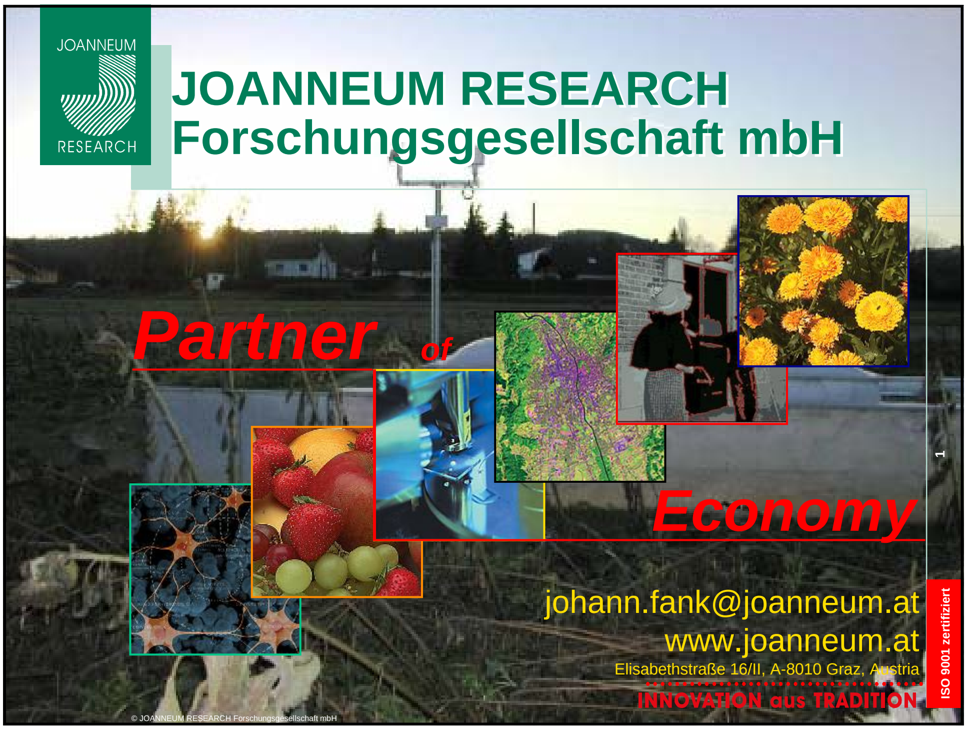

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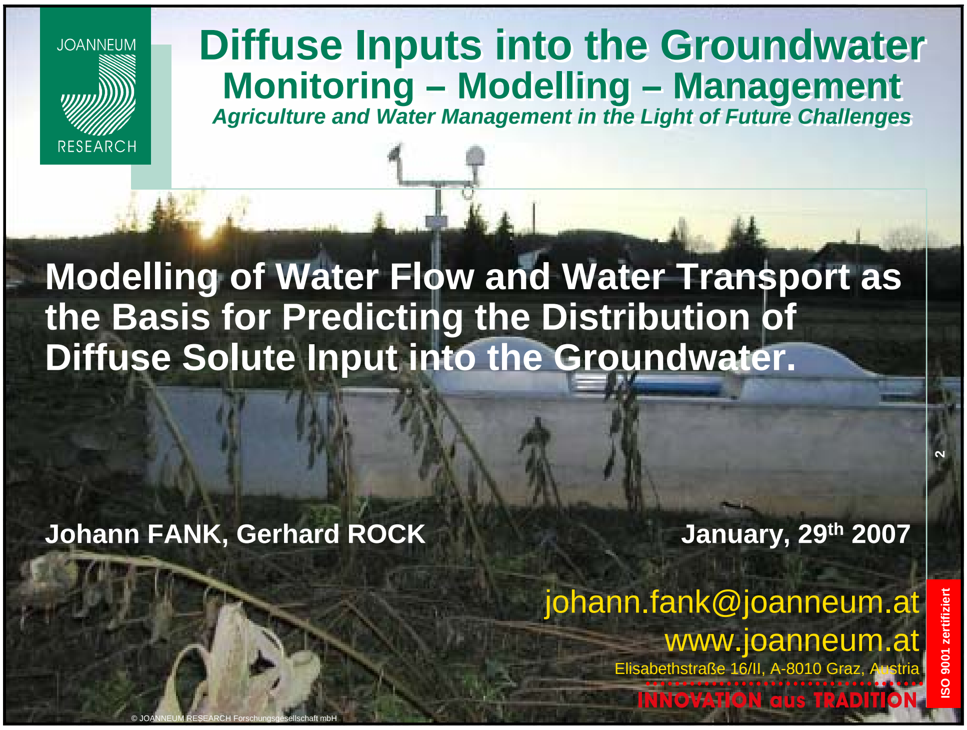

