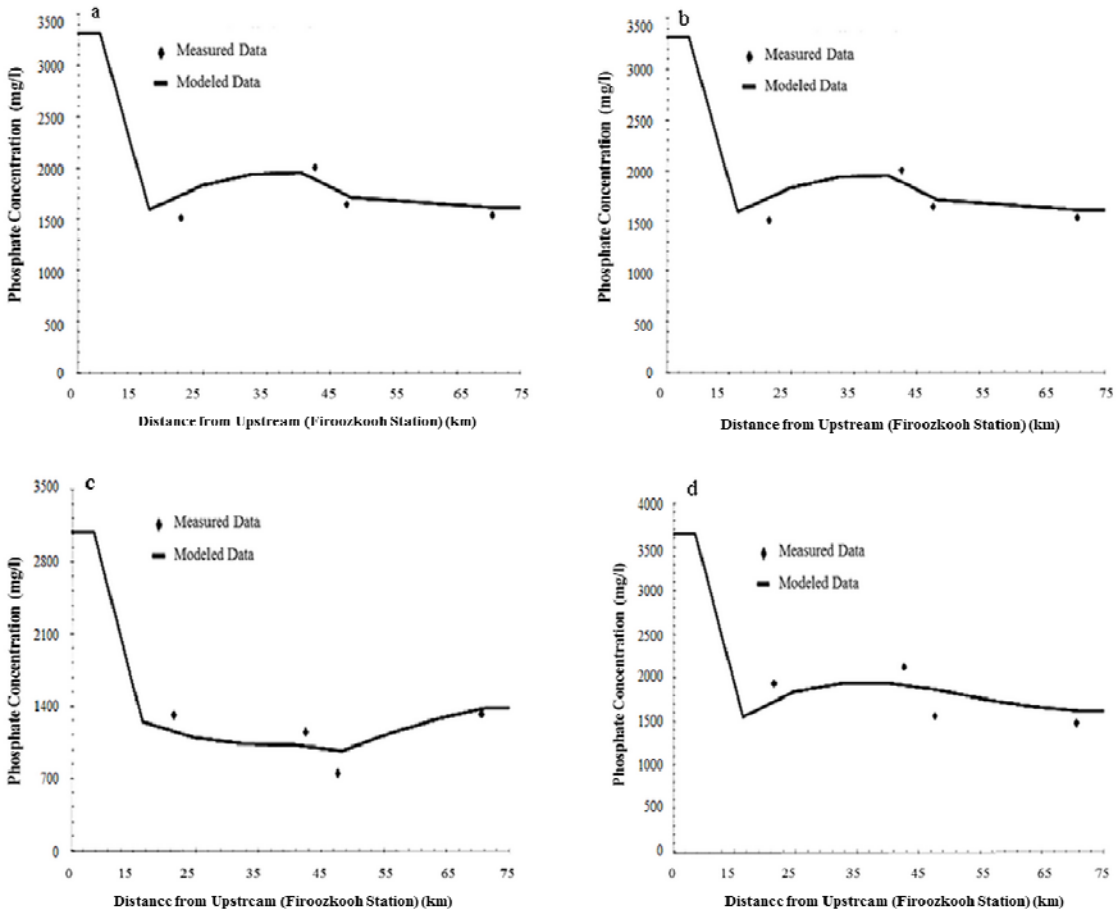


Fig. 6 Results of phosphate concentration modelling in wet years (a) 1995 and (b) 2000 and dry years (c) 1997 and (d) 2007.

Wet year data shows that nitrate concentration levels upstream were approximately 1050 mg/L, which later increased to more than 1600 mg/L, indicating population growth in the region. The same can be said for dry years, as well as for phosphate concentration levels. It should be noted that pollutant concentration levels were higher during dry years than wet years due to more evaporation and less rainfall.

4. Conclusions

This study examined the effects of qualitative features on the Hablehrood River during different hydrological conditions. To establish hydrological conditions for the study, SPI was used to determine wet and dry years.

According to SPI calculations, 1995 and 2000 are considered wet years, and 1997 and 2007 are considered dry years. Changes of nitrate and phosphate concentration levels for these years were modeled based on QUALK2K. The results show that water quality decreases more so during dry years than wet years, and that this decrease in quality is more pronounced at locations where pollutants are introduced into the river.

It is clear that better sustainable management practices are needed in order to protect the water quality of the Hablehrood River, the restoration of which has become an objective of the UNDP. This study presents a modeling approach which can be used to predict pollutant concentration levels in the river, allowing for the development of such management policies.

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