MODELING GROUNDWATER RESOURCES IN AN ALLUVIAL AQUIFER OF SOMALILAND

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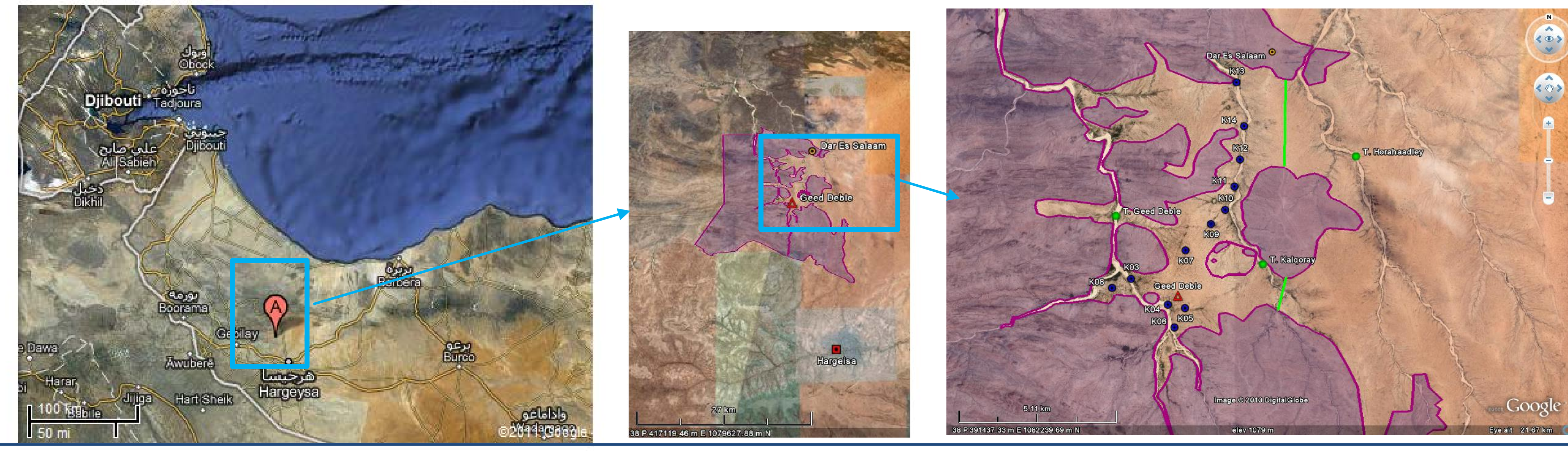
Introduction

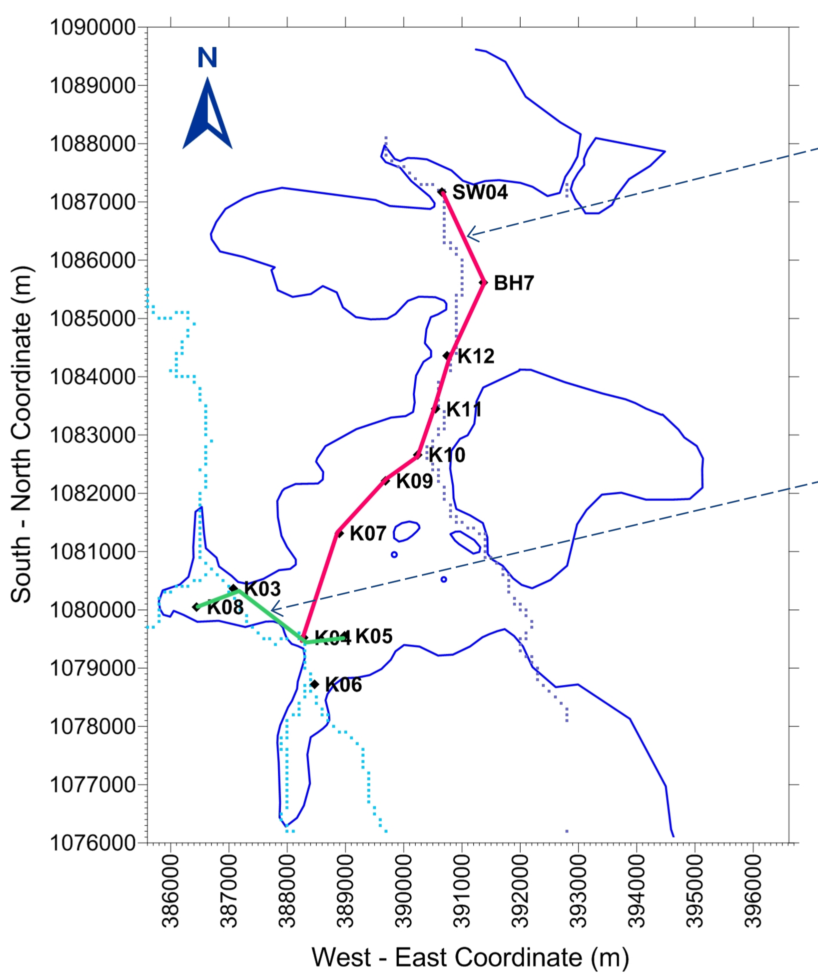
The aquifer of the Ged Deeble basin is the source of water supply of the town of Hargeisa (350,000 inhabitants). Well field were started in the 1970's and water production raised from around 6,000 m^3/day in the first years of the millennium up to 10,400 m^3/day at the beginning of 2010. An EU project performed exploration activities to reconstruct basin shape, geological framework and mechanism of recharge. A mathematical model of this aquifer system has been developed using MODFLOW, in order to verify actual possibility for basin exploitation.