Diffuse Inputs into the Groundwater
Monitoring – Modelling – Management
Agriculture and Water Management in the Light of Future Challenges

Modelling of Water Flow and Water Transport as the Basis for Predicting the Distribution of Diffuse Solute Input into the Groundwater.

Johann FANK, Gerhard ROCK January, 29th 2007

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Content

- **Introduction**
- **Groundwater flow and transport modelling**
    - ➔ Transient groundwater flow modelling
    - ➔ Transient groundwater transport modelling (tracer)
- **Concepts for coupling unsaturated and saturated transport modelling**
    - ➔ Sequential coupling of unsaturated and saturated zone model
    - ➔ Particle tracking of nitrate concentration in the groundwater flow model
    - ➔ Water and solute balancing
- **Conclusions**

Prediction of solute distribution in groundwater

- **Prediction of solutes distribution from point sources**
    - ➔ transport modelling based on groundwater flow models and the concept of hydrodynamic dispersion.
    - ➔ Shallow aquifers:
        - 2D groundwater flow model
        - flow parameters as a mean value over the aquifers depth
        - Transport modelling assumes a full mixing of the solute in the aquifer
- **Prediction of the impact from diffuse sources**
    - ➔ the location of the source equals the area of prediction
    - ➔ entry of solute mass acts on different locations all over the prediction area in a high variability in time

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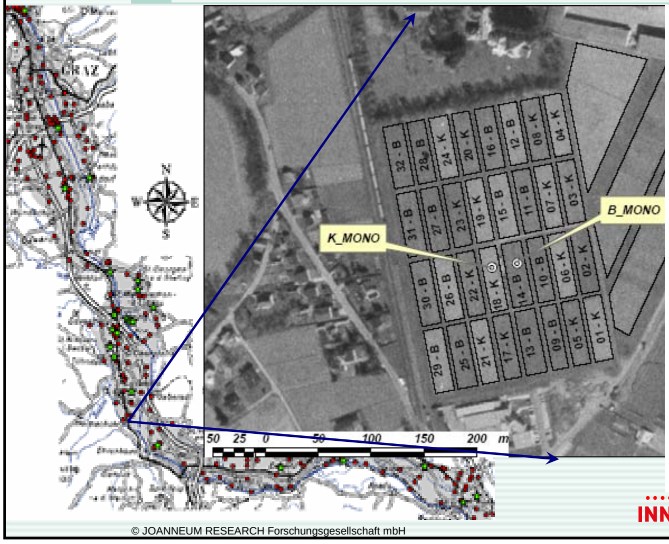
Agricultural test area and research station Wagna


GRAZ
N
E
S
W
K_MONO
B_MONO
32 - B
28 - B
24 - K
20 - K
16 - B
12 - B
08 - K
04 - K
31 - B
27 - B
23 - K
19 - K
15 - B
11 - B
07 - K
03 - K
30 - B
26 - B
22 - K
18 - K
14 - B
10 - B
06 - K
02 - K
29 - B
25 - B
21 - K
17 - K
13 - B
09 - B
05 - K
01 - K
50 25 0 50 100 150 200 m

Latitude	46.7 ° N
Longitude	344.5 ° W
Altitude	266.7 m a.s.l.
Extent	300 x 200 m

36 Test fields (20 x 50 m)

- K – conventional farming
- B - organic farming

2 lysimeters

- K_MONO
- B_MONO

Groundwater

- Flow Direction N – S
- Overburden 3.5 – 5.0 m
- Thickness 3.5 – 5.0 m
- Hydr. Cond. $3.3*10^{-3}$ m/s
- Flow velocity ~ 1 – 2 m/d

