Combined Groundwater Quality and Groundwater Model Approach as Main Tool of an Aquifer Management for Sustainable Water Supply in the Santo Domingo Valley, Baja California Sur, Mexico

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ABSTRACT
The extraction of groundwater and especially the over-exploitation of the Santo Domingo aquifer since 1957 has caused modifications in the natural flow system and induced lateral flow of seawater from the coastline. As a result the groundwater quality in the Santo Domingo Irrigation District is deteriorating. Seawater intrusion and irrigation-return combined with the mobilization of deeper groundwater have been identified as important sources of salinization.

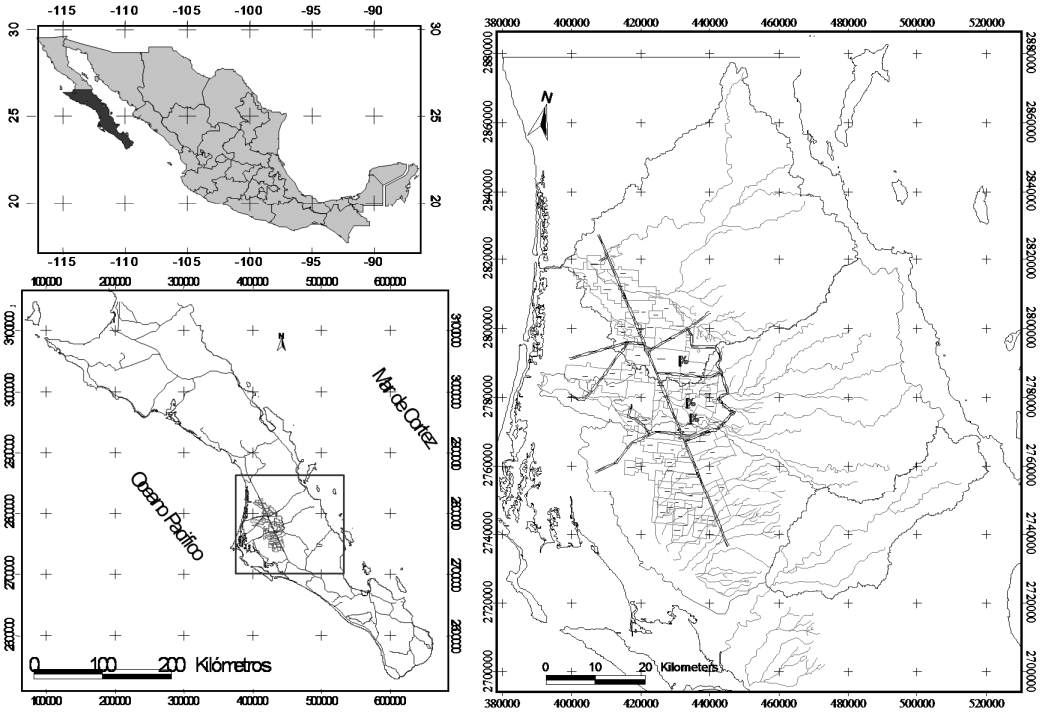

Figure 1. Location of the study area in Mexico, in the southern part of the Baja California Peninsula and detailed map of the Santo Domingo Irrigation District with the most important catchments and drainage systems

INTRODUCTION
Since its colonization in the 1950s the Santo Domingo Valley has become the most important agricultural district of Baja California Sur. As typical for semiarid regions the main source of freshwater is groundwater. Important factors in the water balance of the region are the very intensive rainfalls caused by storms and hurricanes. The runoff from the mountains infiltrates in the subsequent alluvial fans where it recharges the aquifers. The extraction of groundwater and especially the over-exploitation of the aquifer since 1957 has caused modifications in the natural

flow system and induced lateral flow of seawater from the coastline. As a result the groundwater quality in the Santo Domingo Irrigation District is deteriorating.

METHODS

The concentrations of the macro-constituents in 4375 ground water analyses, taken from 710 agriculture wells between 1986 and 2005, were interpreted in respect to changes in the groundwater composition. Another 100 groundwater samples, taken at selected wells in various sample campaigns since 2006 included a wide spectrum of analyzed elements, using an ICP OES Spectrometer.

In order to understand the groundwater flow regime in the past, we used the USGS MODFLOW model, which is widely used for groundwater studies. It was utilized to represent the lower part of the catchments model, and included 40000 cells in each of the two layers. To calibrate the regional groundwater flow, the hydraulic head data of more than 500 wells were included. Additionally runoff data were introduced to the MODFLOW model to represent the effects of catchments in the mountain area. The calculated runoff from these adjoining catchments was combined to the MODFLOW model using the STREAMFLOW package.

