Grid-based Optimization in Groundwater Management

Recent Results and Experiences

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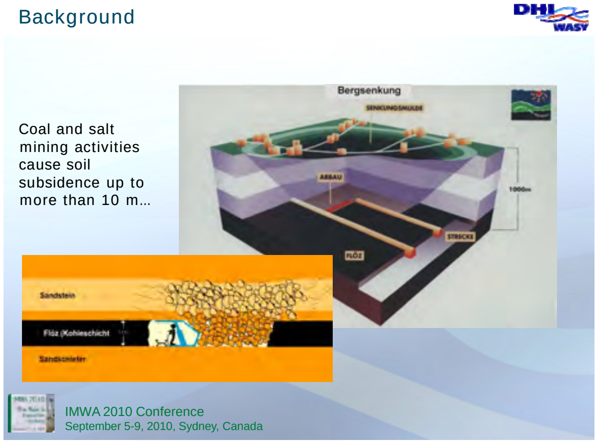

Background

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

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Geographical Orientation

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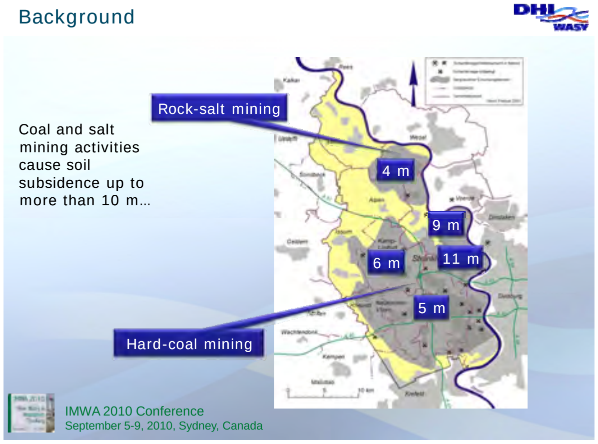

Background

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

Rock-salt mining

Hard-coal mining

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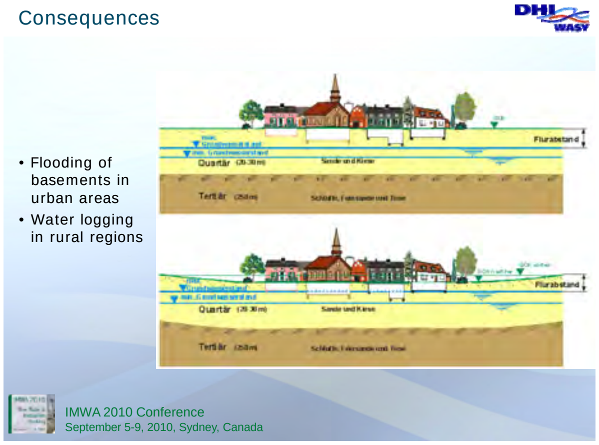

Consequences

- Flooding of basements in urban areas
- Water logging in rural regions

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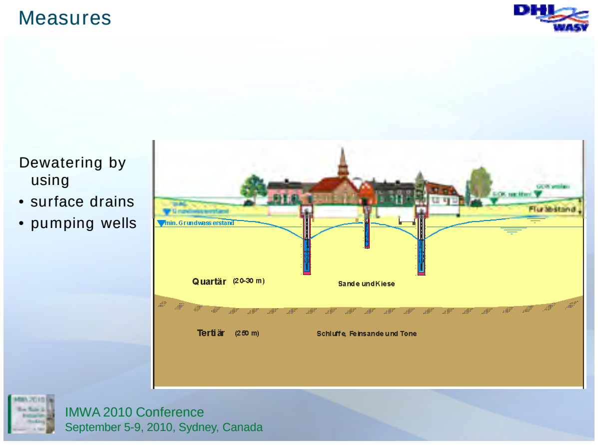

Measures

Dewatering by using
- surface drains
- pumping wells

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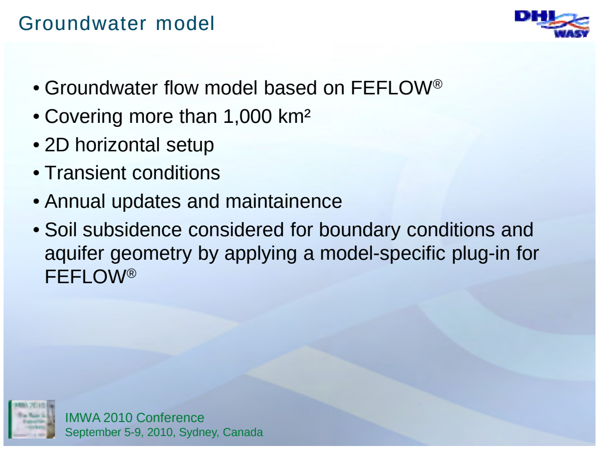

