



Numerical modeling for groundwater management and protection - The case of the Nyanzare well field in Gitega, Burundi

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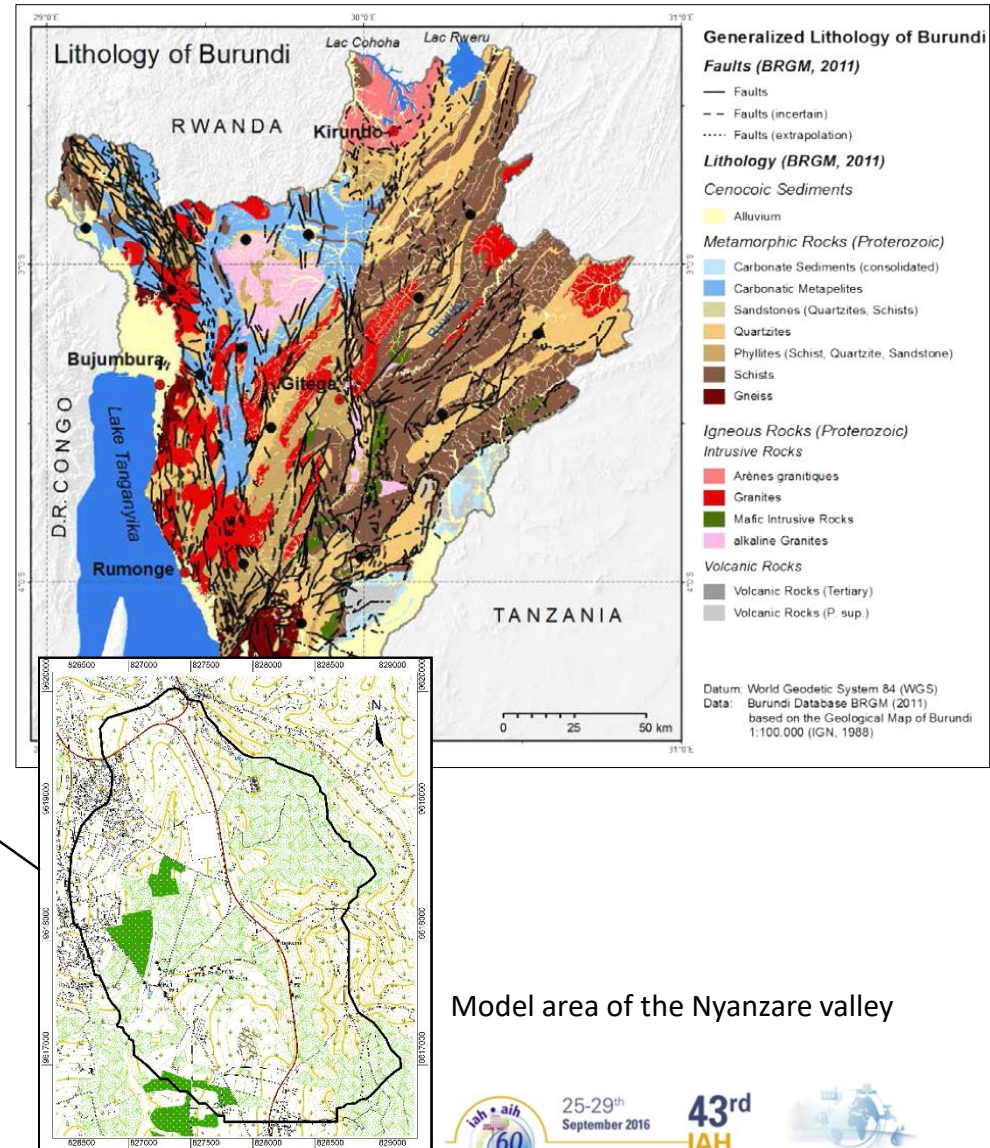
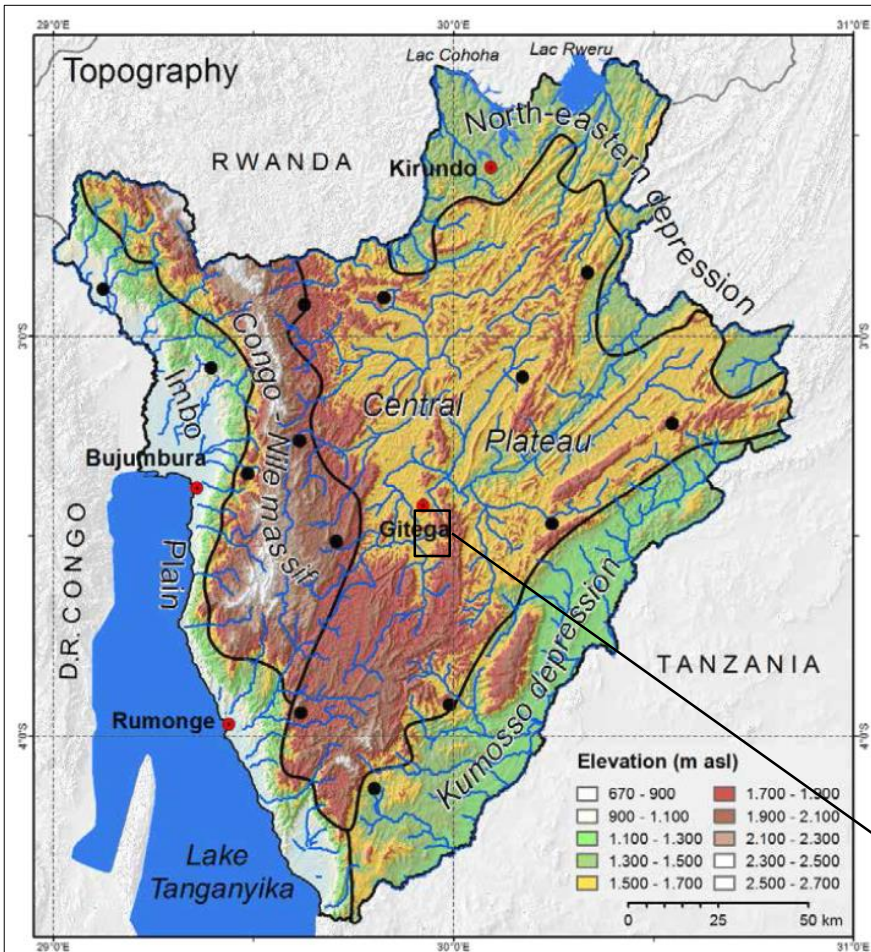
B 2.3 Groundwater Resources