Study Area

Ged Deeble basin is located North of Hargeisa city, in Somaliland (East Africa). Its extension is about 25 km^2. The aquifer system is modelled as an equivalent single-layer aquifer with 2D pseudo-stationary flow. A finite difference conservative scheme has been applied to a square grid with spacing of 100 m.



Well Location and K distribution



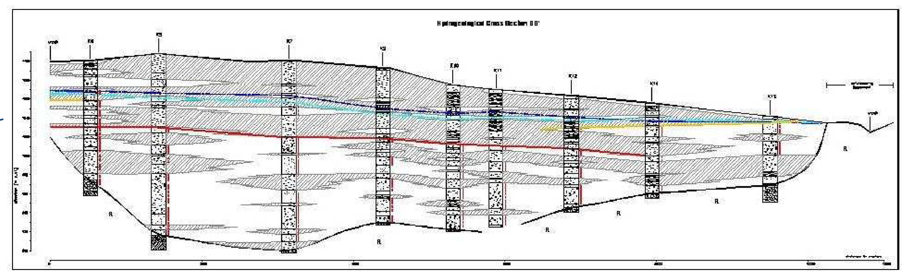


Figure 1. South-north hydrostratigraphic section

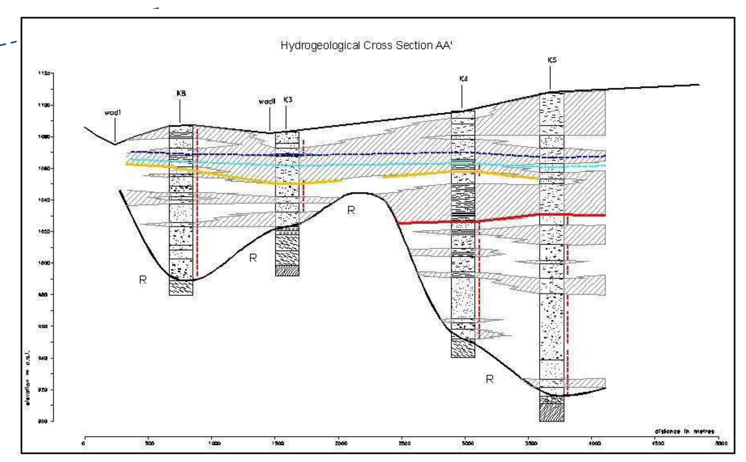


Figure 2. East-west hydrostratigraphic section

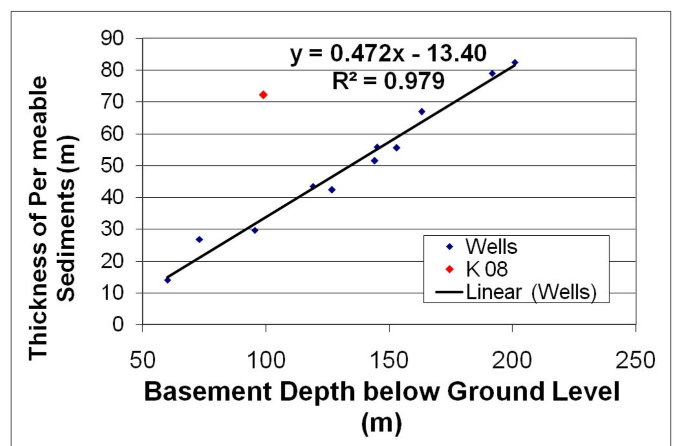
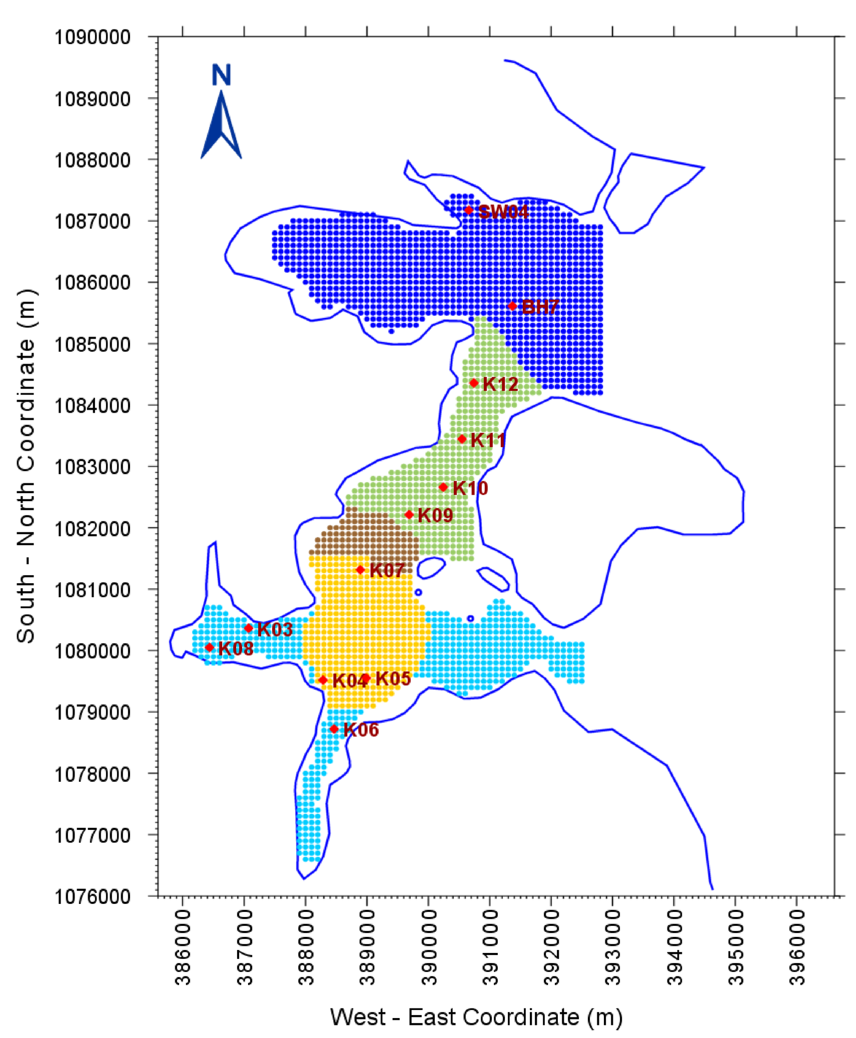


Figure 3. Correlation between effective thickness of permeable sediments and basement depth below ground level.

The hydrostratigraphic structure has been obtained from correlations of well stratigraphic logs (Figg. 1-2), surface geology and geoelectrical soundings. The thickness of permeable sediments has been calculated from the basement depth below ground level through the linear regression shown in Fig. 3.

Figure 4. Spatial distribution of hydraulic conductivities.

Zone	Hydraulic Conductivity (m/s)
K1	5.0×10^{-4}
K2	4.0×10^{-4}
K3	3.5×10^{-4}
K4	5.0×10^{-5}
K5	1.0×10^{-5}



Model Calibration

Natural conditions have been used in a trial-and-error procedure to fix hydraulic conductivities, distributed recharge from rainfall and recharge from losses along two main wadis, Tog-Kalqoray (blue dots) and Tog Ged Deeble (cyan dots).

Calibration of data for 2005 required the introduction of additional source terms close to wells K3, K8, K4 and K5. These terms simulate the inflow which comes through deep fractures and increases as a response to the drawdown caused by water extraction.