RESULTS

There is a strong annual variation in groundwater mineralization with lower values in autumn and winter and higher values in spring and summer (Figure 2 and 3), due to intensive rainfalls caused by tropical storms during the hurricane season (May to November). Although former studies indicated only minor influence of direct seawater intrusion on groundwater quality (Cardona et al. 2004), we found evidence that it is the main source of high mineralization in the three parts of the aquifer (see Figure 4).

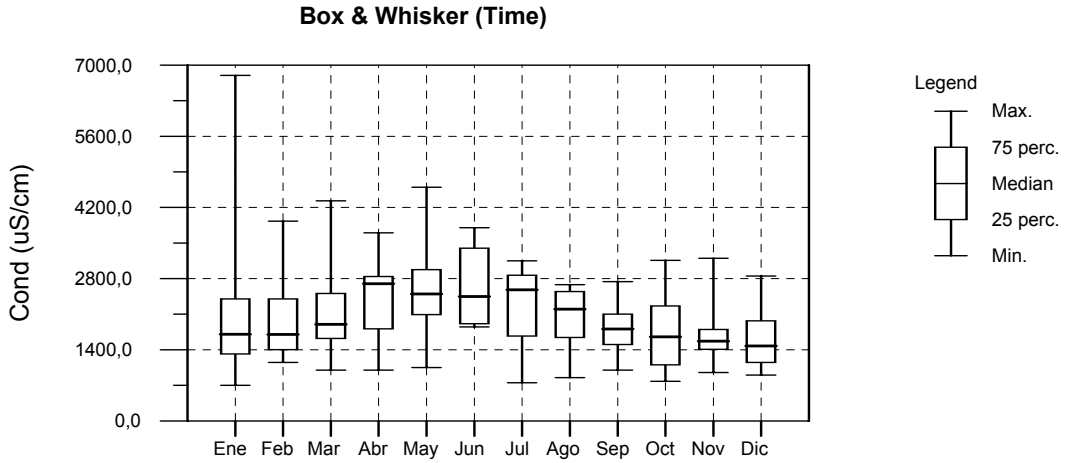

Figure 2. Monthly variation of the electric conductivity in 4375 ground water analyses from 710 agriculture wells between 1986 and 2005