Context

Cooperation Project “Management and Protection of Groundwater Resources in Burundi” (GPES) of the BGR and the Institut Géographique du Burundi (IGEUBU)

- One of the main objects: Assistance for setting up protection zones of the Gitega city water supply catchment
- Specific objectives of this study are:
 - Estimation of groundwater resources
 - Estimation of groundwater flow velocities
 - Evaluate travel times for protection zones
 - Provide a well field management tool
 - Project the aquifer response (water levels) to management alternatives
 - Predicting the response to stress (reduced recharge, increased withdrawal)

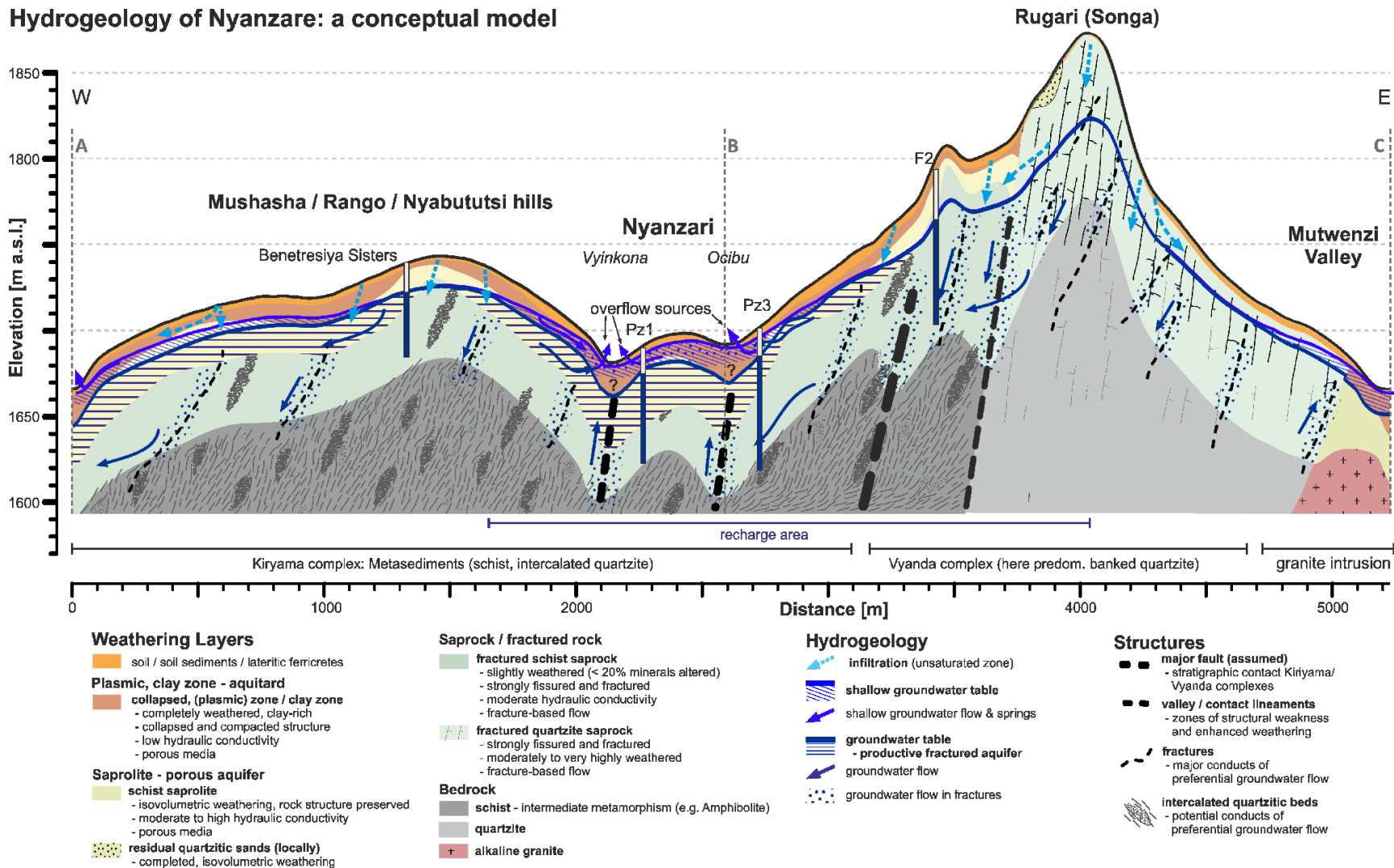
Study area



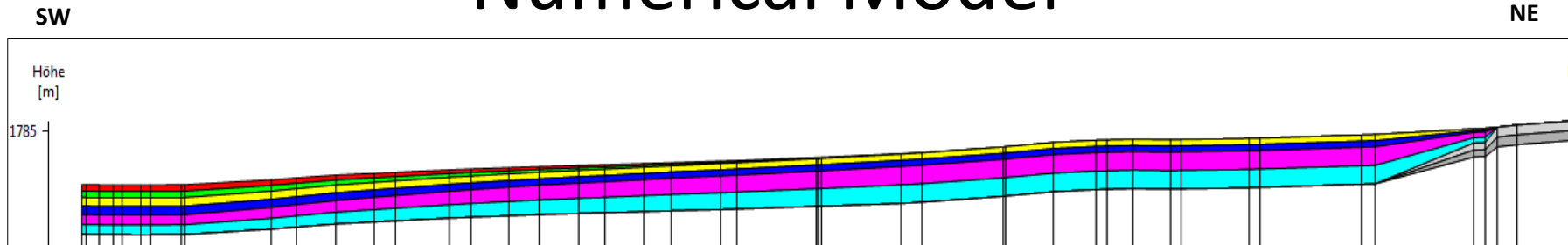
Model area of the Nyanzare valley