Groundwater model

- 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®

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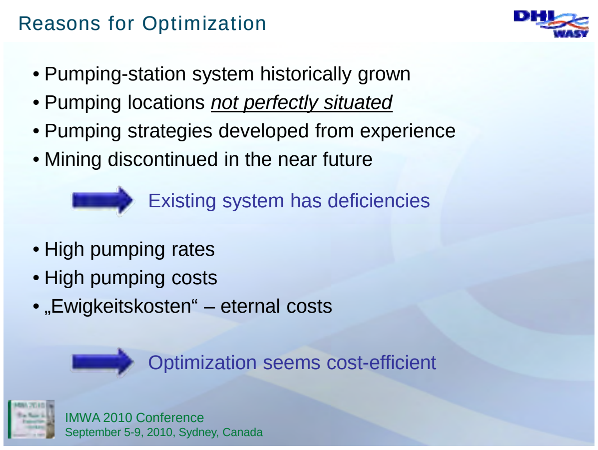

Reasons for Optimization

- 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

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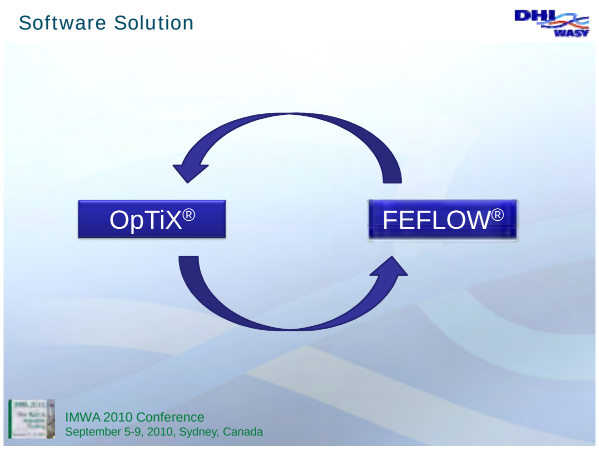

Software Solution

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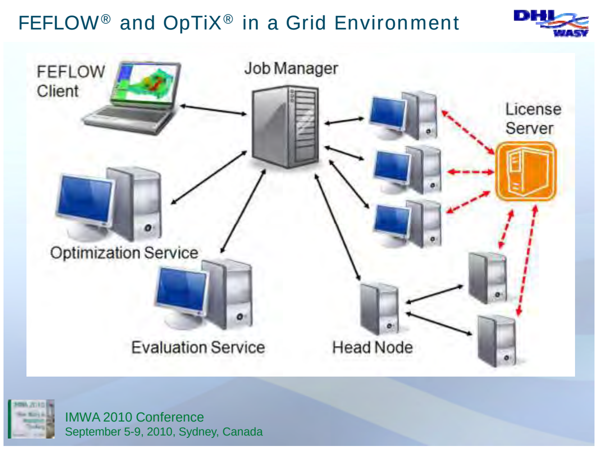

FEFLOW® and OpTiX® in a Grid Environment

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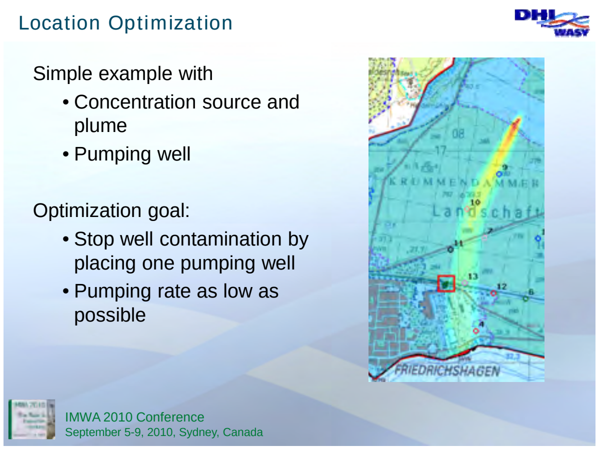