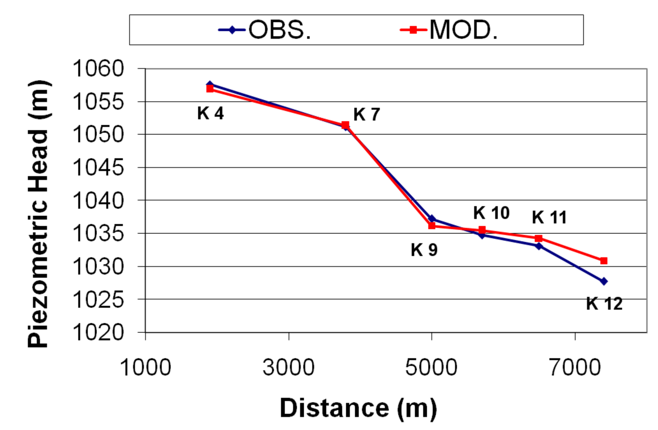


Figure 5. Comparison between Observed and Modeled Heads under natural conditions (in 1980s) at the monitored wells.

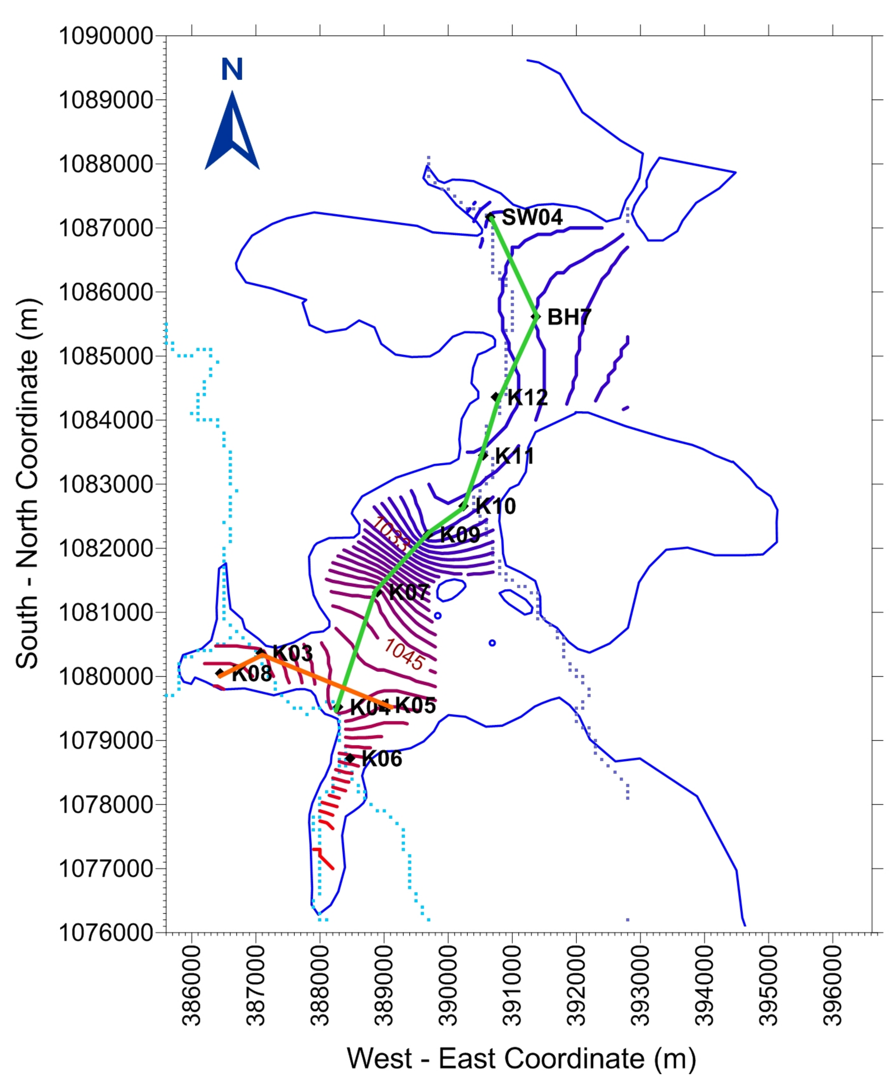


Figure 7. Contour plot of the Observed Heads in 2005 (equidistance 1m). Figg. 5 and 6 show data at monitoring points located along the green and orange lines.