Conceptual Model

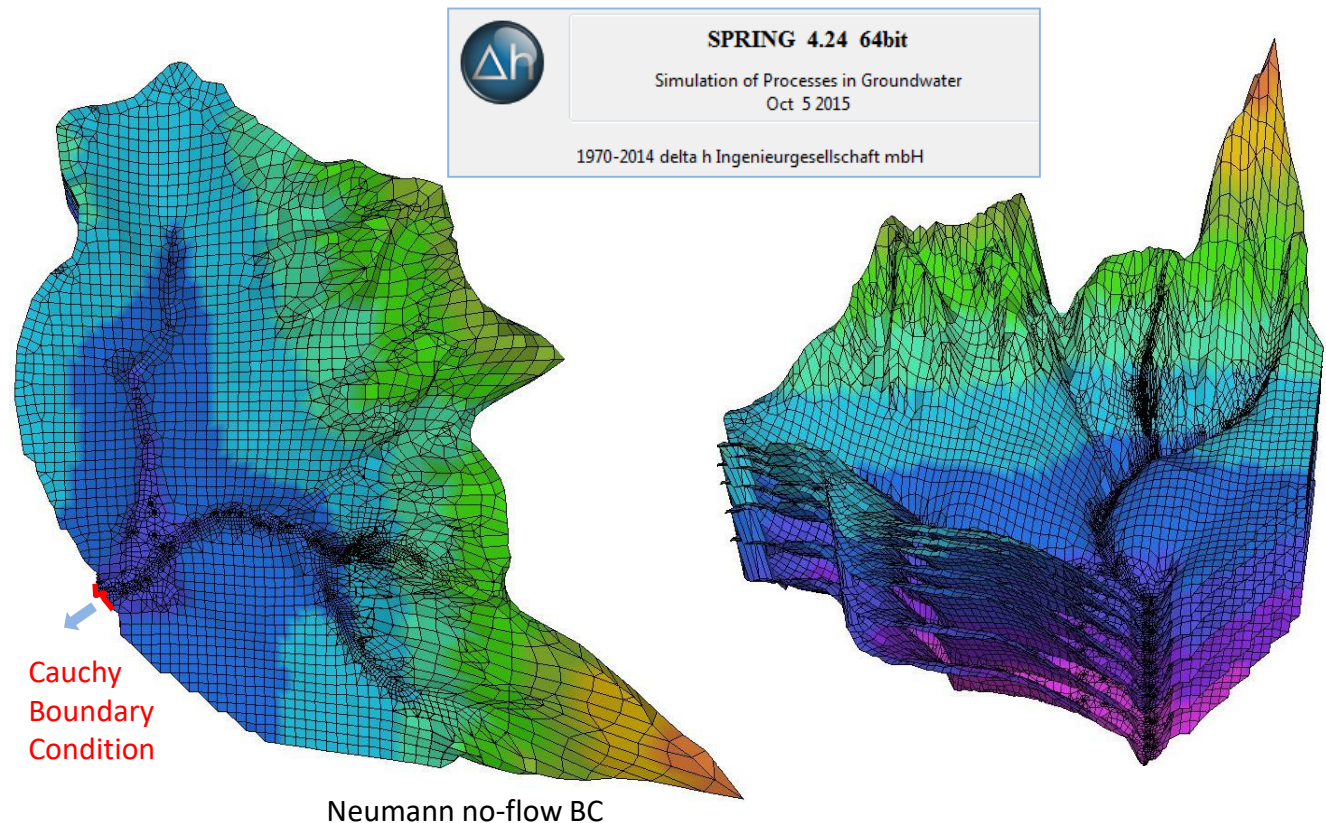
Hydrogeology of Nyanzare: a conceptual model



Numerical Model



- 6.1 km² (3.4 x 2.4 km)
- 4 lithological units transferred into 8 grid element layers
- 6734 elements per layer (triangles & rectangles)
- Grid refinements around wells and tectonic features (valleys)

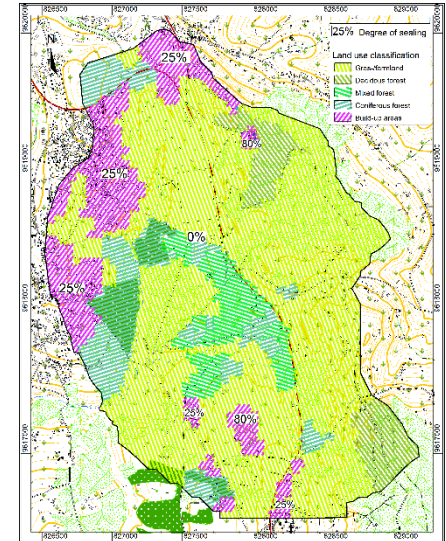


Transient GW Recharge

Method: Soil water balance

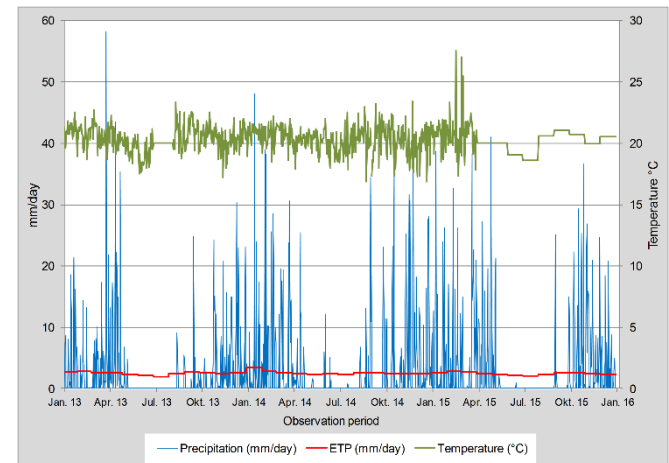
■ Spatial data

- DEM → relief energy (surface runoff based on Schroeder & Wyrwich)
- Initial hydraulic heads (depth to water table, capillary rise)
- Soil type
 - Field capacity
 - Permanent wilting point
- Land use
 - Effective root depth (farm-/grassland, forests)
 - Degree of sealing (build up areas)