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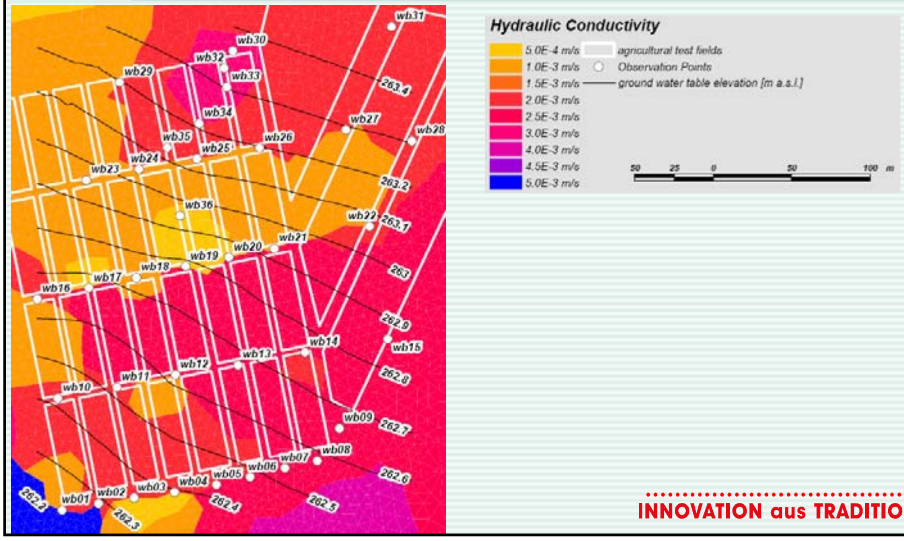
Calibration of a transient groundwater flow model


Hydraulic Conductivity
5.0E-4 m/s
1.0E-3 m/s
1.5E-3 m/s
2.0E-3 m/s
2.5E-3 m/s
3.0E-3 m/s
4.0E-3 m/s
4.5E-3 m/s
5.0E-3 m/s
agricultural test fields
Observation Points
ground water table elevation [m a.s.l.]
50 25 0 50 100 m
wb31
wb30
wb29
wb32
wb33
wb34
wb27
wb28
wb35
wb25
wb26
wb23
wb24
wb36
wb22
wb21
wb20
wb19
wb18
wb17
wb16
wb14
wb15
wb13
wb12
wb11
wb10
wb09
wb08
wb07
wb06
wb05
wb04
wb03
wb02
wb01
263.4
263.2
263.1
263
262.9
262.8
262.7
262.6
262.5
262.4
262.3
262.2

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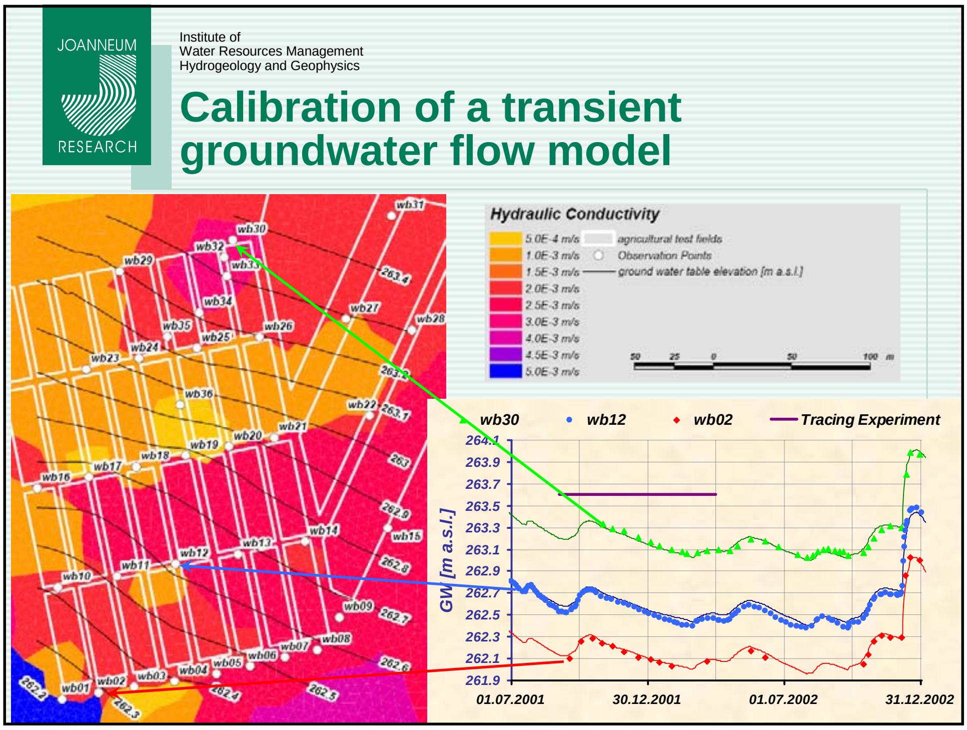

