Groundwater–Surface Water Interaction – Methods and Case Studies

Stephan M. Weise
UFZ-Department of Isotope Hydrology

Groundwater–Surface Water Interaction is a process relevant for ...

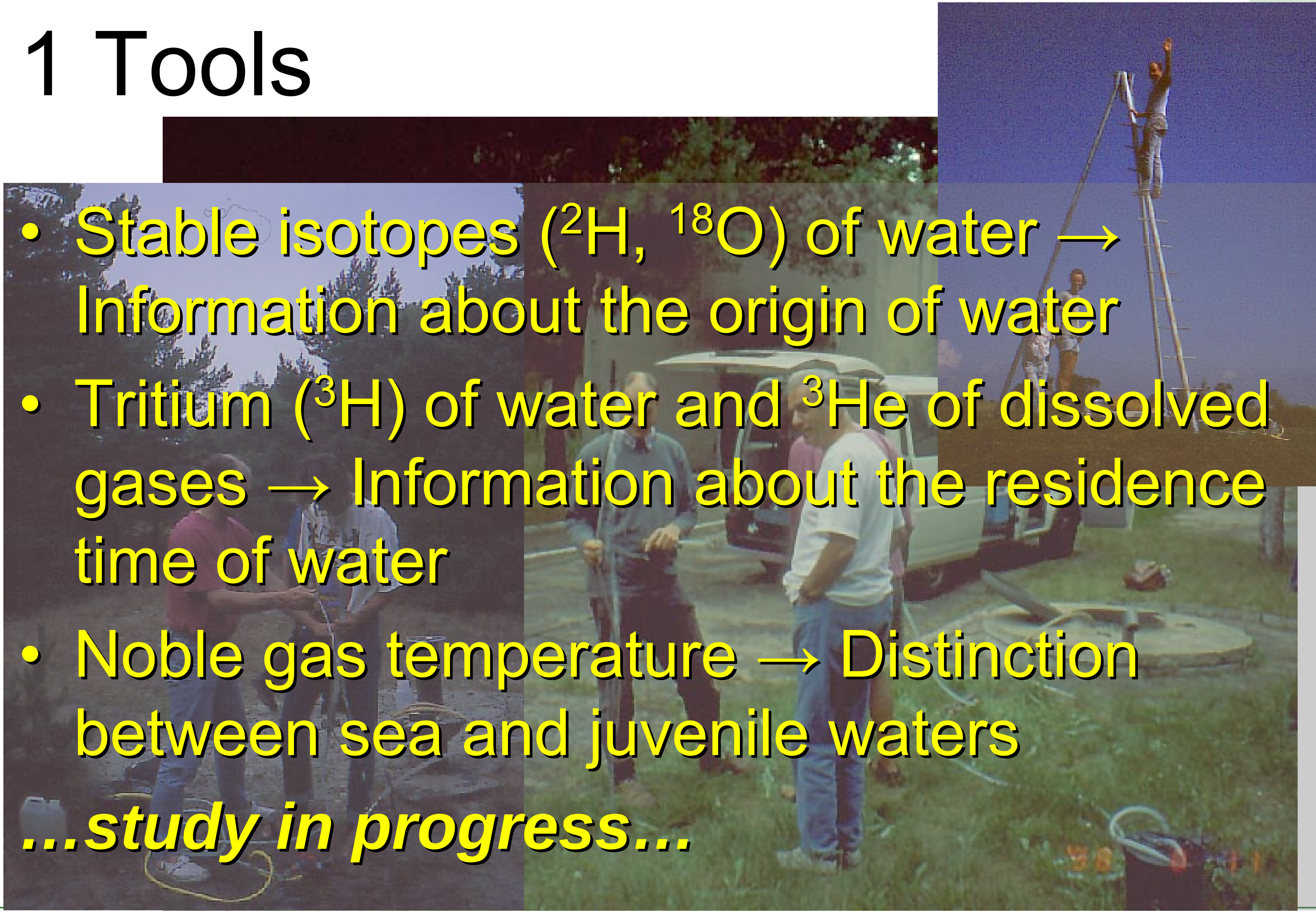
- Salinisation of fresh groundwater due to sea water intrusion
- Intrusion of contaminated groundwaters into surface water
- Developement of pit lakes highly contami-nated and acidified by lignite mining
- Groundwater un-covered by gravel production

1. Sea water intrusion

- Problem:
  Over-exploitation of costal-near groundwater reservoirs causes intrusion of sea water
- Measures:
  Accurate ascertainment of the groundwater reservoir to avoid over-exploitation
- Tools:
  - Monitoring of hydrochemical evolution
  - Definition of size of reservoir with environmental isotopes

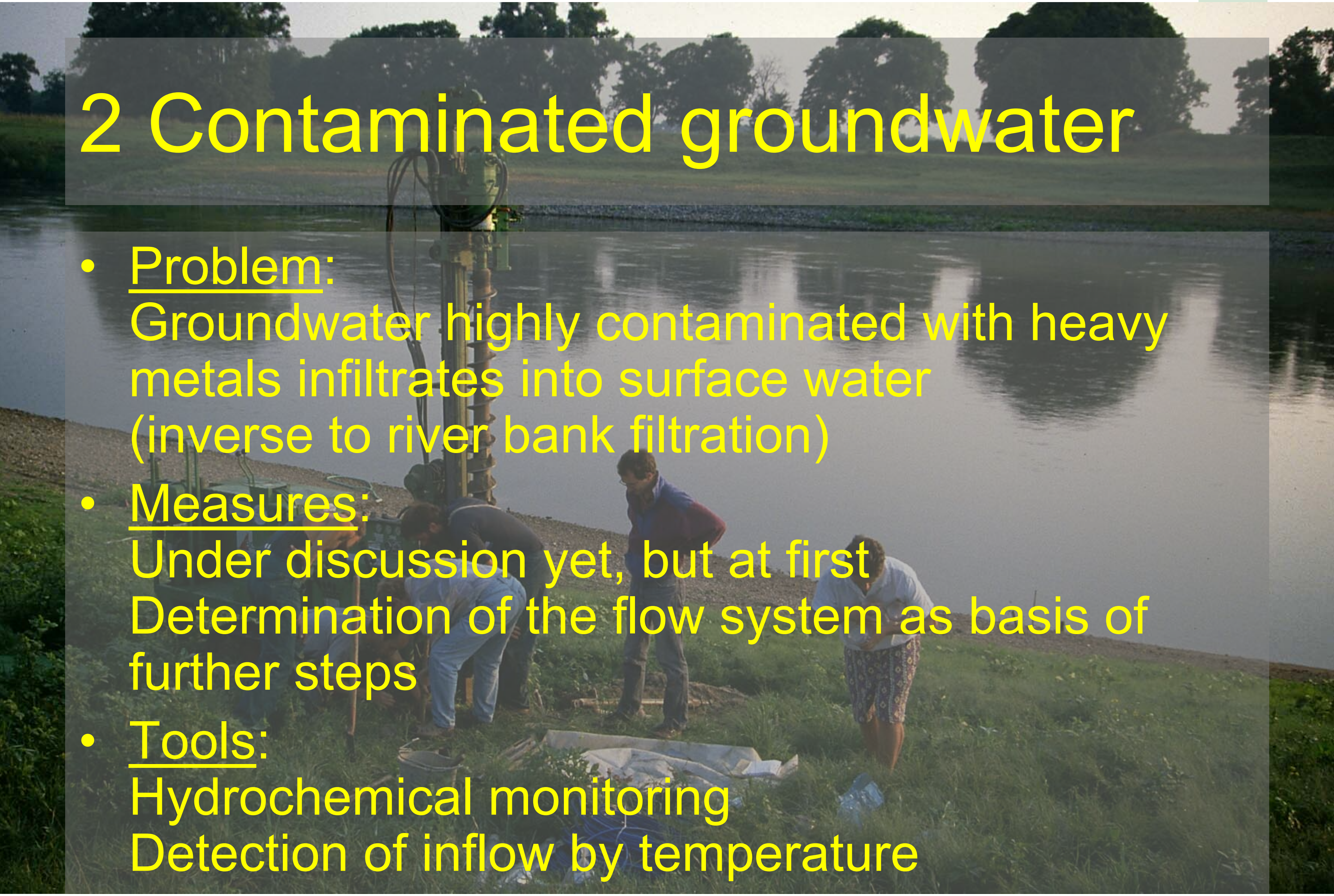
1. Sea water intrusion

1 Tools



- Stable isotopes (^{2}H, ^{18}O) of water → Information about the origin of water
- Tritium (^{3}H) of water and ^{3}He of dissolved gases → Information about the residence time of water
- Noble gas temperature → Distinction between sea and juvenile waters