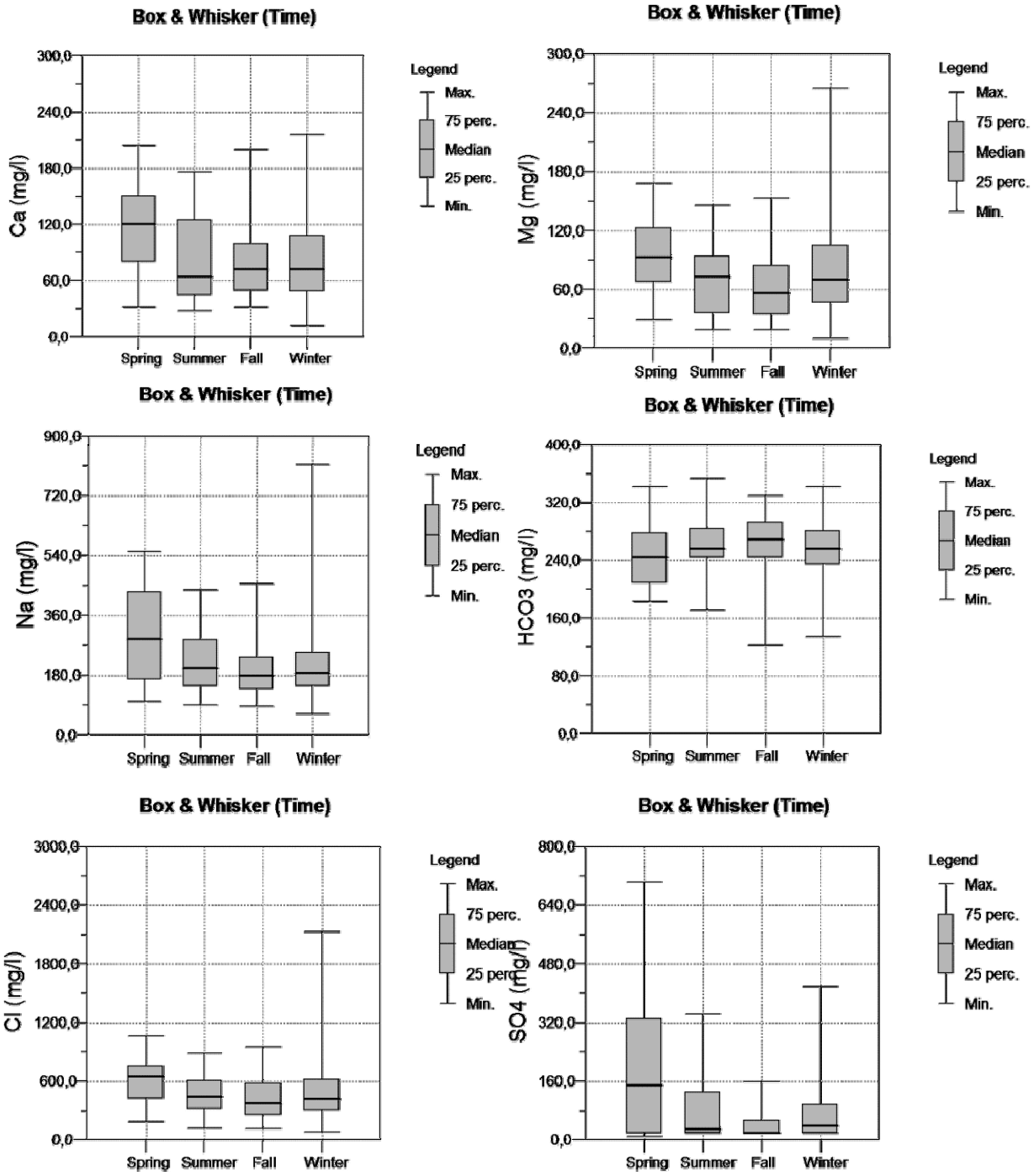

Figure 3. Seasonal variation of Ca, Mg, Na, HCO_3, Cl and SO_4 concentrations in 4375 ground water analyses

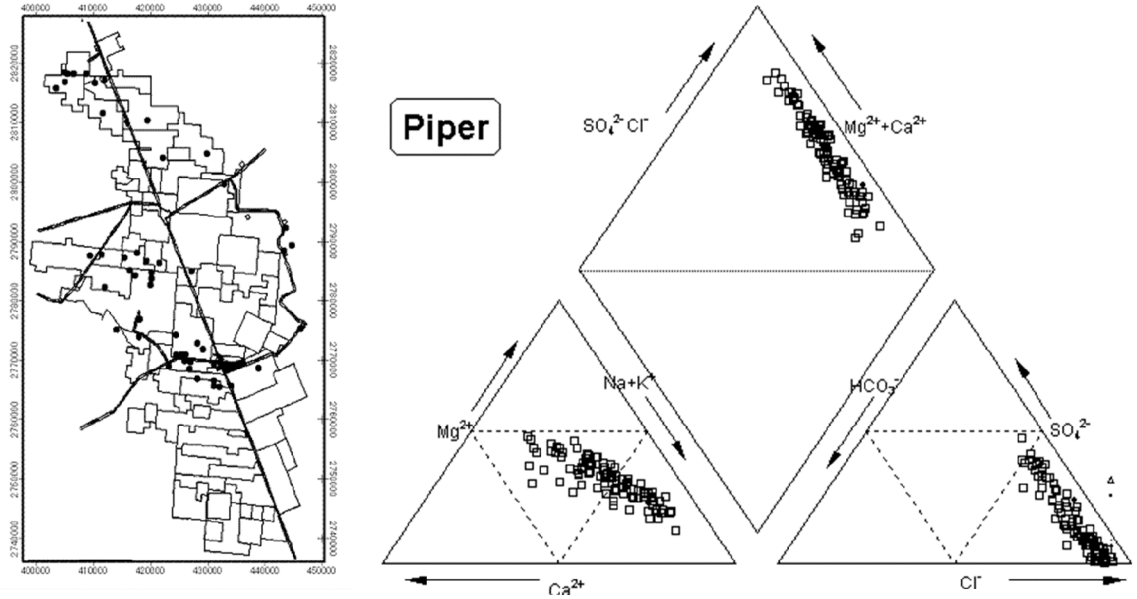

Figure 4. Map of the Santo Domingo Irrigation District. Points indicate wells with salt water intrusion represented by high Cl/SO_4 ratios (>50) and Piper diagram of water samples with electric conductivity of more than 4000 µS /cm

The combined watershed and groundwater model was able to represent the observed groundwater levels including the interaction between runoff and recharge in the lower part of the watershed. In years without runoff infiltration the recharge rate is about 20 % below permitted extraction rate. The recharge caused by base flow is a significant component of the total recharge in the watershed.

OUTLOOK

After the calibration of the coupled watershed groundwater model the next step will be the implantation of scenarios based on the analysis of projected water demands (including the population projections and the future split up of the demand between various generic users). The model will help to plan the water supply and management in the region and to promote sustainable water supply strategies.

REFERENCES

Cardona A; JJ, Carrillo-Rivera; R, Huizar-Alvarez y E, Graniel-Castro, 2004. Salinization in coastal aquifers of arid zones: an example from Santo Domingo, Baja California Sur, Mexico. Environmental Geology, Vol 45 No 3, 350-366.

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