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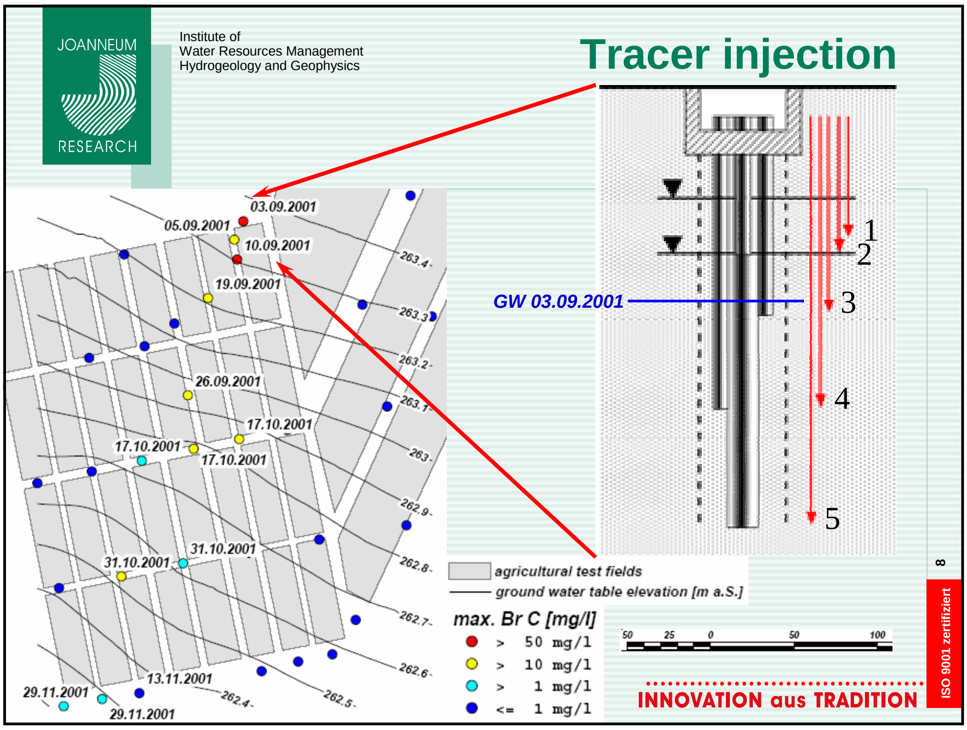
Calibration of a transient groundwater flow model

Hydraulic Conductivity
🟨 5.0E-4 m/s
🟧 1.0E-3 m/s
🟧 1.5E-3 m/s
🟥 2.0E-3 m/s
🟥 2.5E-3 m/s
🟪 3.0E-3 m/s
🟪 4.0E-3 m/s
🟪 4.5E-3 m/s
🟦 5.0E-3 m/s
agricultural test fields
○ Observation Points
ground water table elevation [m a.s.l.]
50 25 0 50 100 m
wb01 wb02 wb03 wb04 wb05 wb06 wb07 wb08 wb09 wb10 wb11 wb12 wb13 wb14 wb15 wb16 wb17 wb18 wb19 wb20 wb21 wb22 wb23 wb24 wb25 wb26 wb27 wb28 wb29 wb30 wb31 wb32 wb33 wb34 wb35 wb36
263.4 263.3 263.2 263.1 263 262.9 262.8 262.7 262.6 262.5 262.4 262.3 262.2
▲ wb30
● wb12
◆ wb02
Tracing Experiment
GW [m a.s.l.]
264.1 263.9 263.7 263.5 263.3 263.1 262.9 262.7 262.5 262.3 262.1 261.9
01.07.2001 30.12.2001 01.07.2002 31.12.2002