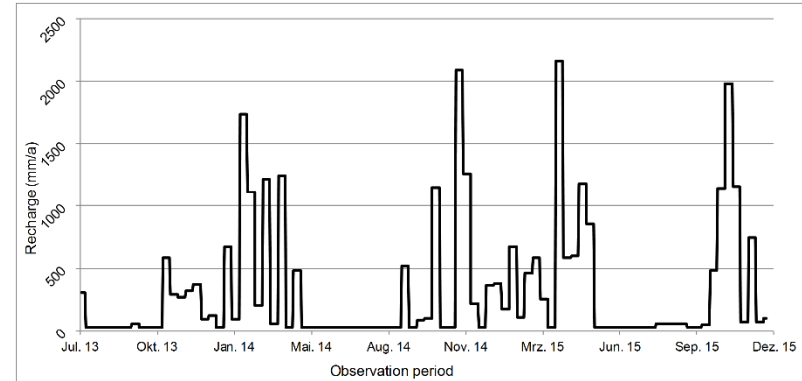
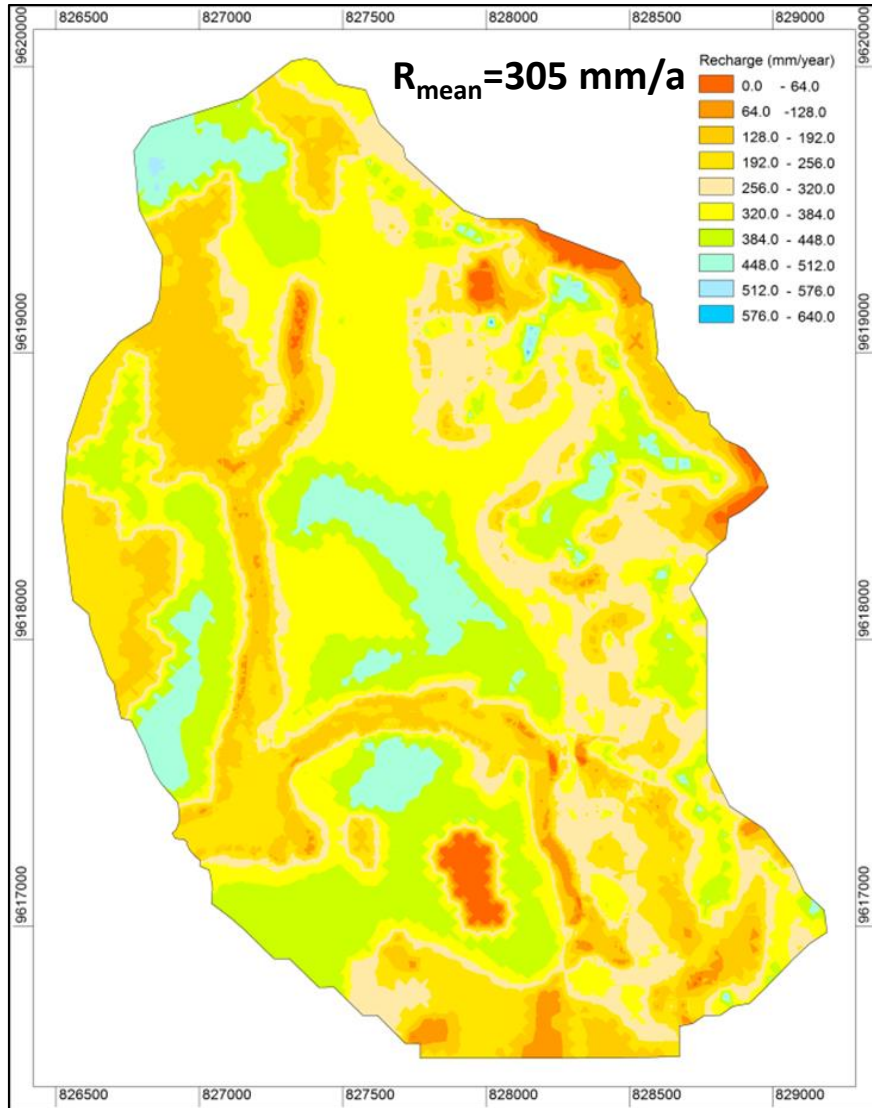


■ Transient climate data:

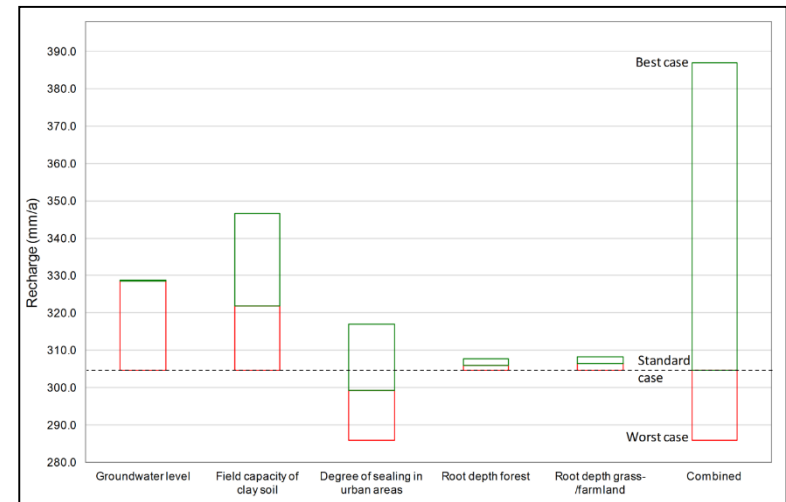
- Precipitation
- Temperature (T)
- Potential Evaporation (ETP):
Thornthwaite (1948) based on temperature and latitude