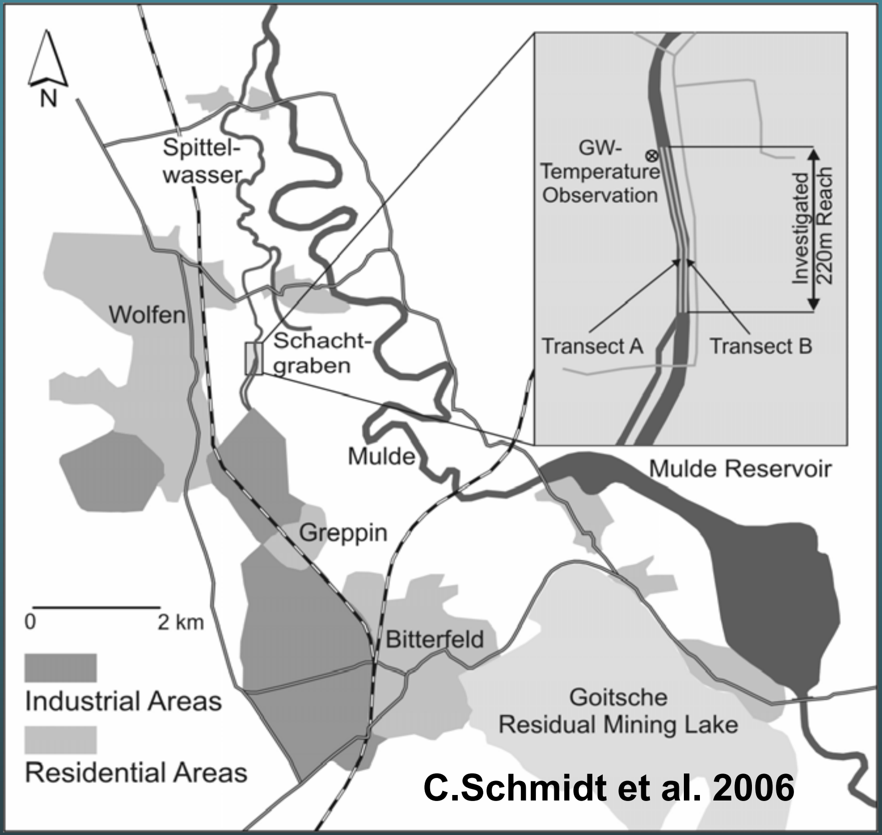
…study in progress…



2 Contaminated groundwater

- Problem:
  Groundwater highly contaminated with heavy metals infiltrates into surface water (inverse to river bank filtration)
- Measures:
  Under discussion yet, but at first
  Determination of the flow system as basis of further steps
- Tools:
  Hydrochemical monitoring
  Detection of inflow by temperature

Study Site



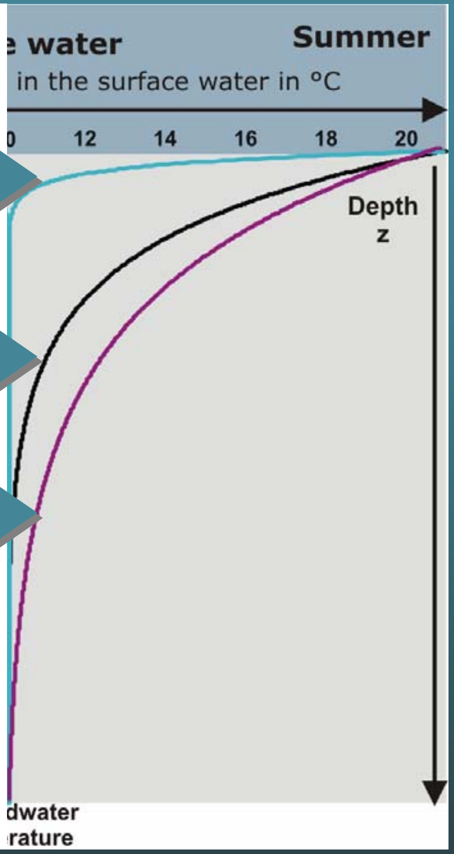
C. Schmidt et al. (2006):Characterization of spatial heterogeneity of groundwater-stream water interactions using multiple depth streambed temperature measurements at the reach Scale. Hydrol. Earth Syst. Sci. Discuss., 3, 1419–1446

Concept

High Groundwater Discharge

Medium Groundwater Discharge

Low Groundwater Discharge



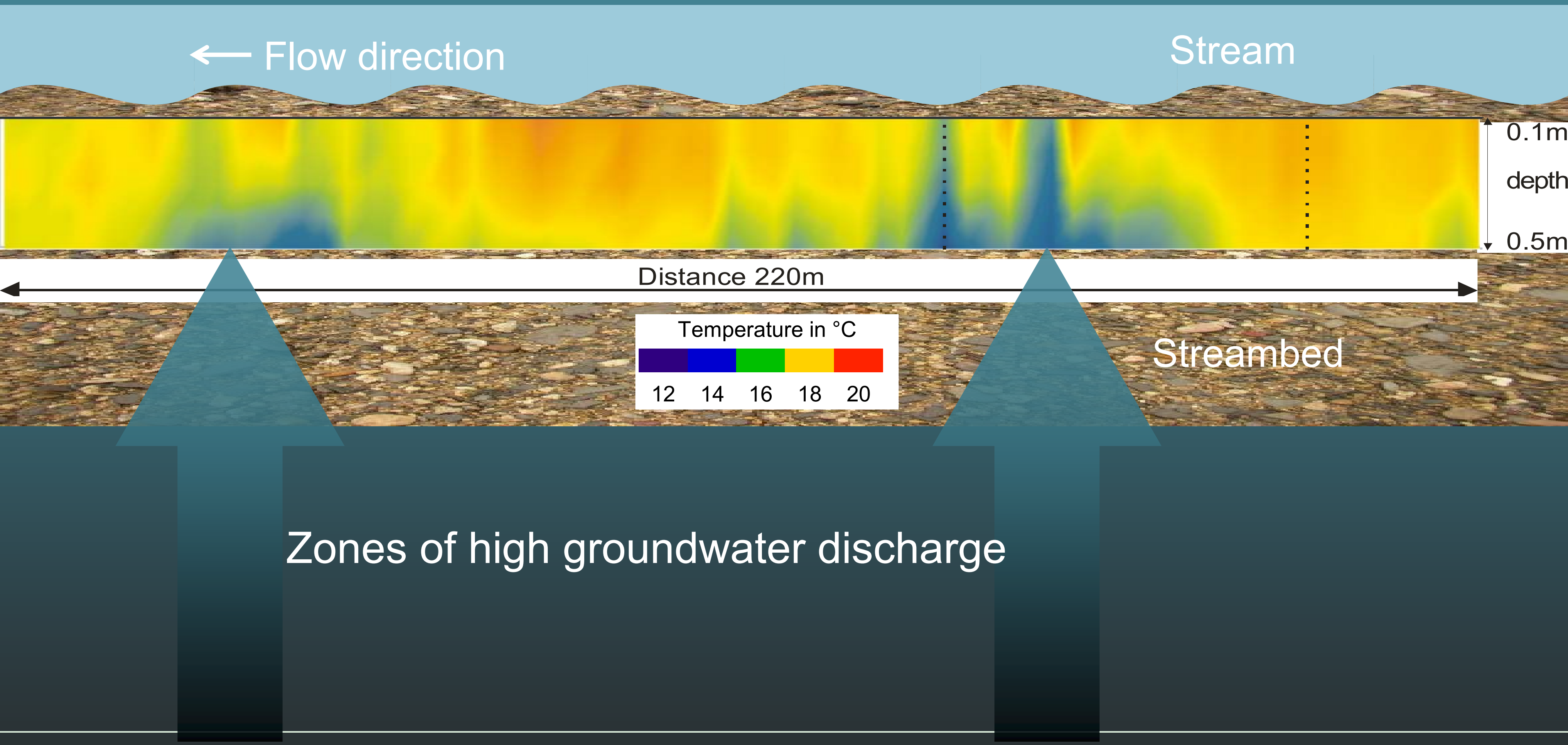
- Vertical Flow can be obtained from a simple one-dimensional analytical solution of the heat diffusion advection equation

Measurements

- Assumption: Observed streambed temperatures represent spatial differences of groundwater discharge

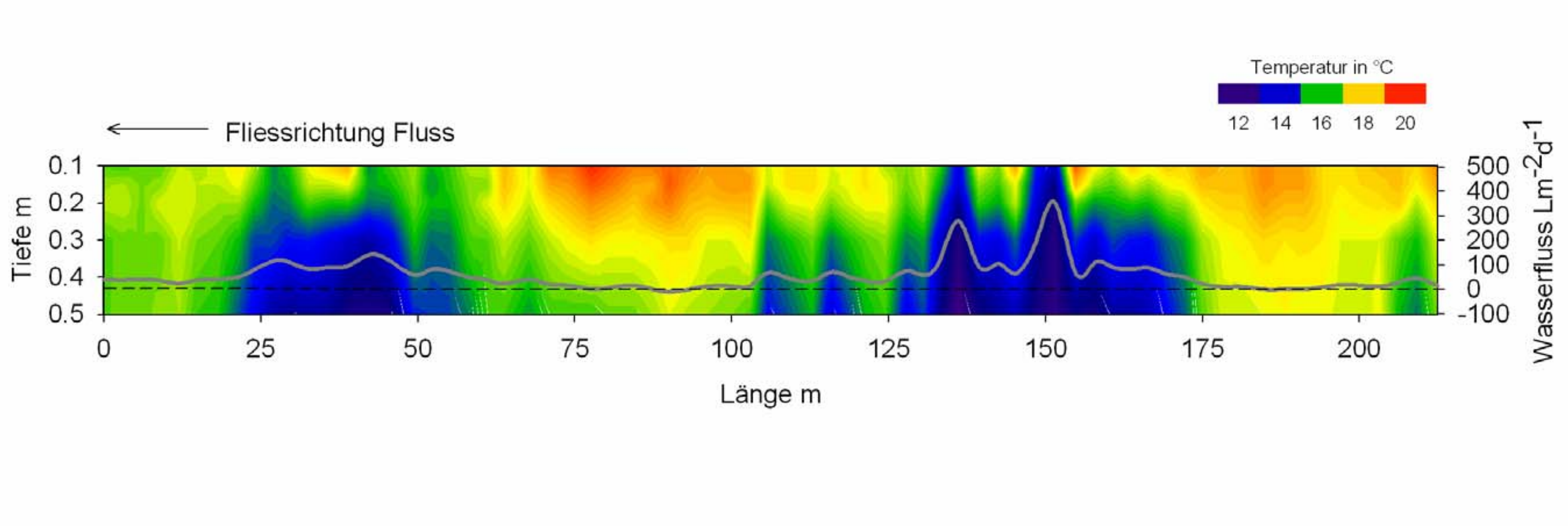
- Streambed temperatures are measured by temporarely inserting a probe into streambed