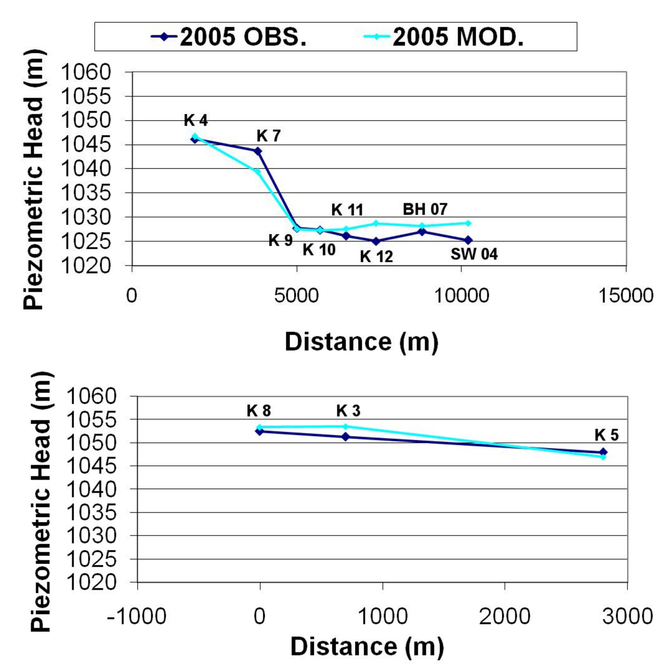


Figure 6. Comparison between Observed and Modeled Heads for 2005 at monitored wells.

Remarks

The calibration has shown the importance of the knowledge of the structural setup of the basin to estimate the areas characterized by fractures in the crystalline basement and the potential flow paths.

The high hydraulic gradient observed for any flow situation between wells K07 and K09 can be modeled only by the presence of a low conductivity region, which creates a separation between the southern ("upstream") and the northern ("downstream") sub-basins (Fig 4).

The increase of water abstraction causes the following effects:

1- in the northern sub-basin, flow direction is inverted with respect to natural conditions, so that the Ged Deeble basin drains water form the eastern Laas-Dhuurre basin;

2- in the southern basin, the water level drops down and is limited only by an increase of the recharge from the wadis and from fractured rocks along the borders of the basin.