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Tracer injection

03.09.2001
05.09.2001
10.09.2001
19.09.2001
26.09.2001
17.10.2001
17.10.2001
17.10.2001
31.10.2001
31.10.2001
13.11.2001
29.11.2001
29.11.2001
263.4 263.3 263.2 263.1 263 262.9 262.8 262.7 262.6 262.5 262.4
GW 03.09.2001
1
2
3
4
5
agricultural test fields
ground water table elevation [m a.S.]
50 25 0 50 100

max. Br C [mg/l]
- 🔴 > 50 mg/l
- 🟡 > 10 mg/l
- 🔵 > 1 mg/l
- 🔵 <= 1 mg/l

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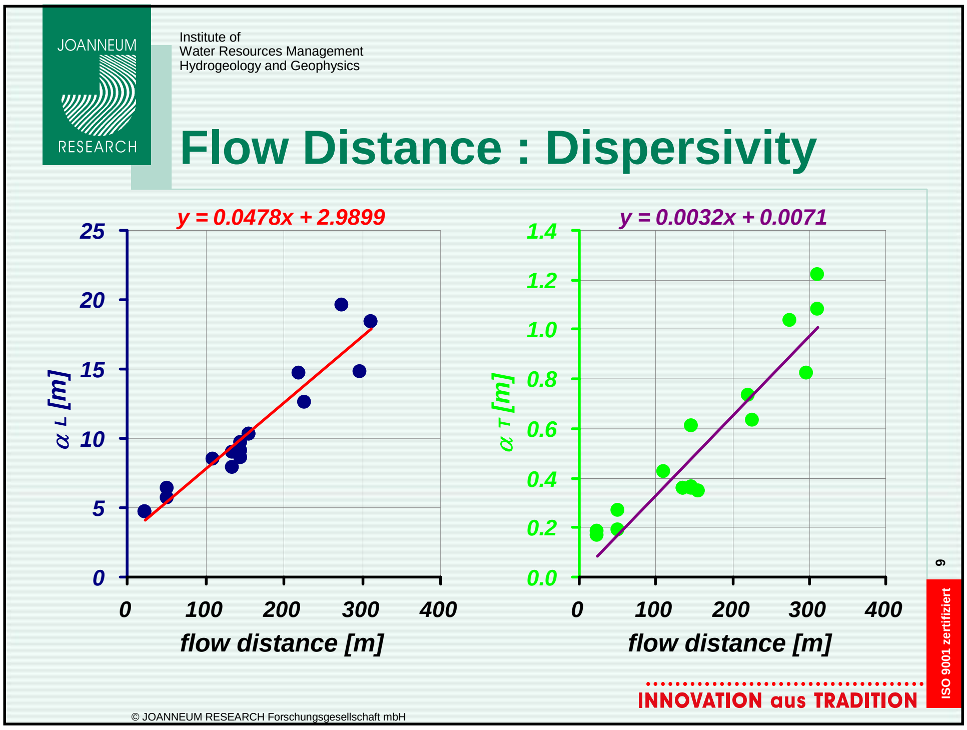

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Flow Distance : Dispersivity