Results



Flow direction
Stream
0.1m
depth
0.5m
Distance 220m
Temperature in °C
12 14 16 18 20
Streambed
Zones of high groundwater discharge

Results

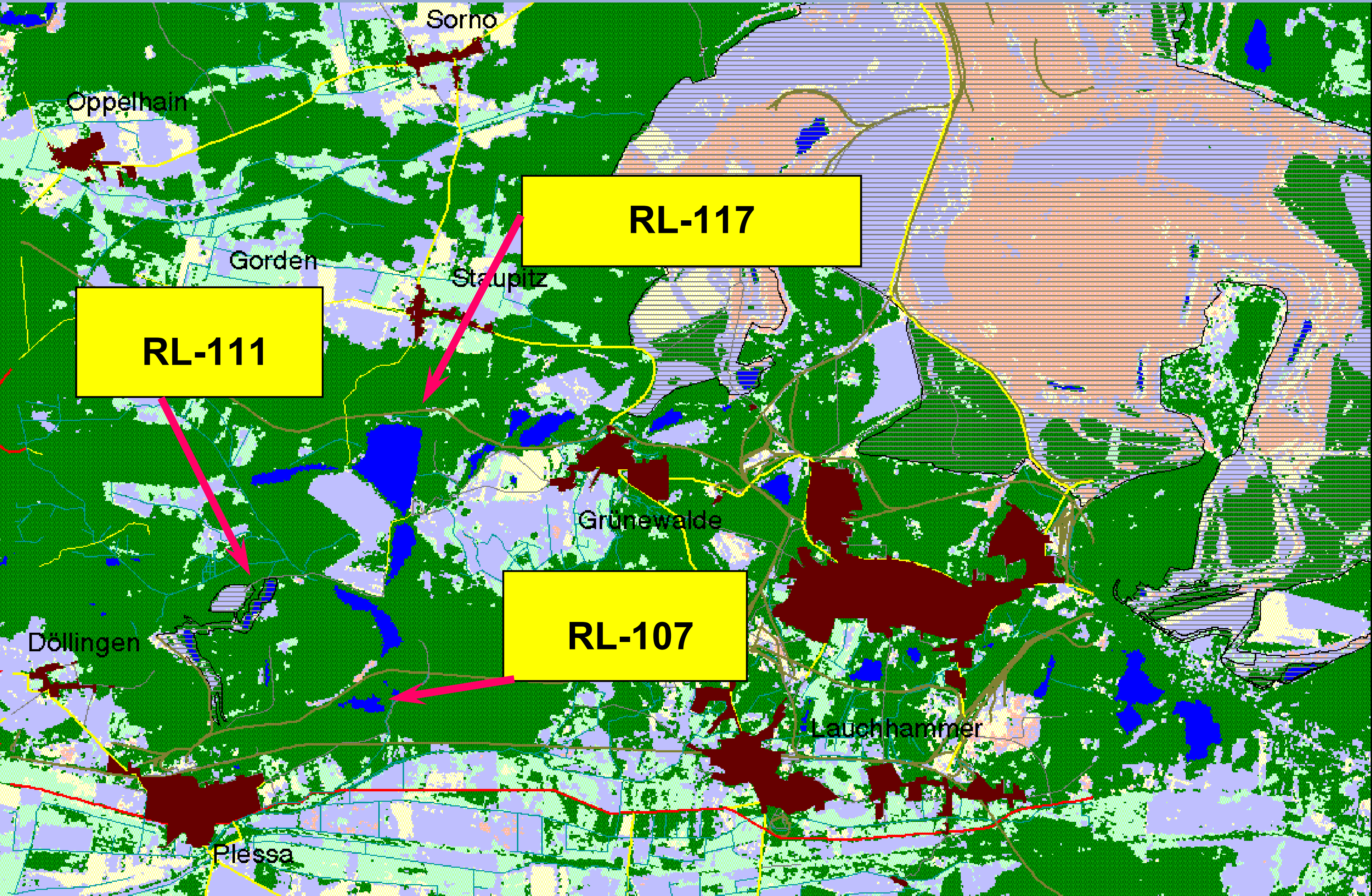


Temperature profil can be converted to a water-influx profil

3 Mining lakes

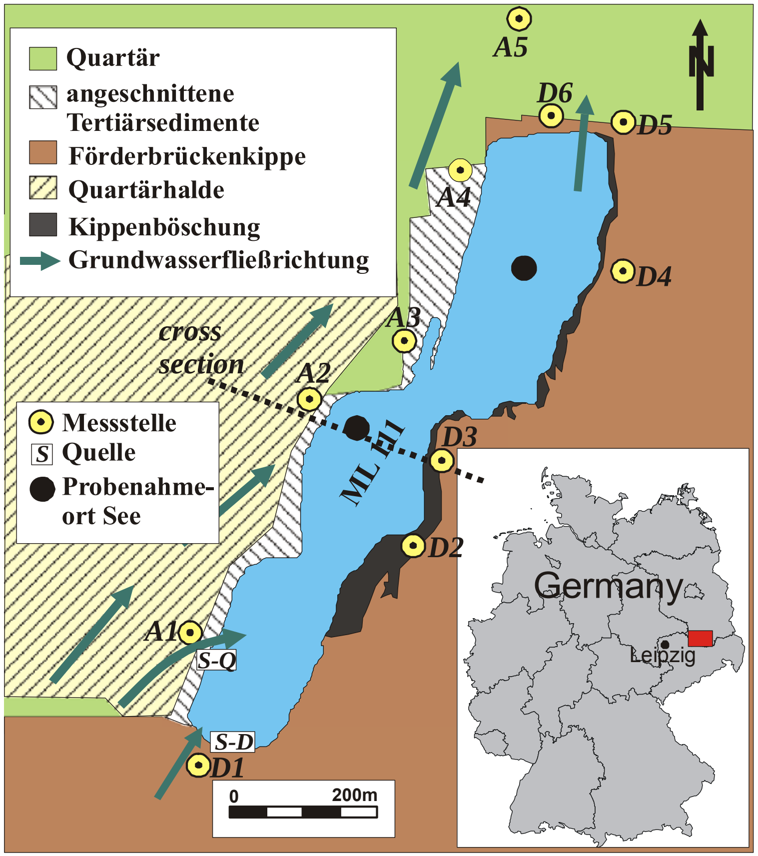
- <u>Problem</u>:
  Flooding of holes from lignite mining activity are acidified (down to pH = 2) and contaminated with heavy metals
- <u>Measures</u>:
  Development of remediation strategies dependent on groundwater-lake water interaction
- <u>Tools</u>:
  - Inflow/outflow balance with environmental isotopes
  - Detection of inflow by ^{222}Rn and stable isotopes
  - Governing biogeochemical cycles at benthos

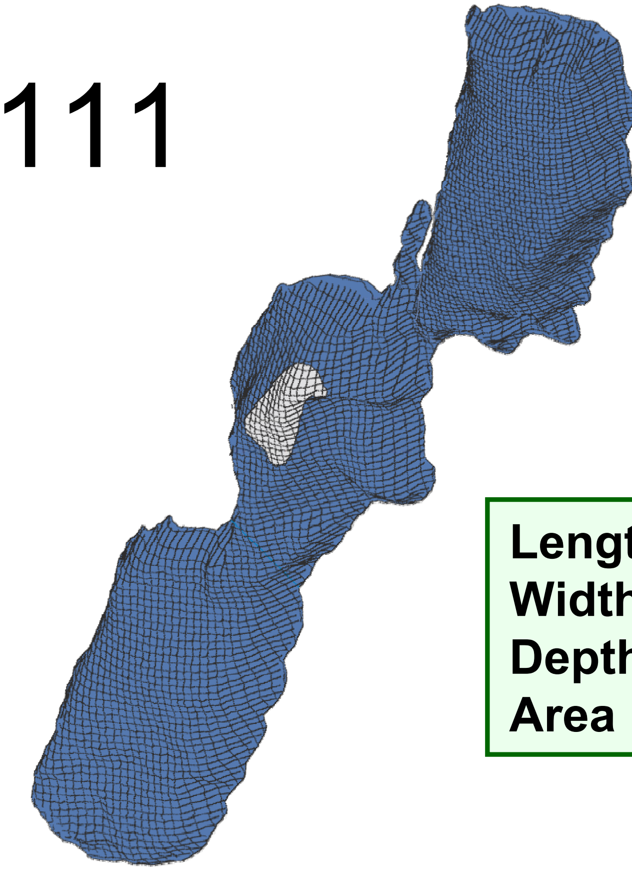
Lignite mine district Koyne-Plessa



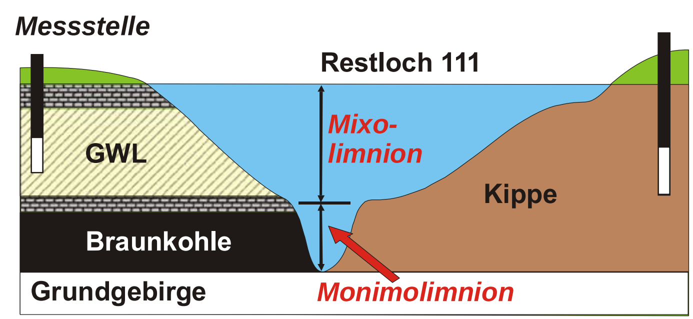
Mining Lake RL 111

3 Test site RL 111





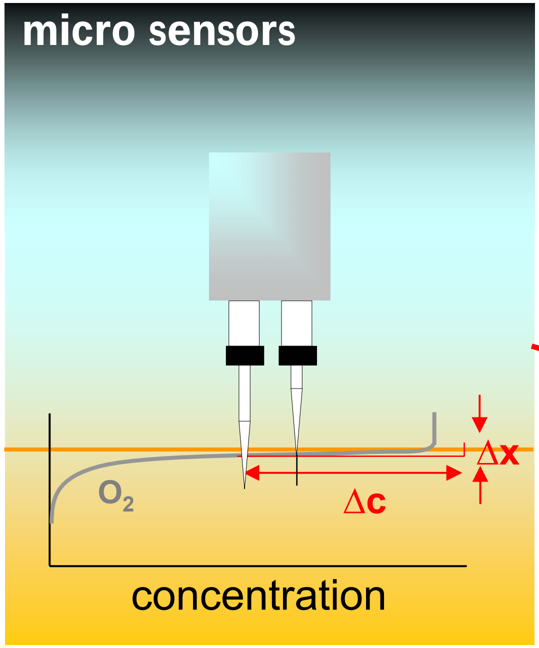
Length	900 m
Width	180 m
Depth	10 m
Area	110.000 m²