Transient GW Recharge



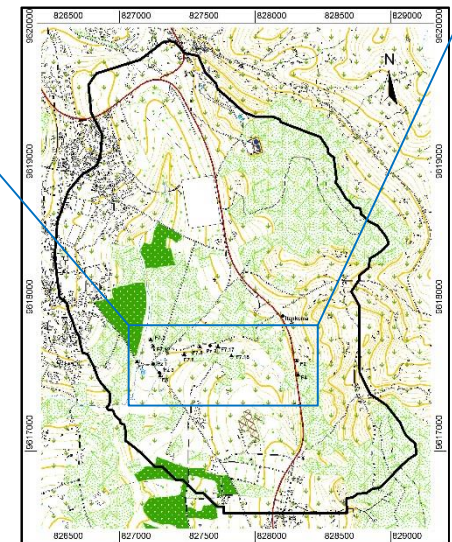
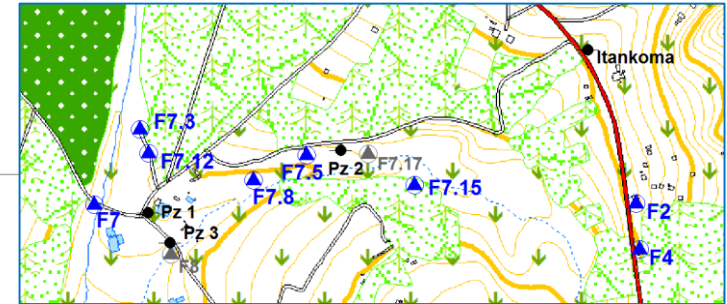
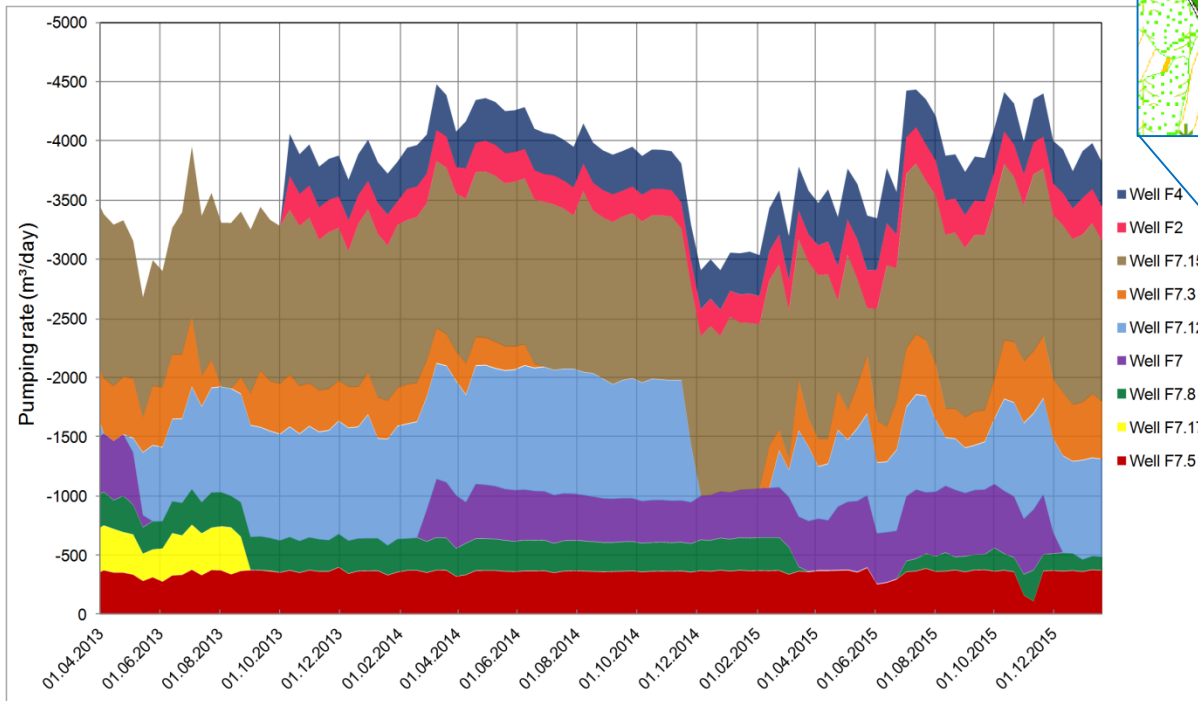
Variation of recharge in time



Sensitivity analysis

Pumping Wells

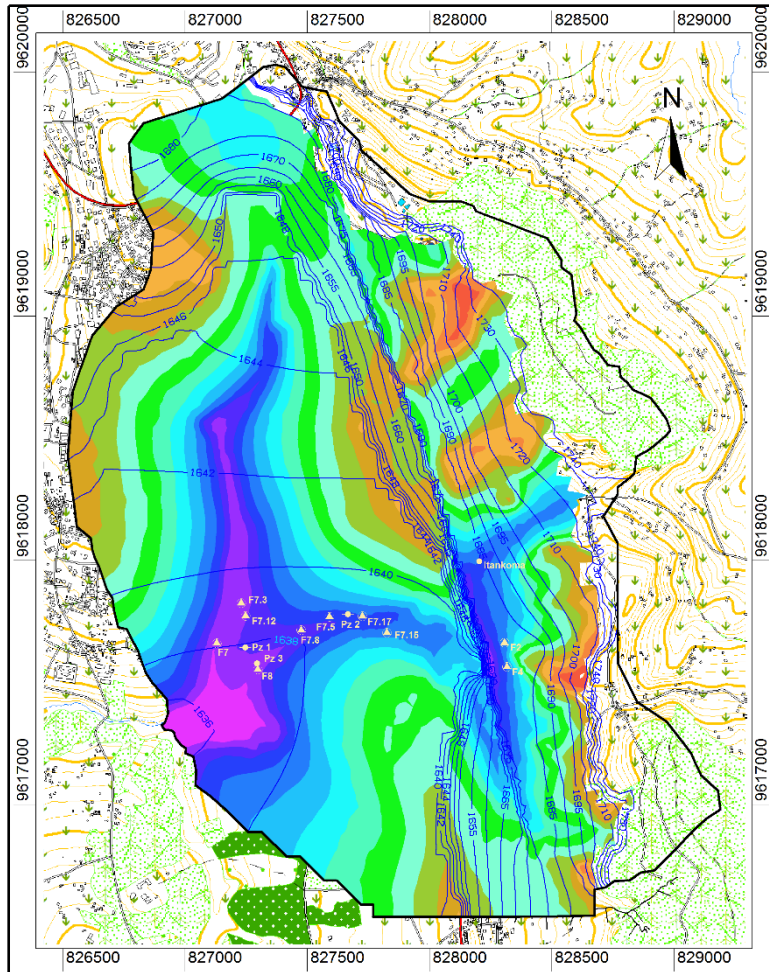
Pumping rates during observation period (01.2013 – 01.2016)