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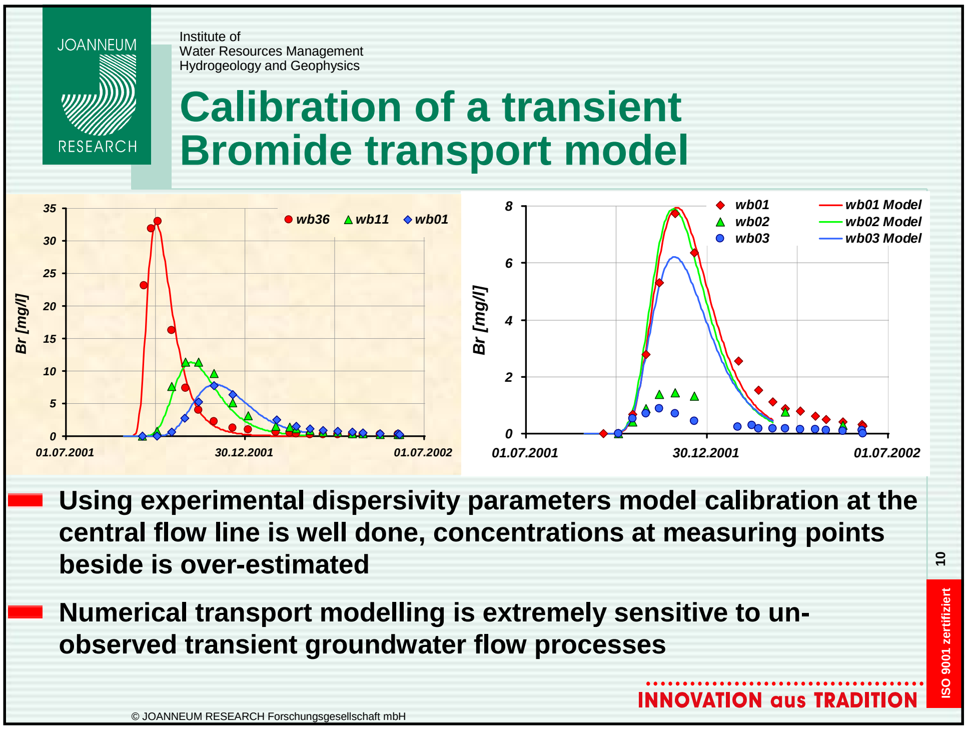

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Calibration of a transient Bromide transport model

- Using experimental dispersivity parameters model calibration at the central flow line is well done, concentrations at measuring points beside is over-estimated
- Numerical transport modelling is extremely sensitive to un-observed transient groundwater flow processes

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Modelling solute distribution from diffuse sources

Data Base

- ➔ Regional scaled transient 2D groundwater flow model for the western part of the Leibnitzer Feld calibrated on a daily basis (1993 – 2003)
- ➔ Detailed calibrated groundwater flow through the agicultural test area “Wagna” based on a dense FE-net on a daily basis (1993 – 2003)
- ➔ SIMWASER & STOTRASIM calculated groundwater recharge and nitrate input into the groundwater for the test field as presented by H. KUPFERSBERGER on a daily basis (1987 – 2003)

Goal: Estimation of Nitrate concentration distribution in space and time for the test area

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Sequential coupling of unsaturated and saturated zone model

Non reactive transient 2D FE groundwater transport model

- ➔ Based on the 2D flow model
- ➔ Dispersivity was set to 5 m, 0.5 m respectively
- ➔ Results of unsaturated zone modelling have been used as an upper boundary condition for
  - Water flow
  - Nitrate concentration

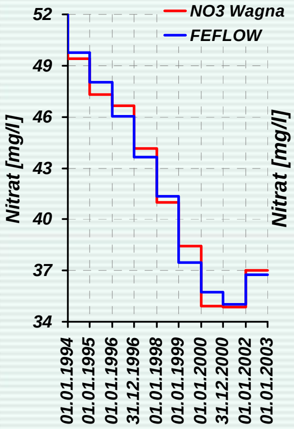
Nitrate concentration at the inflow boundary has been estimated using a solute balance model based on the mixing equation

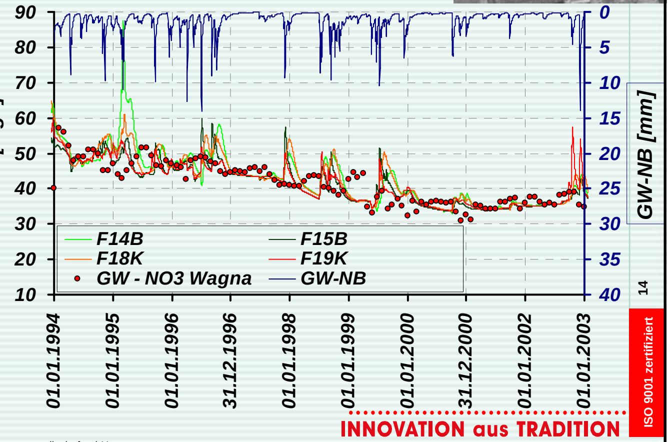
- ➔ Groundwater flow balance at the inflow boundary
- ➔ Groundwater recharge at the test field (unsaturated modelling)
- ➔ Nitrate concentration of seepage water (unsaturated modelling)
- ➔ Measured nitrate concentration in groundwater at the test area

