Grid-based Optimization in Groundwater Management
Recent Results and Experiences

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Background
Coal and salt mining activities cause soil subsidence up to more than 10 m...

Geographical Orientation

Coal and salt mining activities cause soil subsidence up to more than 10 m...

Consequences
• Flooding of basements in urban areas
• Water logging in rural regions

Measures
Dewatering by using:
• surface drains
• pumping wells
Groundwater model

- Groundwater flow model based on FEFLOW®
- Covering more than 1,000 km²
- 2D horizontal setup
- Transient conditions
- Annual updates and maintainence
- Soil subsidence considered for boundary conditions and aquifer geometry by applying a model-specific plug-in for FEFLOW®

Reasons for Optimization

- Pumping-station system historically grown
- Pumping locations not perfectly situated
- Pumping strategies developed from experience
- Mining discontinued in the near future

Existing system has deficiencies
- High pumping rates
- High pumping costs
- „Ewigkeitskosten“ – eternal costs

Optimization seems cost-efficient

Software Solution

OpTiX®

FEFLOW® and OpTiX® in a Grid Environment

Location Optimization

Simple example with
- Concentration source and plume
- Pumping well

Optimization goal:
- Stop well contamination by placing one pumping well
- Pumping rate as low as possible

Location History - APPS
### Location History - PSS

![Location History - PSS Diagram]

### Location Optimization

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Best Result</th>
<th>No of Model Calls</th>
</tr>
</thead>
<tbody>
<tr>
<td>APPS</td>
<td>11,484 m³/d</td>
<td>168</td>
</tr>
<tr>
<td>DPS</td>
<td>13,888 m³/d</td>
<td>1254</td>
</tr>
<tr>
<td>PSS</td>
<td>5,474 m³/d</td>
<td>2958</td>
</tr>
</tbody>
</table>

### Number of Wells and Results

![Number of Wells and Results Diagram]

### Real-World Case

- Test area of about 20 km²
- 17 pumping stations w/ 32 wells
- Pumping rate about 17,000 m³/d

- Pumping-rate optimization
- Optimization of pumping locations
- Constraints:
  - Minimum depth to groundwater
  - Maximum number of wells
  - Maximum pumping rate
  - Go-area and no-go zones

### Scenario Examples

- Each run approx. 1 hour
- 32 runs in parallel
- Run time less than one to several weeks

<table>
<thead>
<tr>
<th>No of Wells (max)</th>
<th>Rate Interval</th>
<th>Former Extraction Rate</th>
<th>Optimized Extraction Rate</th>
<th>Reduction</th>
<th>No of Simulations</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>5000 m³/d</td>
<td>12,443 m³/d</td>
<td>12,064 m³/d</td>
<td>3.0 %</td>
<td>2506</td>
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<tr>
<td>10</td>
<td>3000 m³/d</td>
<td>12,443 m³/d</td>
<td>9,999 m³/d</td>
<td>19.6 %</td>
<td>5515</td>
</tr>
</tbody>
</table>

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Influencing factors

- Number of decision variables:
  - high enough to get enough valid solutions for obtaining initial reference set
  - low enough to limit degrees of freedom

- More global optimization algorithms may lead to better results but require more model runs.

Conclusions

- Optimization techniques can be used for location optimization
- Significant reduction of pumping rates is possible
- Enormous numbers of simulations are required
- Optimization is only feasible using massive parallelization
- Grid computing may provide the solution