Location Optimization

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

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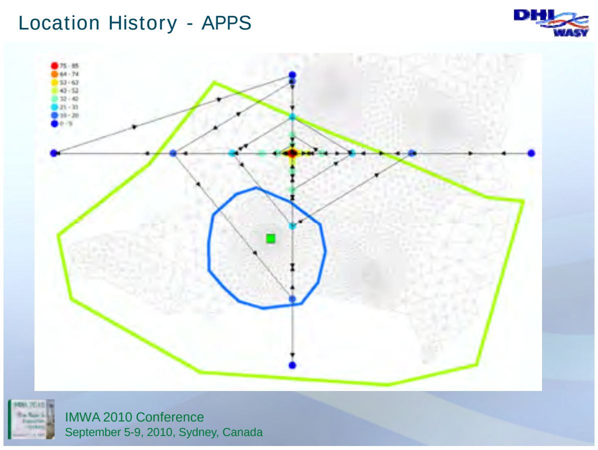

Location History - APPS

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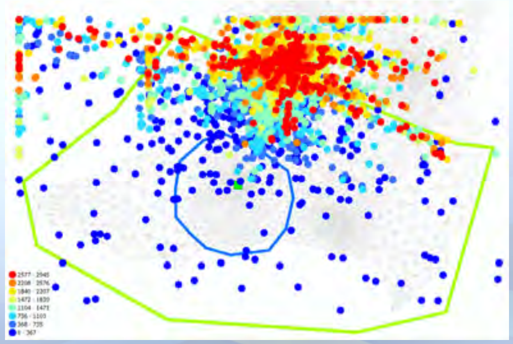
Location History - PSS



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Location Optimization

Algorithm	Results	
	Best Result	No of Model Calls
APPS	11,484 m³/d	168
DPS	13,888 m³/d	1254
PSS	5,474 m³/d	2958

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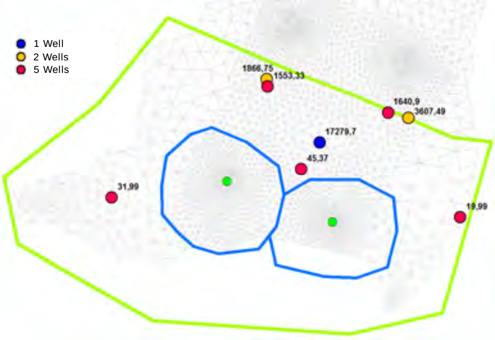
Number of Wells and Results



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Real-World Case

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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

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Scenario Examples

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

No of Wells (max)	Rate Interval	Former Extration Rate	Optimized Extraction Rate	Reduction	No of Simu-lations
10	0-5000 m³/d	12,443 m³/d	12,064 m³/d	3.0 %	2506
10	0-3000 m³/d	12,443 m³/d	9,999 m³/d	19.6 %	5515

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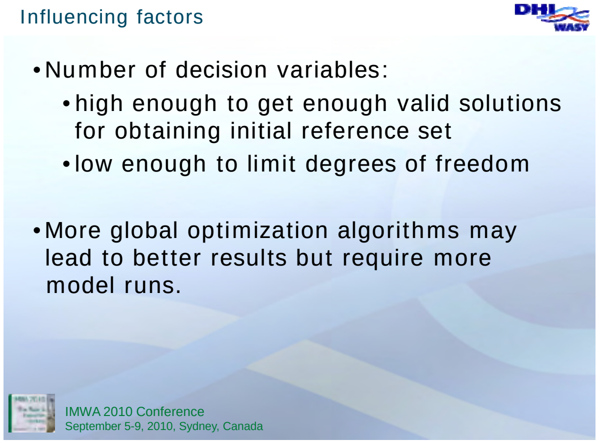

Influencing factors

- 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.

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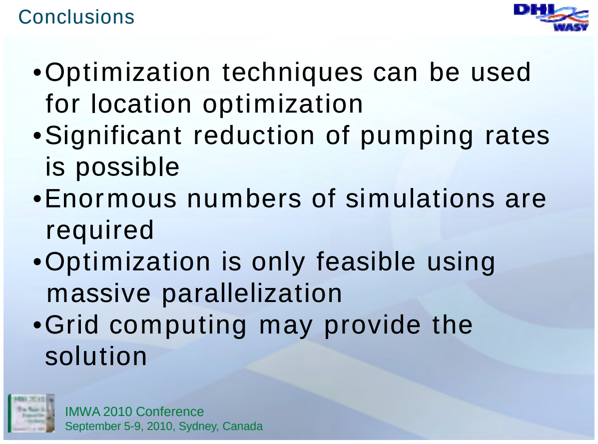

Conclusions

- 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

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