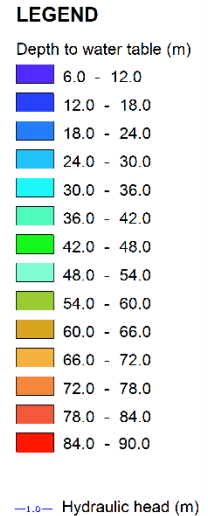
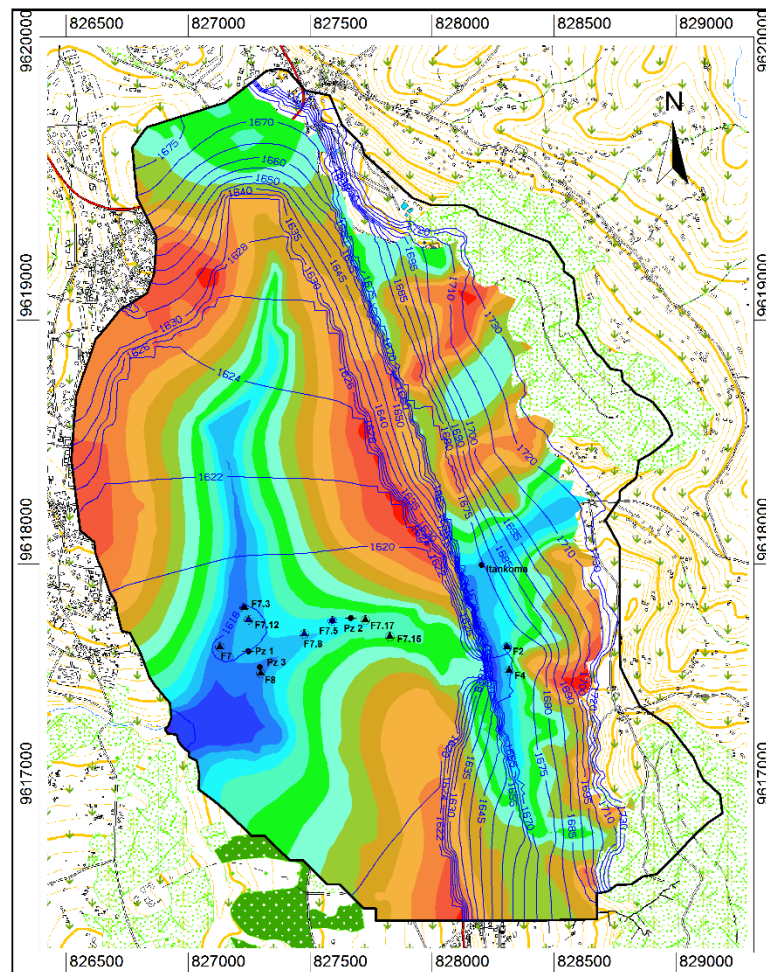
- Withdrawal of 4000 m³/d
- Frequent interruptions