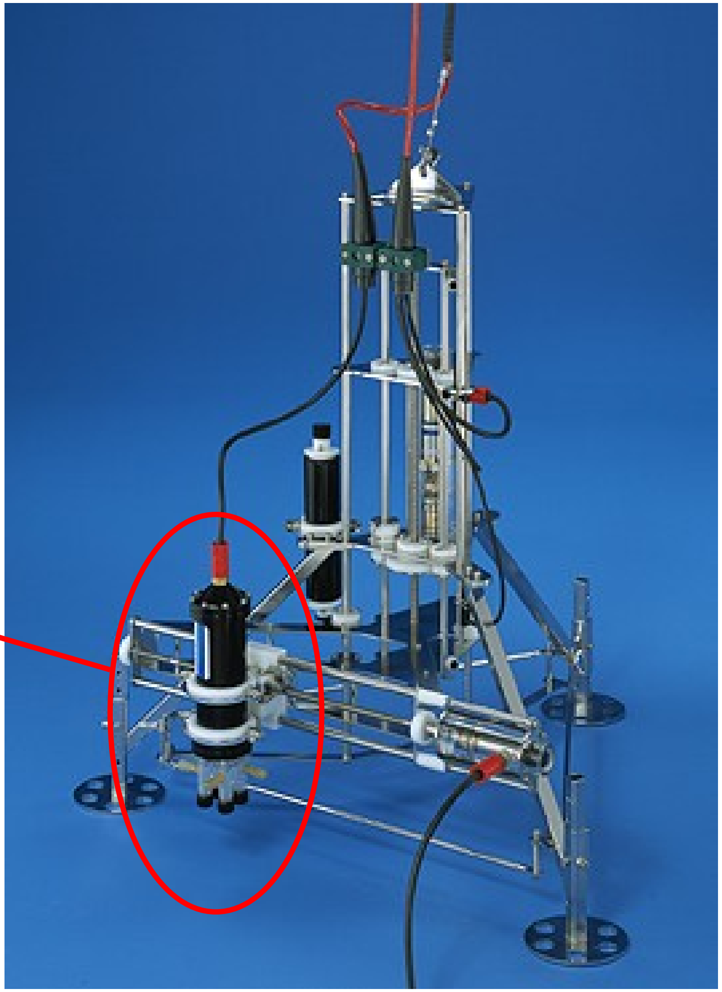


3 Determination of fluxes

high-resolution concentration profiles

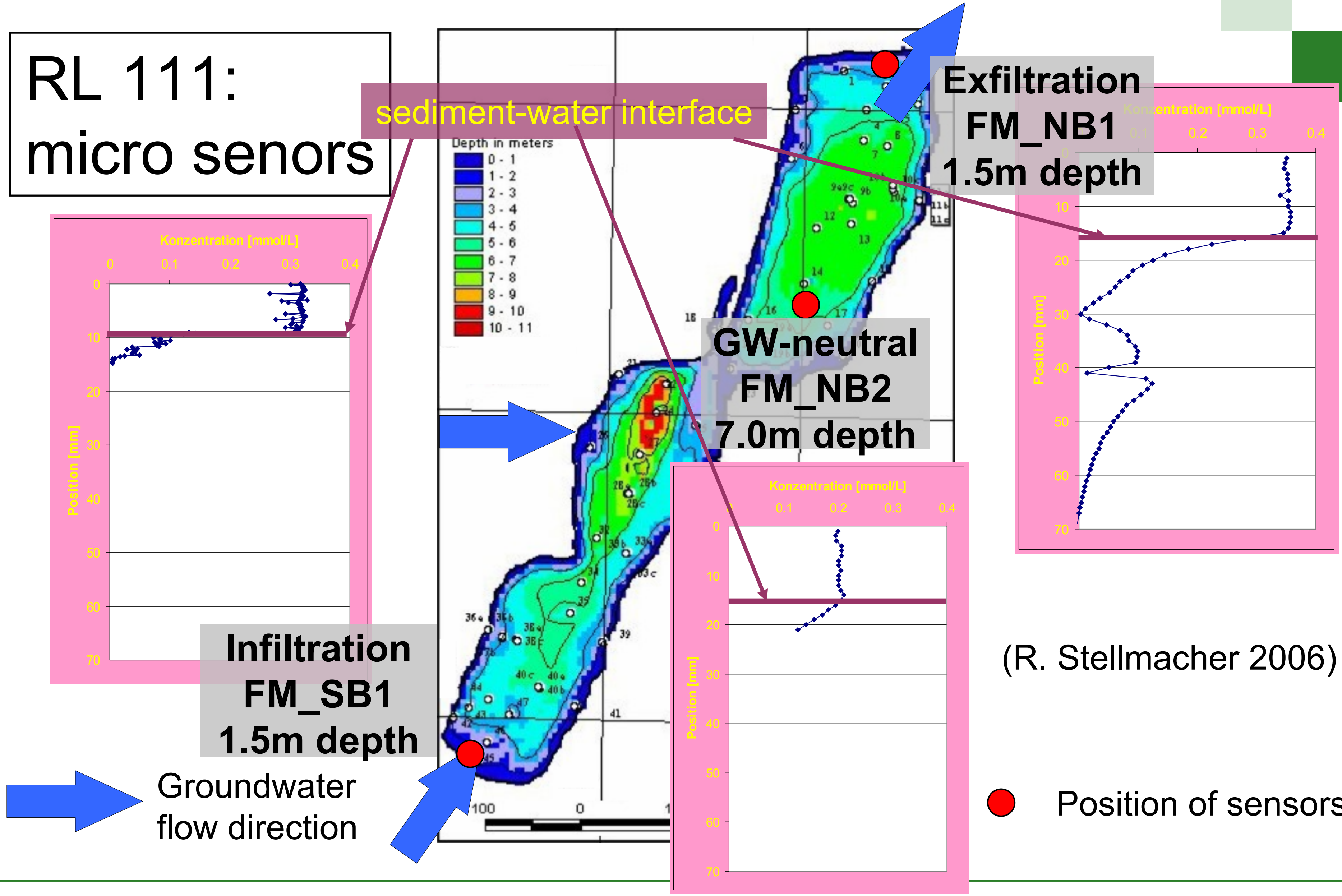
→ Millimeter scale





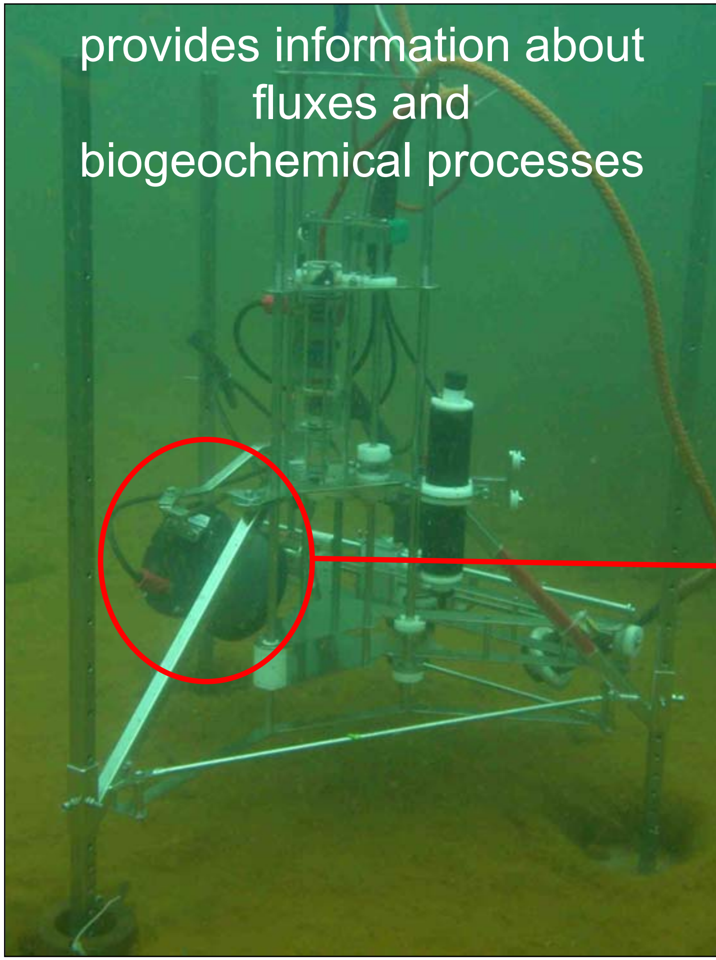
(R. Stellmacher 2006)