Sequential coupling of unsaturated and saturated zone model

- **Due to numerical oscillation, problems arised in modelling nitrate distribution in space and time**
  - ➔ Model configuration
    - Density of FE-net
    - Timesteps for calculation
  - ➔ Boundary conditions
    - Concentration boundary condition at the groundwater inflow part
    - Mass boundary condition at the groundwater level
- **Where nitrate concentration has been calculated, an overestimation at or after periods of groundwater recharge is visible**

FEFLOW – Modelling results





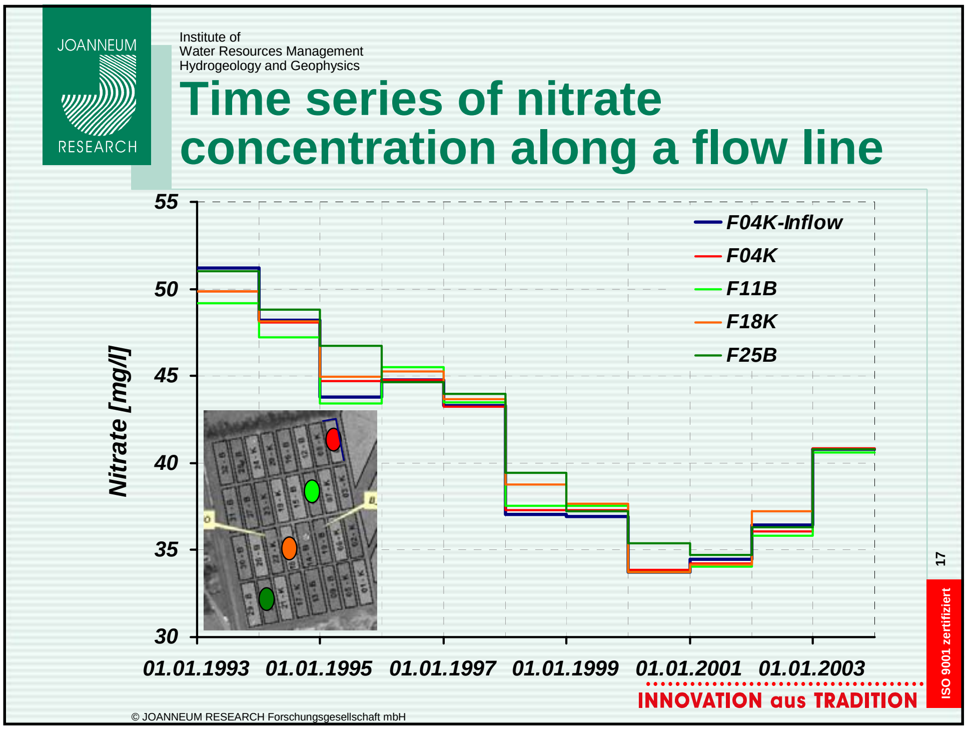
Particle tracking of nitrate concentration in the flow model

- To obviate numerical problems with transport modelling
- Nitrate concentration from unsaturated zone modelling and from groundwater inflow boundary will be transferred to particles
- This particles are used as time and space distributed input to the groundwater flow model.
- Using particle tracking method the flow path will be followed through the entire groundwater in the model area. At any certain time step nitrate distribution may be visualized. Modelling results are consistent with the well calibrated flow model
- Up to now this method is not workable on regional scale due to an extreme demand on computer capacity (CPU, memory, hard disk, run time).