Steady-state Calibration

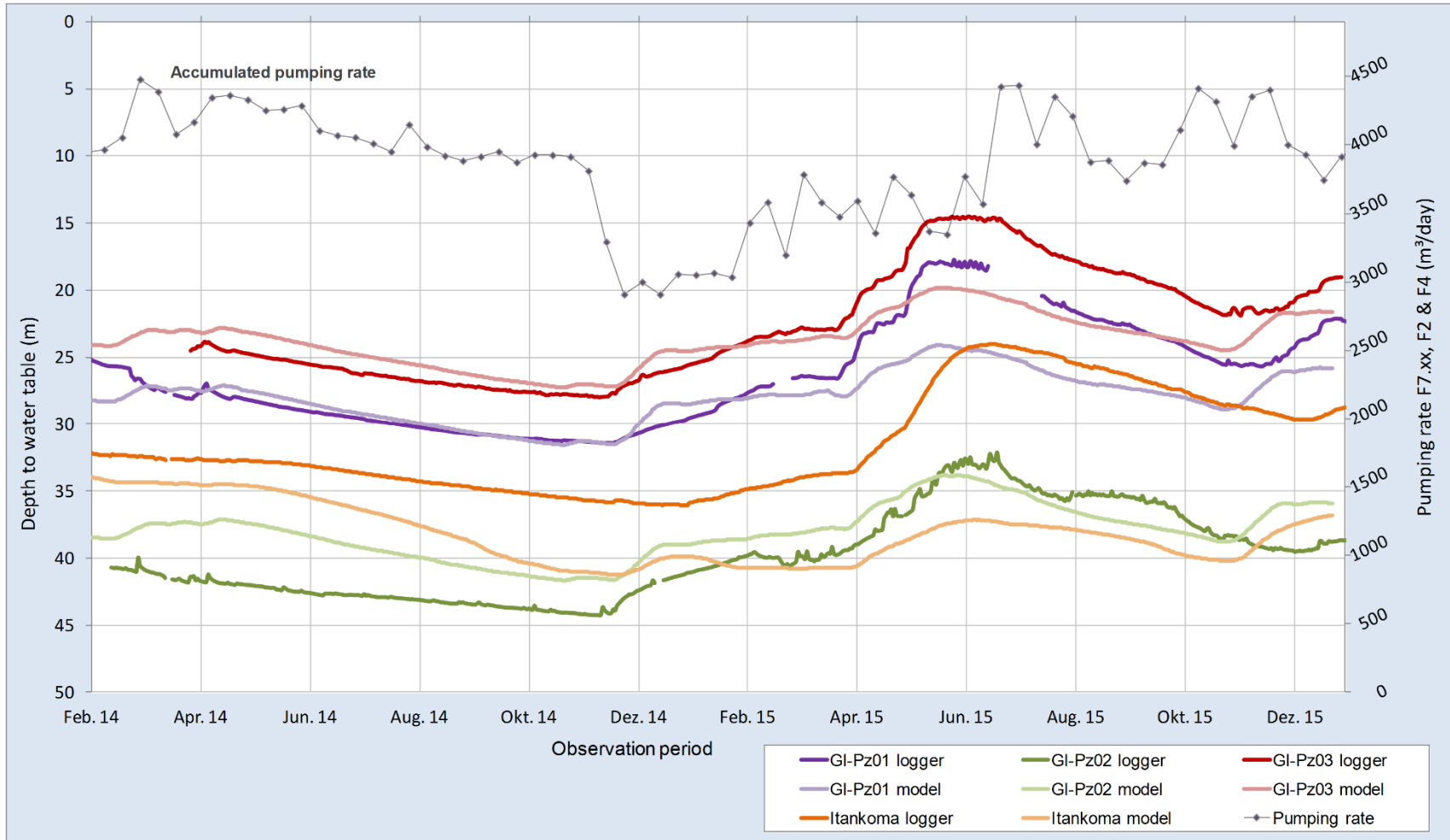
Pre-pumping



Post-pumping



Transient Calibration



Calibration of Hydr. Parameters

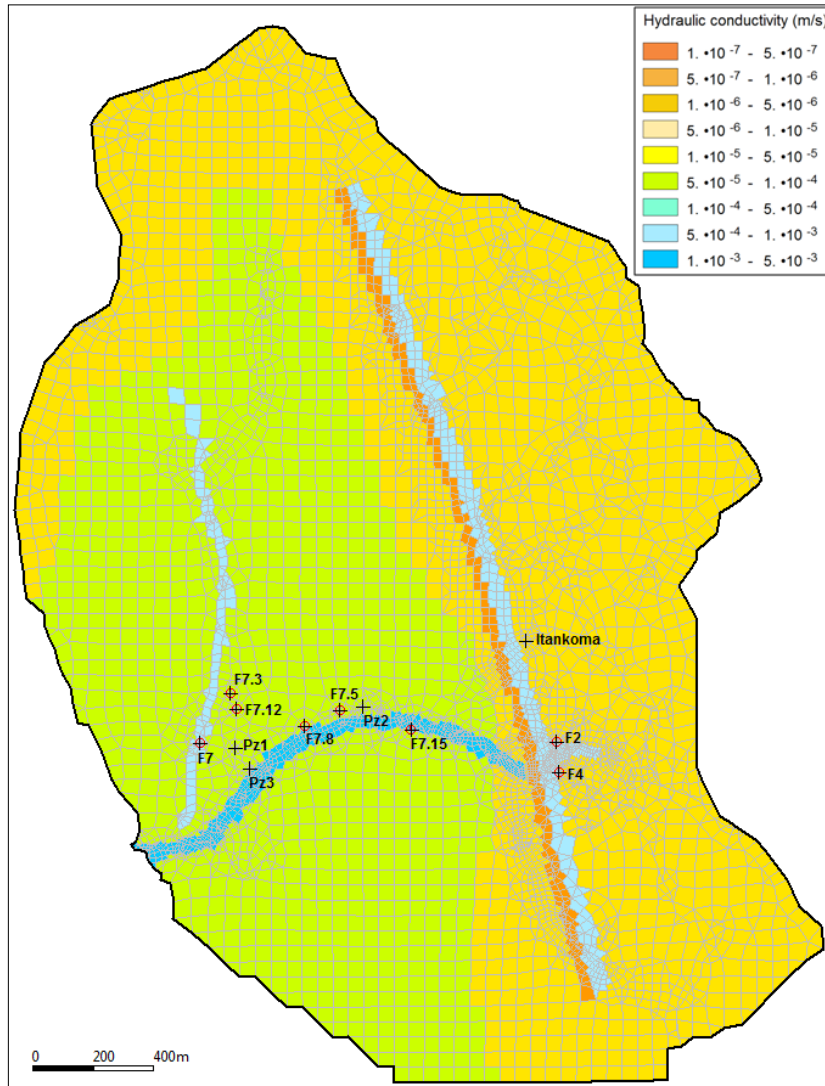


Table 4: Hydraulic parameters resulting from calibration

Zone/Lithology	Differentiation	Hydraulic conductivity K (m/s)	Anisotropy K_H/K_V	Effective Porosity (-)
Clay zone	-	5.0E-07	10	0.03
Schist saprolite	Valley / low slope	1.0E-05	10	0.04
	High slope area	1.0E-06		
Fractured schist saprock	1st order valley lineament	3.5E-03	1	0.04
	2nd order valley lineament	5.0E-04		
	Valley / low slope	9.0E-05		
	High slope	1.0E-06		
	Fault zone (conduit vs. barrier)	5.0E-04; 1.0E-07		0.04
Fractured quartzite saprock	-	1.0E-06	10	0.04

- Highly differentiated aquifer
- Lineaments determine flow field
- Identification of a fault (F2, F4)

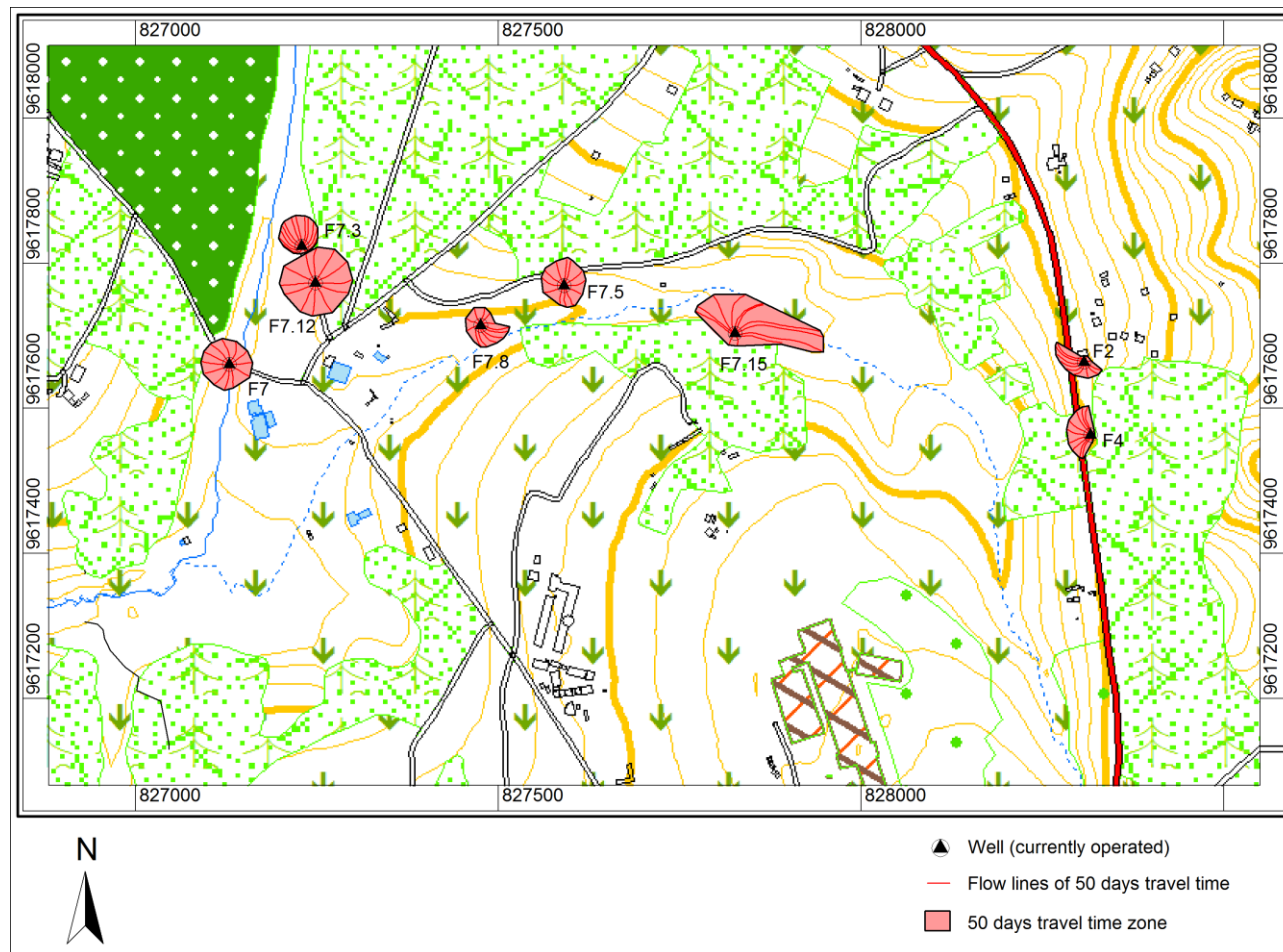
Protection Zones

50-day isochrones

Protection Zone 2:

- Prevents contamination by pathogens and other degradable substances

Result: ~ 50 m distance
125 m for F7.15



Future Scenarios

1. New well

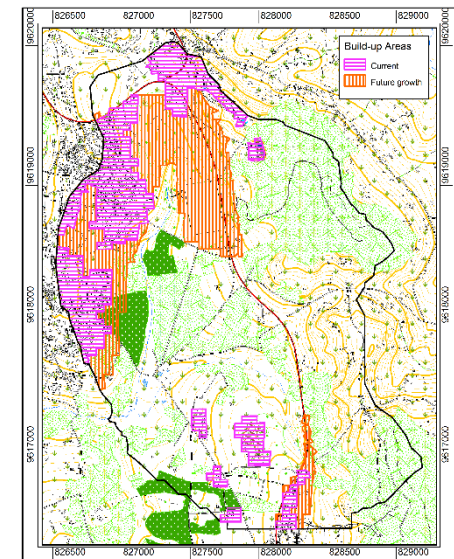
- Demand of Gitega city is still rising
- Well F7.17 had technical problems, but high transmissivity
- Adding a pumping rate of 1200 m³/day combined with continuing withdrawal of the other wells, exceeds mean recharge

2. Expansion of Urban Areas

- Affecting recharge due to changes in land use towards more sealing and therefore less infiltration
- Anticipated city expansion would reduce mean recharge rates by about 10 %
- Reduction of travel time between urban areas and well field from 5 years to 3 years

3. Less recharge due to climate change

- Precipitation data of 2005 (33 % less than observation period)
- **Recharge is reduced by almost 75 %**
 - Water supply for Gitega cannot be preserved



Conclusion & Recommendations


- Numerical groundwater model was successfully calibrated on measured head values. It allows for:
 1. Characterisation of the aquifers hydraulic parameters (conductivity, eff. porosity)
 2. Estimation of groundwater recharge
 3. Identification of Protection zones for drinking water wells
- Indications were found for a hydraulically effective fault near the wells F2 and F4
 - Geophysical investigations and tracer tests needed for a better identification
- Recent pumping capacities of the existing wells already reach the limit of water availability in the catchment
 - Frequent technical malfunctions in the past have preserved the aquifer from larger water level decline
 - Low storativity of the aquifer
 - Unsustainable use cannot be maintained for a long time

Conclusion & Recommendations

- Future developments carry risks of an unsustainable use of the aquifer
 - An additional well is not recommended
 - If a series of low precipitation years occurs:
 - Recharge will be dramatically reduced
 - Pumping rate of the well field must be reduced accordingly to avoid drying out of the pumps
 - Expansion of build-up areas will result in:
 - Reduction of groundwater recharge & water availability
 - Reduced travel times of anthropogenic contaminants towards the drinking water wells

- Groundwater model can be updated and improved on future data

Many thanks for your attention!



The screenshot shows the BGR website interface. At the top, there's a header with the BGR logo and navigation links: NEWS, SCIENTIFIC INDEX, SITEMAP, and DEUTSCH. Below this is a search bar. The main navigation bar includes links to Homepage, About BGR, Topics, and Service. The left sidebar contains a list of topics: Earthquakes, georisk assessment, Energy resources, Final disposal of radioactive waste, Geodata management, Groundwater (selected), Basic information, Environmental monitoring, Exploration, Quality and protection, Resources management, Projects, Products, Meetings, Marine resource exploration, Mineral commodities, National / International Cooperation, Polar research, Soil, Subsurface use / CO2 storage, and Geoscientific collections, geo-.

The main content area displays the project title "TC Burundi: Management and Protection of Groundwater Resources" under the breadcrumb "Homepage » Topics » Groundwater » Projects ». Below the title is a "Report of the project:" section with two bullet points: "Burundi - Management and Protection of Groundwater resources" and "Burundi - Management und Schutz von Grundwasserressourcen".

The "Background:" section states: "Burundi is a small country of 27,834 km² located in the centre of Africa. According to the 2008 census, the population sums up to 8.04 million persons. The country is mainly conformed by a high plateau with variable altitude (from 772 m.a.s.l at the Tanganyika Lake to 2,670 m.a.s.l. at mount Heha). It has an equatorial climate with mean annual temperatures that vary according to the altitude between 23 °C to 17 °C. The mean precipitation is 1277 mm with two rainy seasons (February to May and September to November) and two dry seasons (June to August and December to January)."

The text continues: "Presently the domestic water supply is based on the about 25,000 springs with different discharge rates that provide water through local gravity systems. However, these systems have their natural limitation and cannot respond to future higher domestic water needs caused by the enormous population growth (around 3 %). Therefore, there is an urgent need for the country to estimate the quantity and quality of groundwater resources, if future water demand is to be covered."

The "The Project:" section states: "The project 'Management and Protection of Groundwater Resources' is a bilateral cooperation project of the Burundian Ministère de l'Eau, l'Environnement, l'Aménagement du Territoire et de l'Urbanisme (MEEATU) and the German Federal Institute for Geosciences and Natural Resources (BGR). The direct project partner is the Institut Géographique du Burundi (IGEBU) located in Gitega. The project is integrated in the Programme Sectoriel Eau (ProSecEau), a national water and sanitation programme financed by the German Federal Ministry for Economic Cooperation and Development (BMZ) that includes the Gesellschaft für Internationale Zusammenarbeit (GIZ) and KfW as further operative and financing organisations. Aim of the BGR project is the quantification and protection of groundwater resources. The technical activities take place in various intervention zones, each with a different goal, as follows:

Below the text is a "Hydrological map of Burundi" showing the country's borders, major cities, and water bodies. A legend indicates different types of water bodies and administrative boundaries.

Further details on the
BGR homepage:

http://www.bgr.bund.de/EN/Themen/Wasser/Projekte/laufend/TZ/Burundi/burundi_fb_en