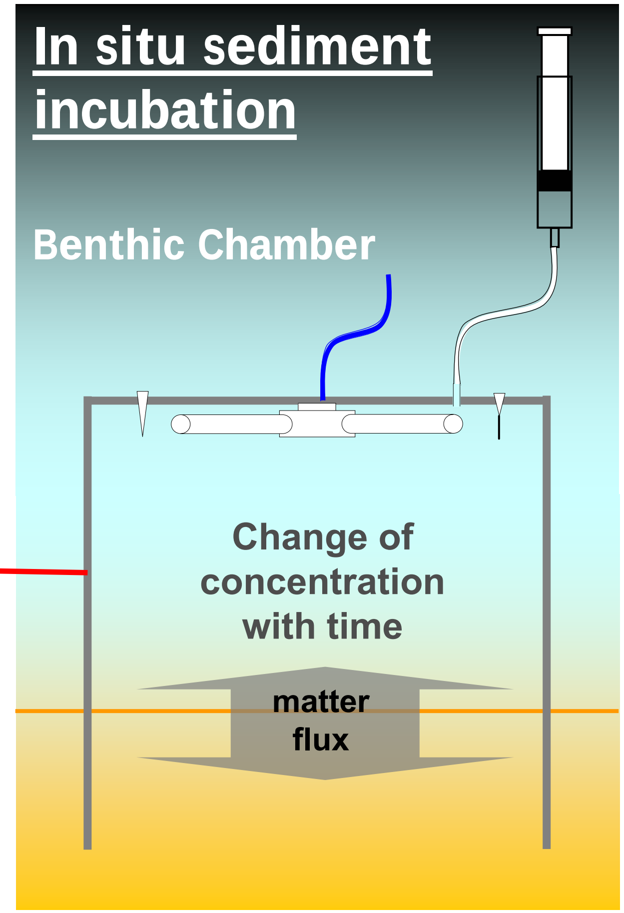
RL 111: micro senors



(R. Stellmacher 2006)

3 Determination of fluxes



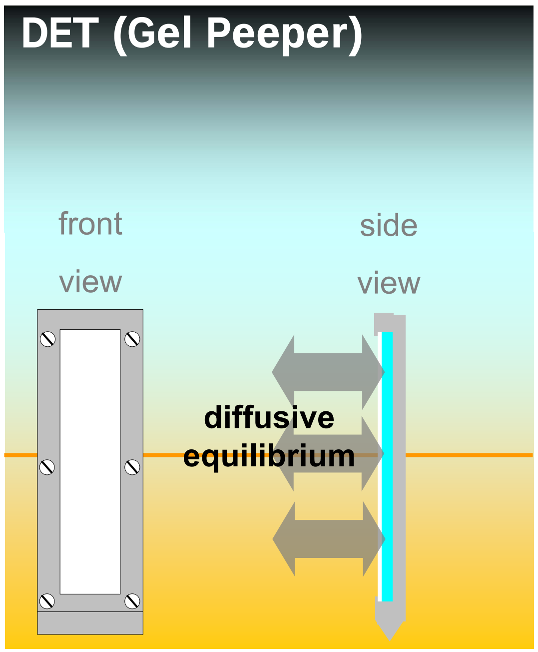


→ "direct" flux determination with simulated flow

3 Determination of fluxes

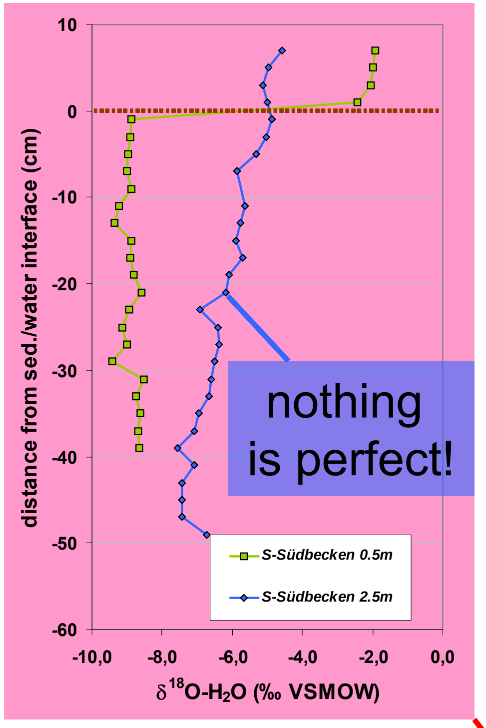
high-resolution concentration profiles

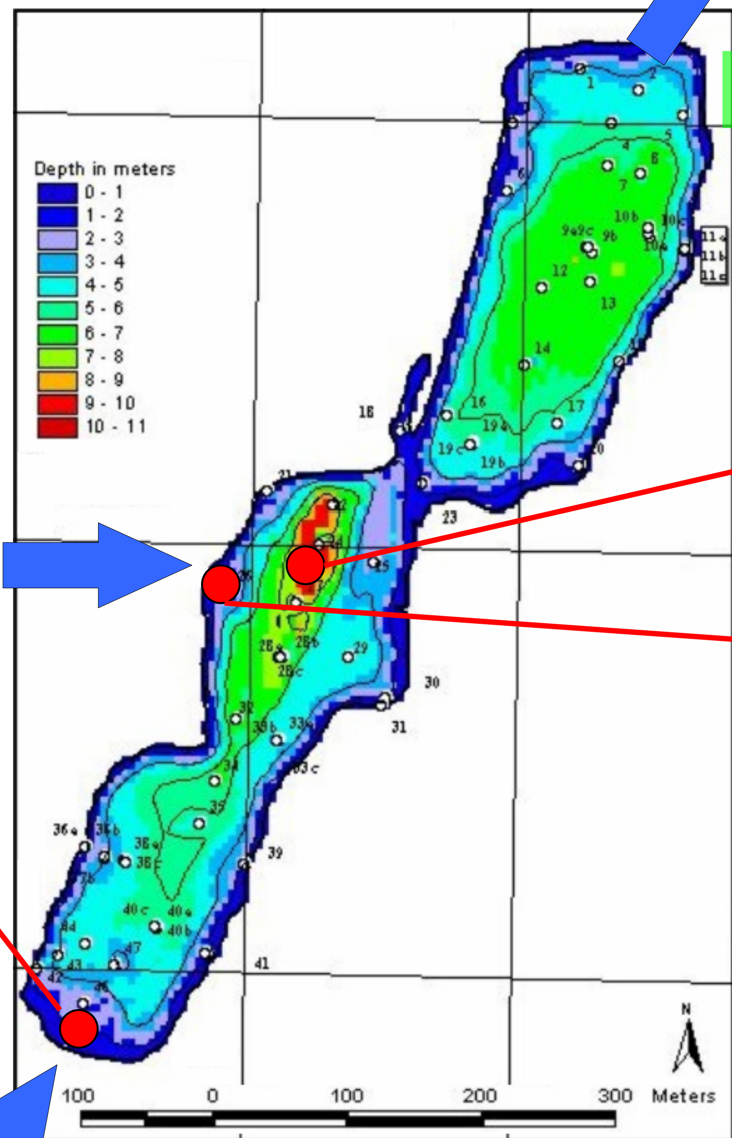
→ Decimeter scale

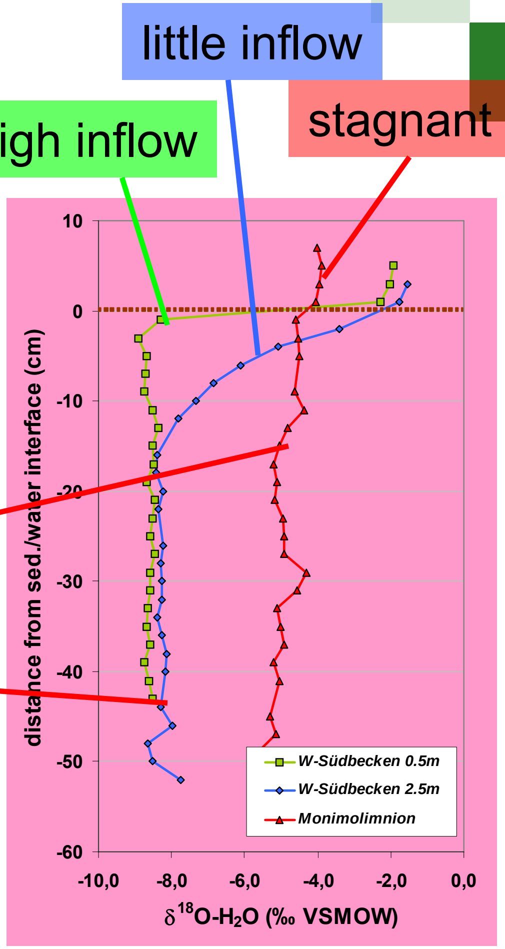


(R. Stellmacher 2006)

RL 111: DP sampler







Groundwater flow direction

Position of DPS

(K. Knöller and S. Weise 2006)

Using ^{222}Rn to detect groundwater inflow into a lake

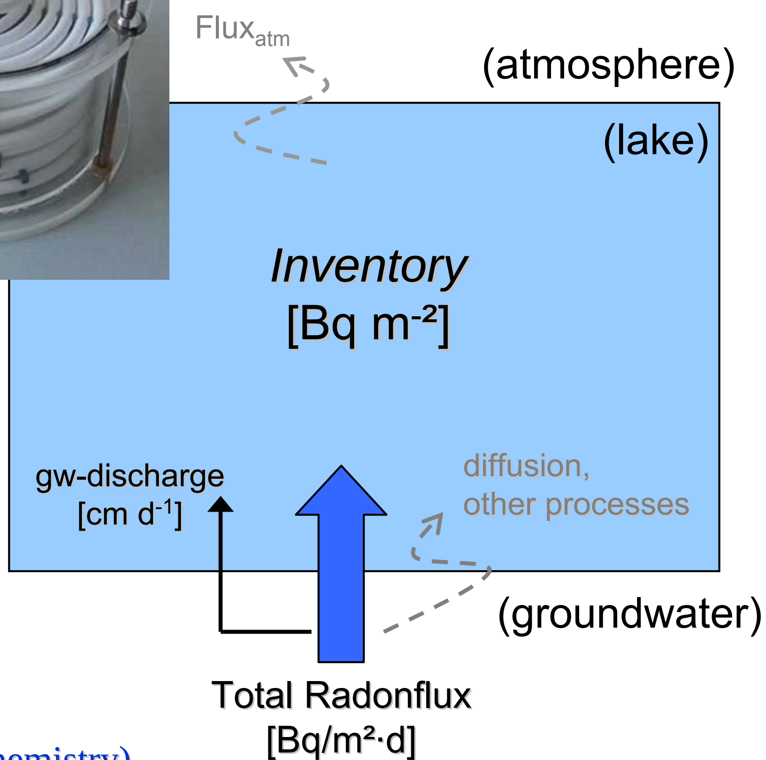
Radon is a naturally occurring radioactive gas, with a non-reactive nature and a short half-life ($t_{1/2}$ = 3.83 d)

Radon concentrations of groundwater are very large enriched to surface water (often 1000-fold or more)

Radon is an excellent tracer to identify and quantify significant groundwater discharge.

