Integrated modeling and assessment of regional groundwater resources in Germany and Benin

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Scope of this Presentation

→ **Water Resources Management** requires often a Regional Approach (interaction between different parts of catchments, different hydrological systems, different users, upstream-downstream relations, sources and sinks ….).

→ Water Resources Management on the Regional Scale requires **Integrated Approaches** (Groundwater - Surface Water, Natural Processes – Socio-economic Factors ….)

→ **Groundwater Management** is very often an essential part of Water Management, however: Integrated Management does not mean “Aquifer Management” (see “River Basin Management Plans” - WFD)

→ **Management requires Models**: to predict the effects of human interventions (social, economical, technical changes) as well as Climate Change

→ Regional Integrated Groundwater Models are required.
Key Questions

• How can we meaningfully model, assess and manage groundwater resources on the regional scale to meet the requirements of Integrated Water Resources Management?

• Are regional, integrated numerical groundwater models a suitable tool?

RIVERTWIN (www.rivertwin.org)

‘A Regional Model for Integrated Water Management in Twinned River Basins’

- Apply the principles of the European Water Framework Directive (WFD) to other continents.
- Develop the integrated water and land use management tool MOSDEW (9 data-coupled sub-models)

Central Europe: Neckar basin
Central Asia: Chirchik basin
West Africa: Oueme basin

Gaiser et al., 2008, PCE, Volume 33, Issues 1-2, 2008, Pages 92-114
Groundwater Model - Neckar Catchment

Discretisation:
1 x 1 km cells;
9 Layers (6 Aquifers)

~ 14000 km²

Main Aquifers:
- Fractured Sandstone
- Carstic / Fractured Limestone

Model Results - Stationary Calibration

y = 0.9x + 46.5
R² = 0.9521
MAE = 30.77 m
RMSE = 30.91 m
Transient Model Results

Can these results really help us to manage Groundwater Resources in the Neckar Catchment?
Benin - Ouémé-Basin: Geology

Water Availability: Climate; Wells

XXXVI IAH Congress: 26 October to 1 November 2008, Toyama, Japan
1. **“Data Driven” Approach**: Regionalization of Data from a countrywide database (~5,000 wells)
   - Groundwater Availability and Quality, Hydraulic Parameters, Extraction Potential
   - Socio-Economic Analysis of Groundwater Accessibility, Extraction Costs and Health Aspects

2. **“Model Driven” Approach**: Groundwater Flow Model Coupled to Hydrological Model to evaluate Climate Scenarios

Results: A) Data Driven Approach

**Biggest Problem:**
>5000 well data, but only very few, short time series available

Data partly unreliable or not comparable

### Table: Regionalized hydraulic and well properties (3x3km grid)

<table>
<thead>
<tr>
<th>a</th>
<th>b</th>
<th>c</th>
<th>d</th>
<th>e</th>
<th>f</th>
<th>g</th>
<th>h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Important locations and administrative boundaries</td>
<td>Potential of the aquifers (yields)</td>
<td>Aquifer rock type</td>
<td>Maximum yield [m³/day]</td>
<td>Specific yield [m³/yr/m]</td>
<td>Average depth of the wells</td>
<td>Hydraulic conductivity [m/s]</td>
<td>Natural groundwater quality (not influenced by human activity)</td>
</tr>
</tbody>
</table>
Groundwater Flow Modeling

Crystalline Basement,
- thin weathered ‘saprolitic’ layer with varying thickness on top (0-20m),
- locally intensively fractured (fault zones)
- otherwise no connected regional groundwater systems

Coastal Sedimentary Basin,
- gently dipping,
- weakly consolidated
- porous aquifers and aquitards (sand & silt)

Problems in both parts: Very few time series, groundwater recharge very difficult to determine

Groundwater related Management Issues

Crystalline Basement:
- shallow (dug) wells in Saprolite: low yields, **strong dependency on seasons**
- deep drilled wells in fracture zones: low to medium yields (hand or motor pump)

Coastal Sedimentary Basin,
- Shallow and deep (dug!) wells in rural areas: medium yields, seasonal variations
- deep drilled wells and well fields to supply big cities (and rural areas): higher yields

Unfavorable, unreliable conditions for groundwater extraction with low, seasonally varying yields

Good conditions for groundwater extraction

Cotonou

Ocean
Groundwater Flow Model

Using the Model for Management? Rural Areas

Problem 1: Hygienic Conditions / Water Quality
Problem 2: Low Yields, Scarcity in the dry season

Shallow, unprotected wells, Strong climatic influences (dry season)
Using the Model for Management? Urban Areas

Summary:

- **Northern Crystalline Region / Rural Areas:**
  - Management Tasks: Optimizing well locations and well design to improve yield, reliability and hygienic conditions
  - Problems that have to be worked on the local scale

- **Southern Coastal Plateau / Urban Areas:**
  - Management Tasks: Development of new resources, prevent seawater intrusion, prevent depletion
  - Problems that mainly have to be worked on the local scale

- **Specific Regional Problems:**
  - High Fluoride concentrations

- **In General:**
  - Management Tasks: Assess and predict groundwater availability under changing boundary conditions - increase reliability and reduce effect of seasonality on water availability
  - Problems that have to be worked on both on the local and regional scale - yet not necessarily using groundwater flow models
Benin Case Study: Questions & Answers

- Is the geological situation suitable for regional groundwater flow modelling?
  - Yes in the South, no in the North

- Is the data availability sufficient for regional groundwater flow modelling?
  - No. Transient data missing, other data inaccurate, not reliable

- Are there any groundwater related tasks that require a basin wide, integrated, regional groundwater flow model?
  - There are many specific problems but they require local models or no (numerical) model
  - There are regional problems (water availability in the dry seasons) but they do not require (necessarily) a 3D groundwater flow model

Conclusions

- Accuracy of RGM results is often too low to be meaningfully applied to management problems (often local scale)

- Regional scale groundwater management problems can often be solved with hydrological or water balance approaches. Main issue: Groundwater Recharge rather than Groundwater Flow.

- But, regional groundwater flow models can be beneficial anyway, because:
  - Even if the results are not good, they help to better understand groundwater systems and interactions with surface water, unsaturated zone and climate
  - Thus, they can enhance the applicability of hydrological models in the field integrated water management
  - They are a good means for checking the plausibility of other models and to come to reliable spatially and temporally distributed groundwater recharge calculations.
  - They guarantee that hydrogeological conditions are taken into account and that a hydrogeologist is involved in the project!
Thank you for your attention!