Water and solute balancing

$$C_{QT} = \frac{Q_{NB} \cdot C_{NB} + Q_Z \cdot C_{QZ}}{Q_T}$$

C_{QT}	Nitrate concentration [mg/l] in the groundwater below the investigated test field
Q_{NB}	Groundwater recharge [l/s] from infiltrating precipitation (result of SIMWASER modelling) at the investigated test field
C_{NB}	Nitrate concentration [mg/l] of seepage water at groundwater level (result of STOTRASIM modelling) for the investigated test field
Q_Z	Groundwater inflow [l/s] into the investigated test field (groundwater flow balance from the transient groundwater flow model)
C_{QZ}	Nitrate concentration [mg/l] in groundwater at the inflow boundary of every test field in the research area Wagna (calcualtion result from the upstream test field)
Q_T	Total Water balance [l/s] in the investigated test field (Q_{NB} + Q_Z)



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Time series of nitrate concentration along a flow line

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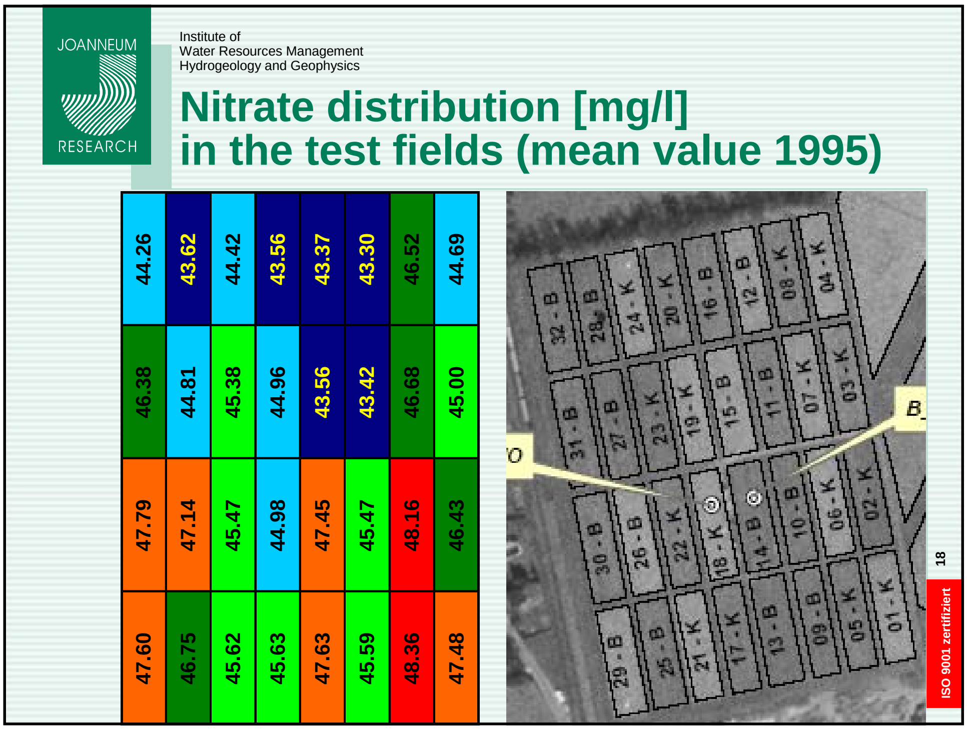
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32 - B
28 - B
24 - K
20 - K
16 - B
12 - B
08 - K
04 - K
31 - B
27 - B
23 - K
19 - K
15 - B
11 - B
07 - K
03 - K
30 - B
26 - B
22 - K
18 - K
14 - B
10 - B
06 - K
02 - K
29 - B
25 - B
21 - K
17 - K
13 - B
09 - B
05 - K
01 - K
O
B_

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Nitrate distribution [mg/l] in the test fields (mean value 1995)

44.26	43.62	44.42	43.56	43.37	43.30	46.52	44.69
46.38	44.81	45.38	44.96	43.56	43.42	46.68	45.00
47.79	47.14	45.47	44.98	47.45	45.47	48.16	46.43
47.60	46.75	45.62	45.63	47.63	45.59	48.36	47.48

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Conclusions

- **The prediction of the distribution of nitrate from diffuse sources in shallow aquifers is an unresolved problem**
- **Numerical transport modelling is extremely sensitive to un-observed transient groundwater flow processes**
- **Coupling of unsaturated transport and nitrate transport in the saturated zone has to be discussed further**
- **Water and solute balancing gave significant results on the distribution of nitrate in groundwater in space and time (yearly mean values for the test fields)**
  - ➔ A simple mixing equation couple
    - Unsaturated zone modelling
    - Groundwater flow modelling
    - Measurements of nitrate concentration at the inflow boundary
  - ➔ The equation (after transformation) may be used to estimate nitrate leaching to groundwater, if amount of fertilizer is unknown