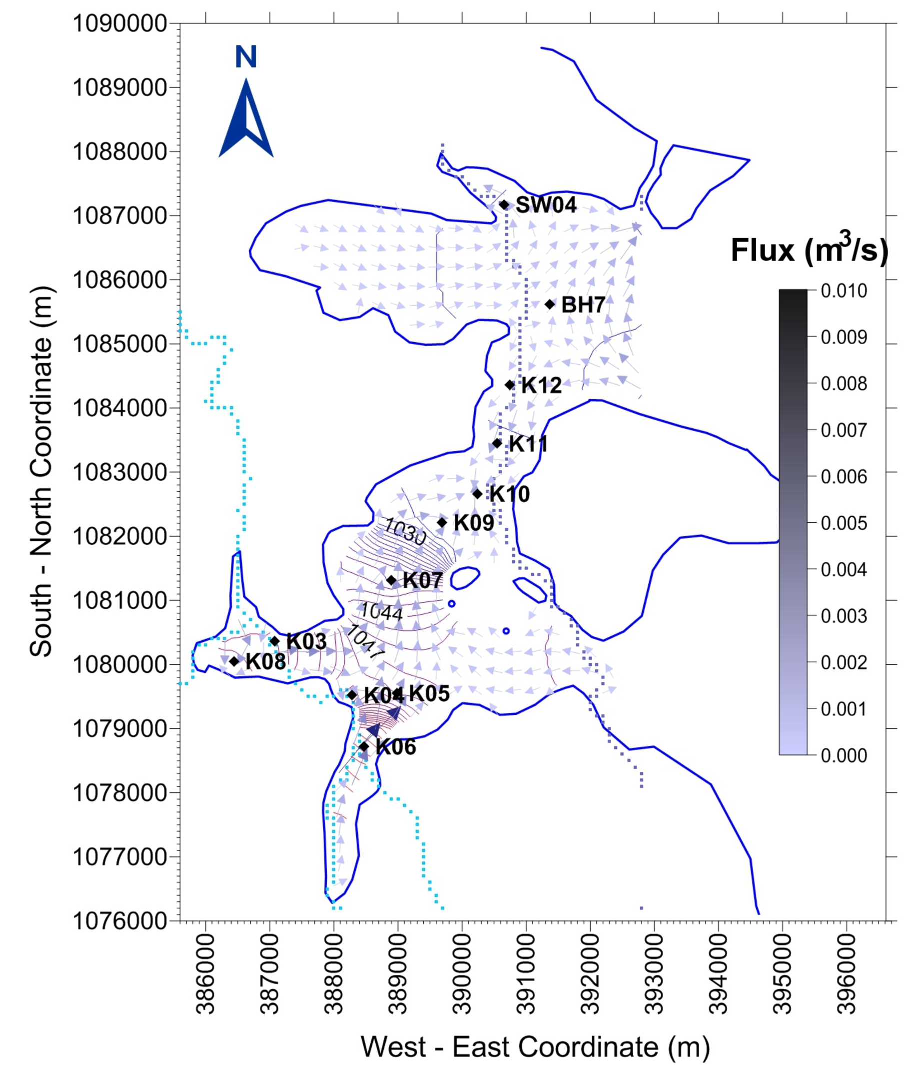


Figure 8. Contour plot of the Modeled Heads for 2005 (equidistance 1 m) and corresponding Flux lines (arrows).

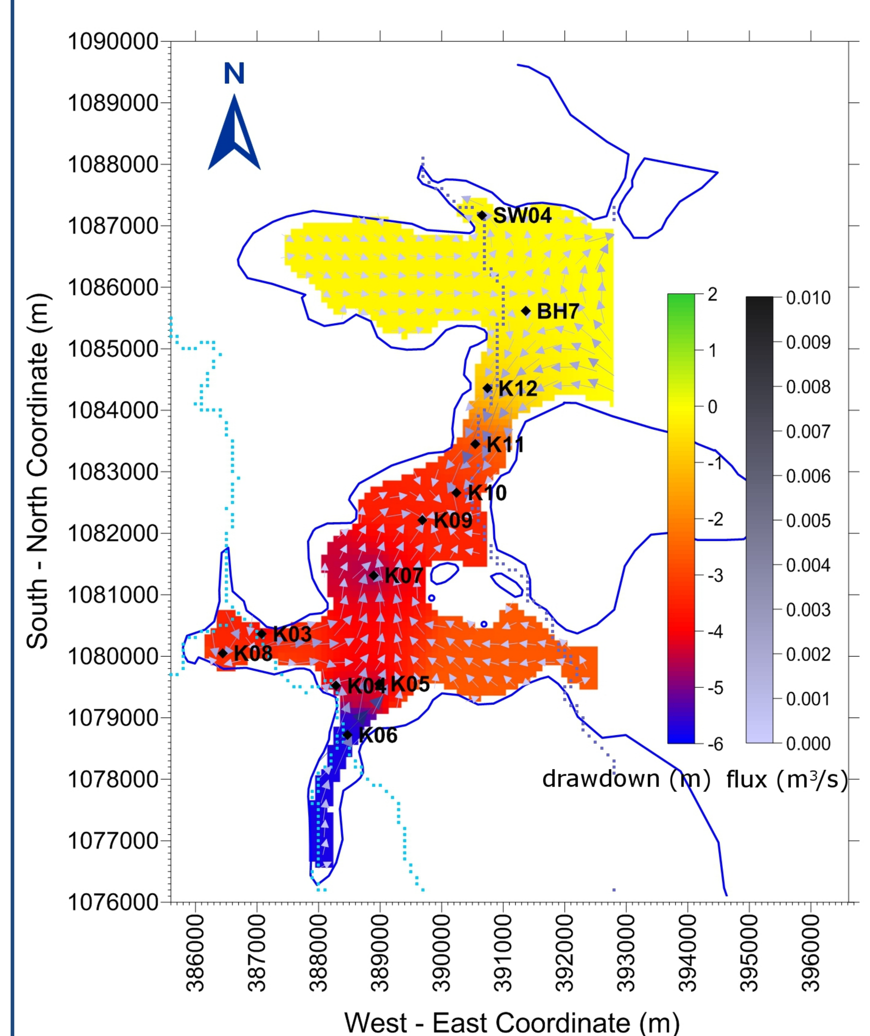


Figure 5. Flux Lines (Arrows) and DrawDown for Modeled Heads for 2010.

The inversion of the flux direction in the area of connection between the Ged-Deeble and the Laas Dhuurre basins caused by the pumping wells shows that the Ged-Deeble basin is now draining water from the oriental basin, whereas it was probably feeding it under natural conditions. In other words, the local water resources of the Ged-Deeble basin are not sufficient to sustain the current water demand. This is a worrying indication about the possibility of increasing the long lasting abstraction rate in a sustainable way.