The approach for quantifying gw discharge is a steady-state system with a consideration of all ^{222}Rn sources and sinks related to the lake.

Diffusion cell for on-site Rn analytik



(Axel Schmidt, UFZ, Dept. Analytical Chemistry)

Using ^{222}Rn to detect groundwater inflow into a lake

Example: Tagebaurestloch RL 107, Plessa

- ○ area: 125,000 m², medium depth: ~3 m
- ○ pH = 2.4; Fe = 400-840 mg/l; SO_4^{2-} = 1.8-3.7 g/l

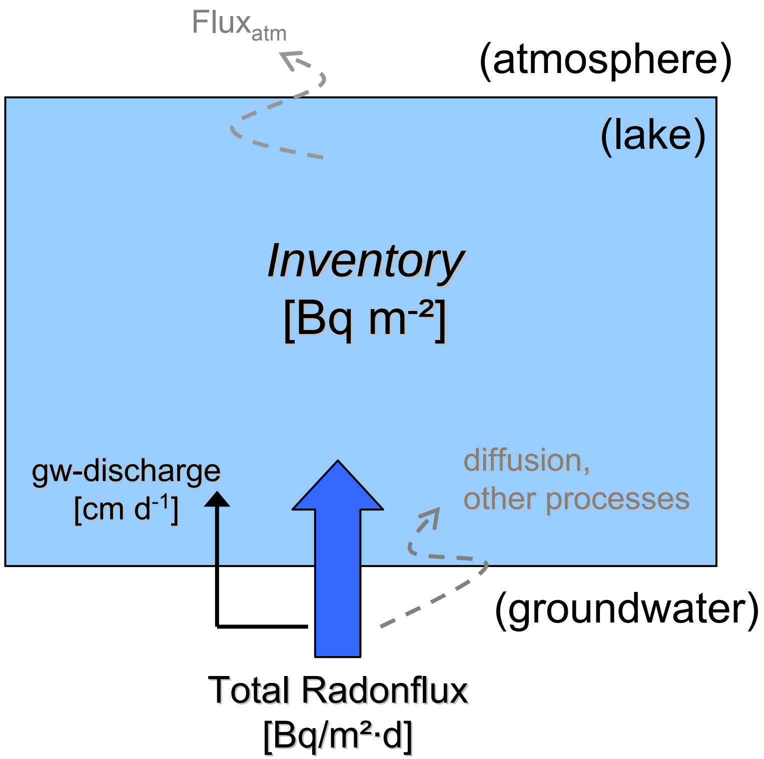
Data:

$Flux_{atm}$ = 2 ± 0.16 [Bq m^{-3}]
Inventory = 75 ± 1.8 [Bq m^{-2}]
Diffusion = 0.2 [Bq m^{-3}]
Radonflux = 414 ± 9.9 [Bq/m²·d]

Groundwater discharge:

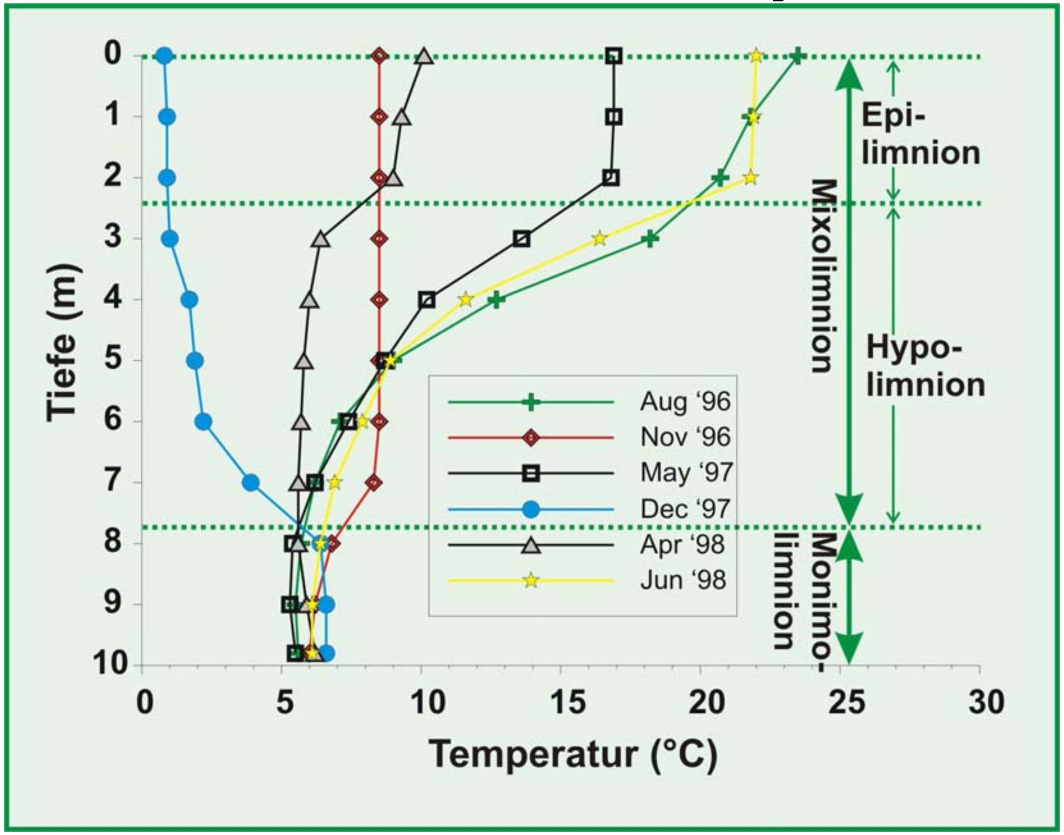
0.182 ± 0.057 cm d^{-1}

Radon is a excellent tracer to quantify groundwater discharge



(Axel Schmidt, UFZ, Dept. Analytical Chemistry)

RL 111: Isotopic balance



Basic input:

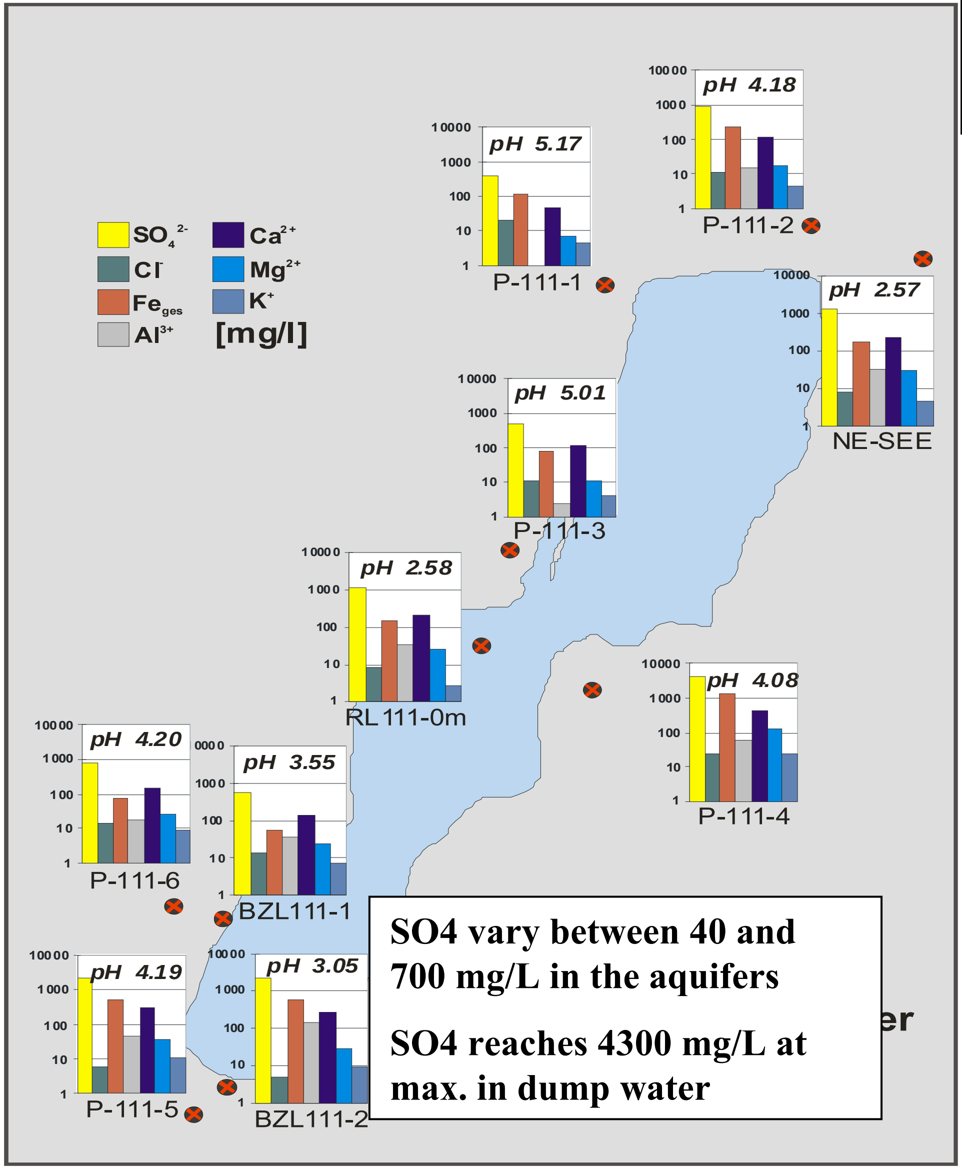
- **annual variation in isotopic composition of lake water**
- **isotopic composition and amout of precipitation**
- **isotopic composition of groundwater**
- **surface in- and output**
- **(estimates of) evaporation**

annual groundwater inflow: 23700m^3

annual groundwater outflow: 15700m^3

(K. Knöller 2001)

RL 111: Ground- and dump water (isotope-) geochemistry

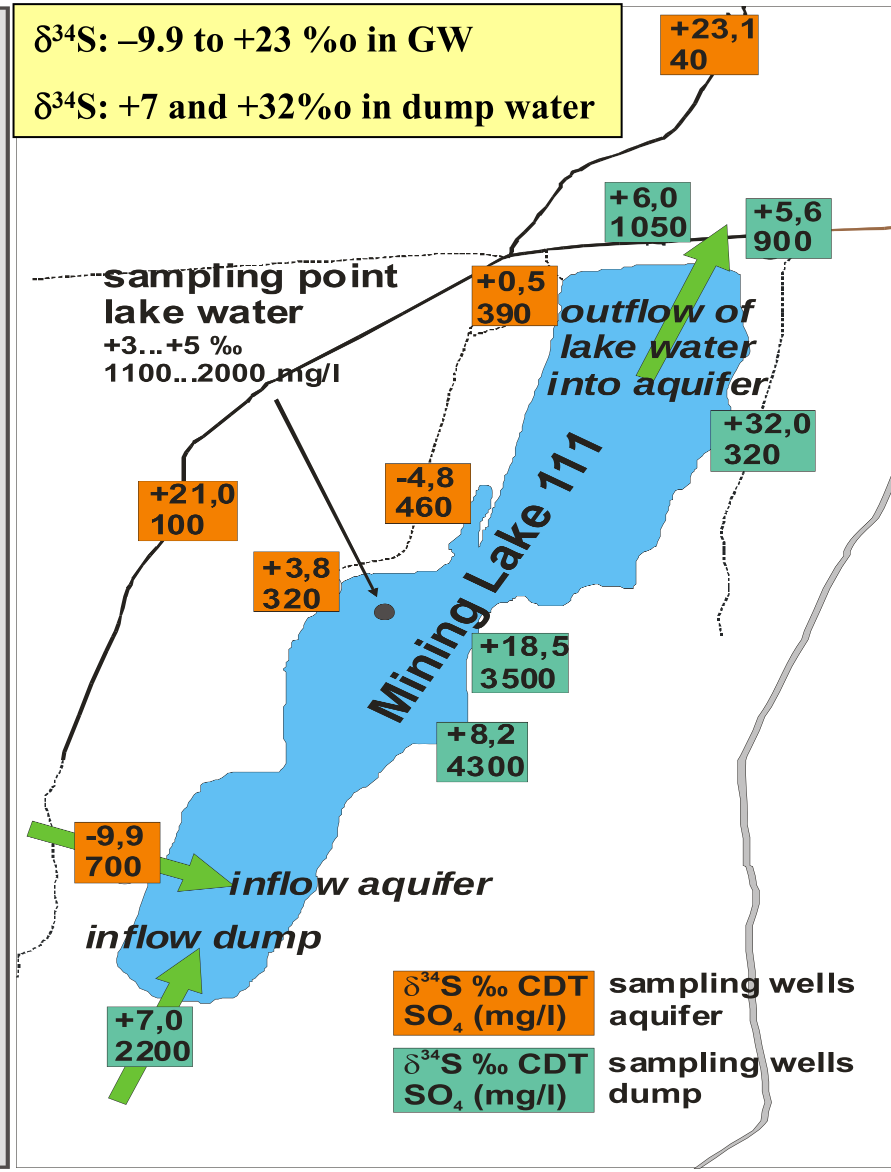


SO4 vary between 40 and 700 mg/L in the aquifers

SO4 reaches 4300 mg/L at max. in dump water

$\delta^{34}S$: –9.9 to +23 ‰ in GW

$\delta^{34}S$: +7 and +32‰ in dump water



RL 111: Results of isotope geochemical investigations

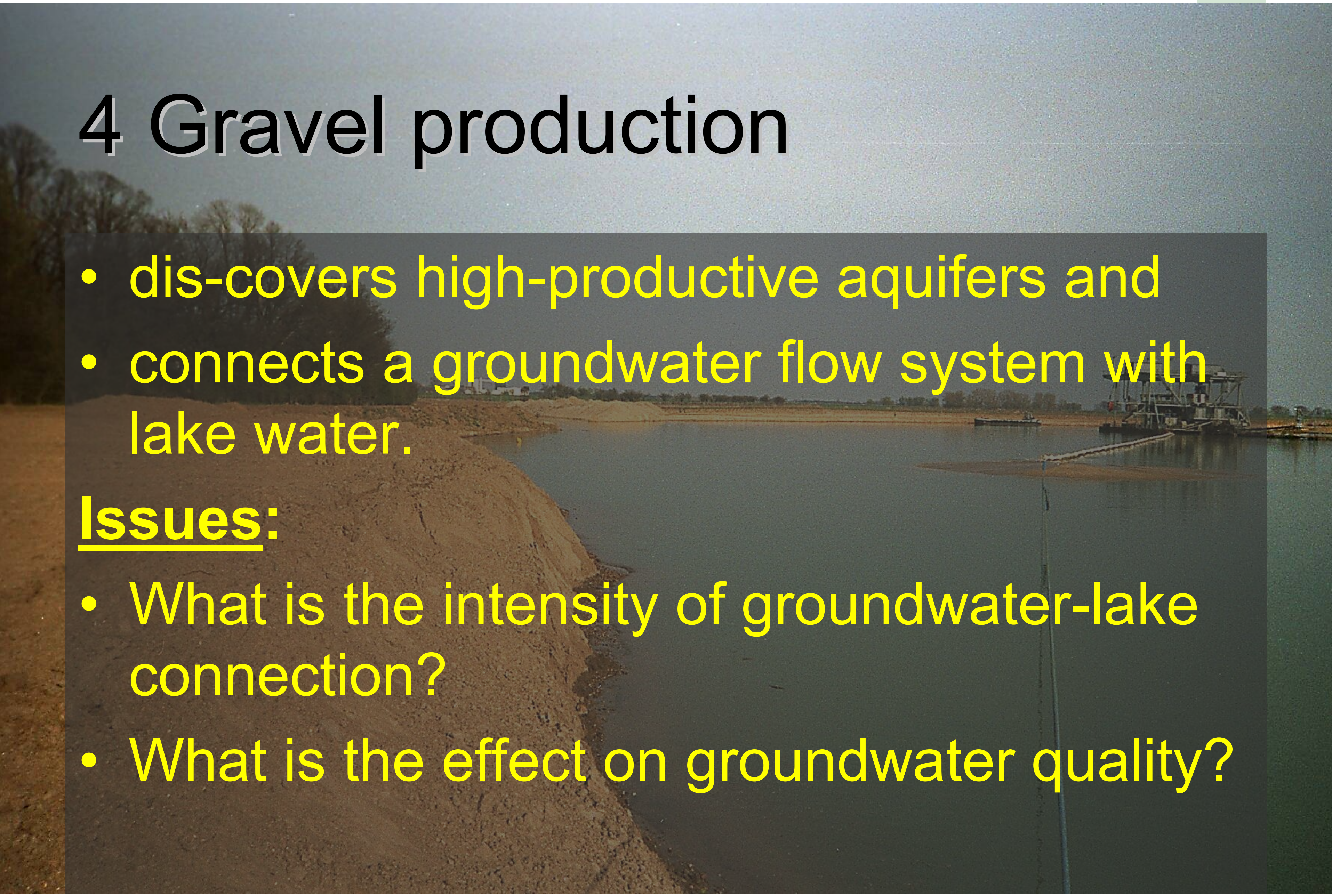
- Sulfat from mining dumps is reduced in the aquifer west of RL 111.
- In the dump, oxidation of pyrite and mobilisation still provides a permanent sulphate input into the lake.
- Consequently, for remediation measures the groundwater inflow from dumps have to be taken into account

Mining lakes: Perspective…

from mining landscape…

…to recreation landscape

Cospuden mining area (south of Leipzig)



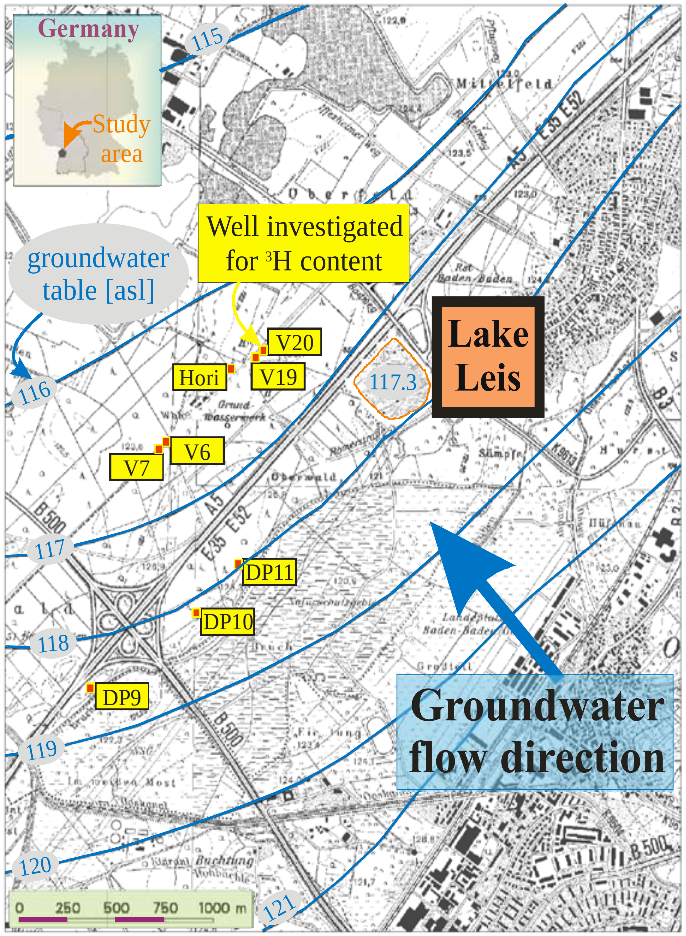
4 Gravel production

- dis-covers high-productive aquifers and
- connects a groundwater flow system with lake water.

<u>Issues</u>:

- What is the intensity of groundwater-lake connection?
- What is the effect on groundwater quality?

4 Case study *Lake Leis*



<u>Lake Leis</u>:

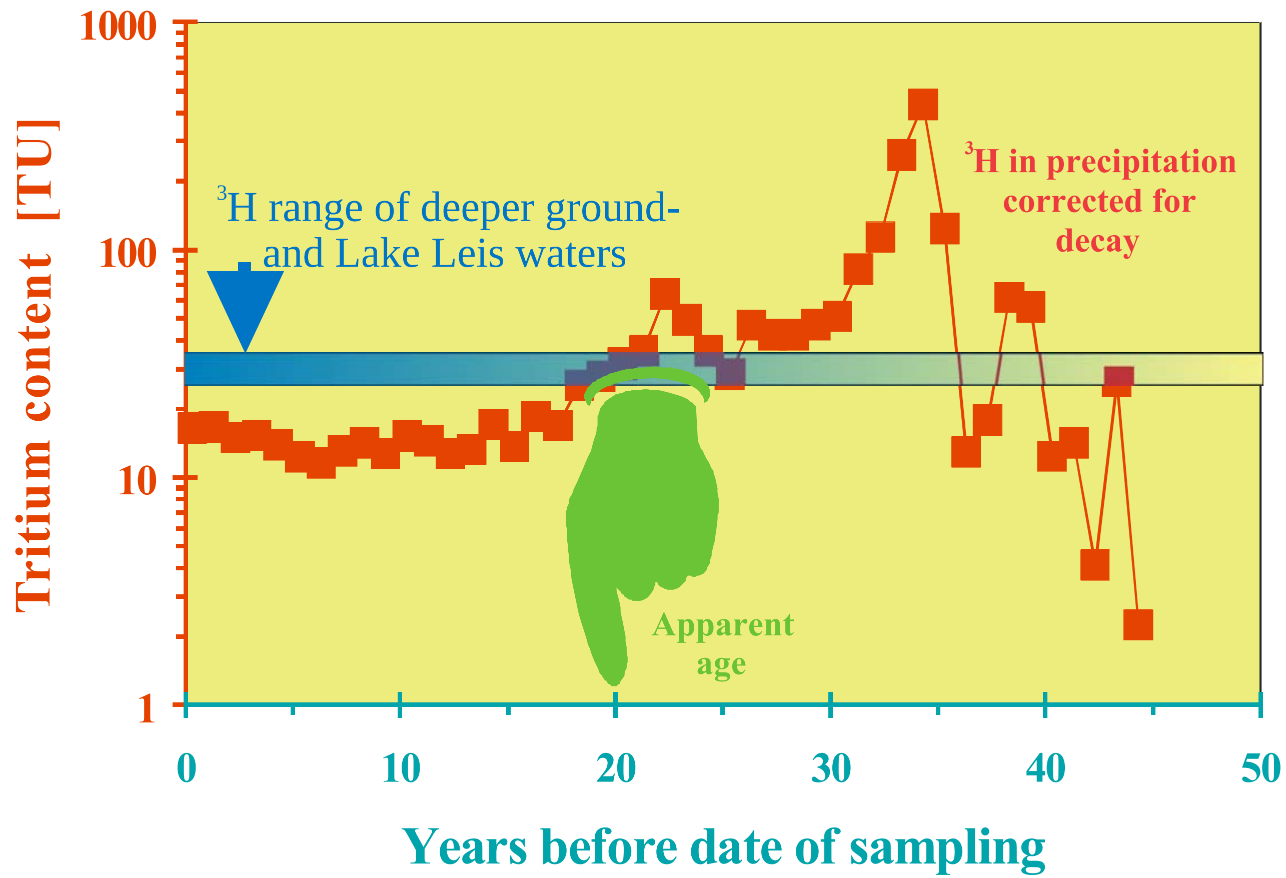
Surface area: 116,000 m^2
Depth: 21 m (in average)
annual turnover

<u>Aquifer</u>:

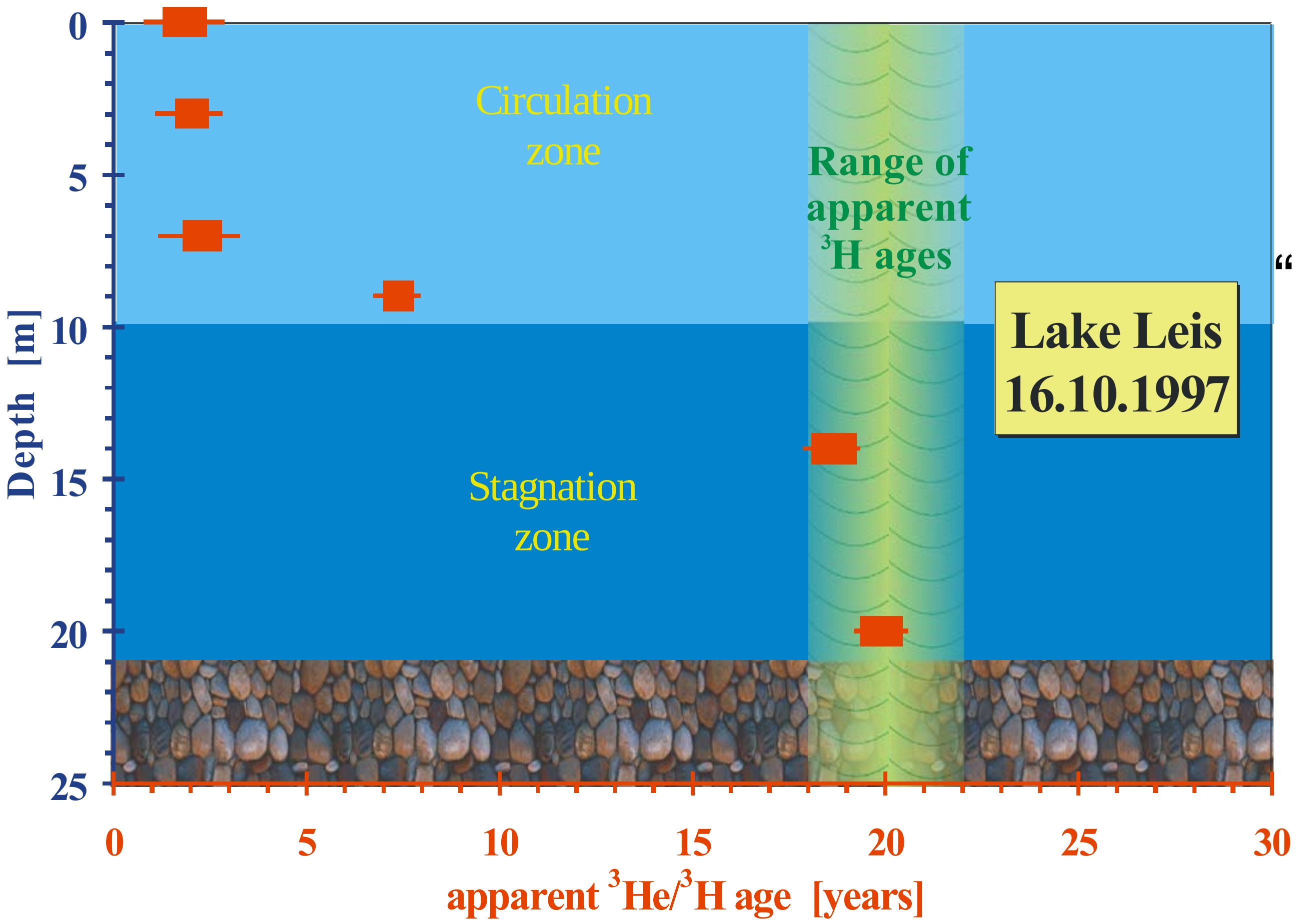
Geology: Quaternary gravel and sands
Groundwater flow velocity: 0.5 – 2 m/d

(S. Weise, W. Stichler, B. Bertleff 2001)

4 Lake Leis: Tritium ”age“



4 Lake Leis: $^3He/^3H$ ”age“



exchange with atmosphere (degassing) resets $^3He/^3H$ “age” close to zero

“age” of about 20 years though the lake turns over every year

4 Case study *Lake Leis*

Results from $^3He/^3H$ investigations:

- groundwater inflow is about 2000 m^3/d.
- regarding known hydraulic conductivities, the area effective for inflow is between 500 and 7500 m^2, consistent with lake's cross-section area of about 6000 m^2.
- Lake Leis must be extremely good incorporated into the regional ground water flow regime.


Thank you for attention!
Mining lakes Merseburg Ost