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Salinisation and freshening of phreatic groundwaters in Zeeland, The Netherlands

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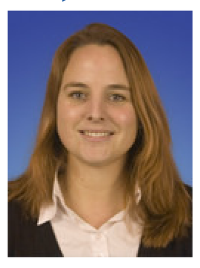

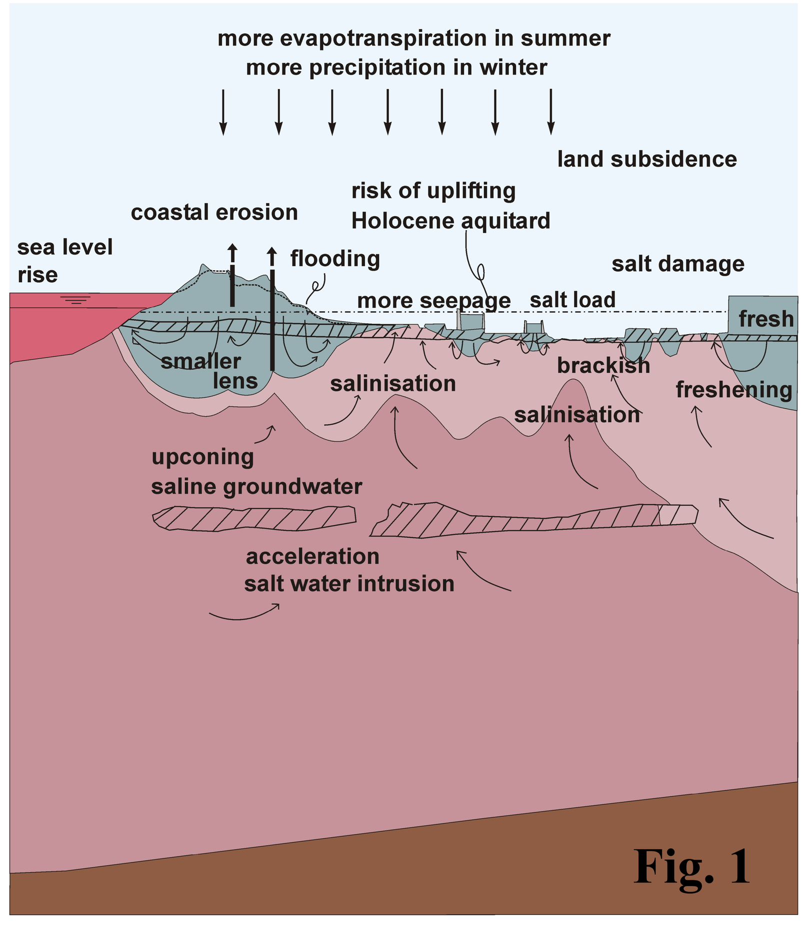

Fig. 1: Concepts of salinisation processes in Dutch coastal areas in case of sea level rise and climate change.

INTRODUCTION

At present, the fresh water resources in the groundwater system of the Province of Zeeland are jeopardized by various causes. Floods, droughts, eutrophication and salinisation of ground- and surface waters are some pressing topics. In addition, sea level rise and climate change threaten the groundwater system even more (Fig. 1). This study is initiated to get a better insight in the salinisation and freshening processes in the top of the water system (Fig. 2). Goal is to analyse what measures are effective to make fresh water supply in this area climate proof. Special attention is given to the shallow rainwater lenses in agriculture plots (De Louw *et al.*, 2008; Oude Essink *et al.*, 2009). Agricultural crops in this brackish-saline environment depend on these shallow vulnerable water systems. This poster is focused on: a. the development of the large 3D numerical model of the region, and b. on the determination of the initial chloride distribution.

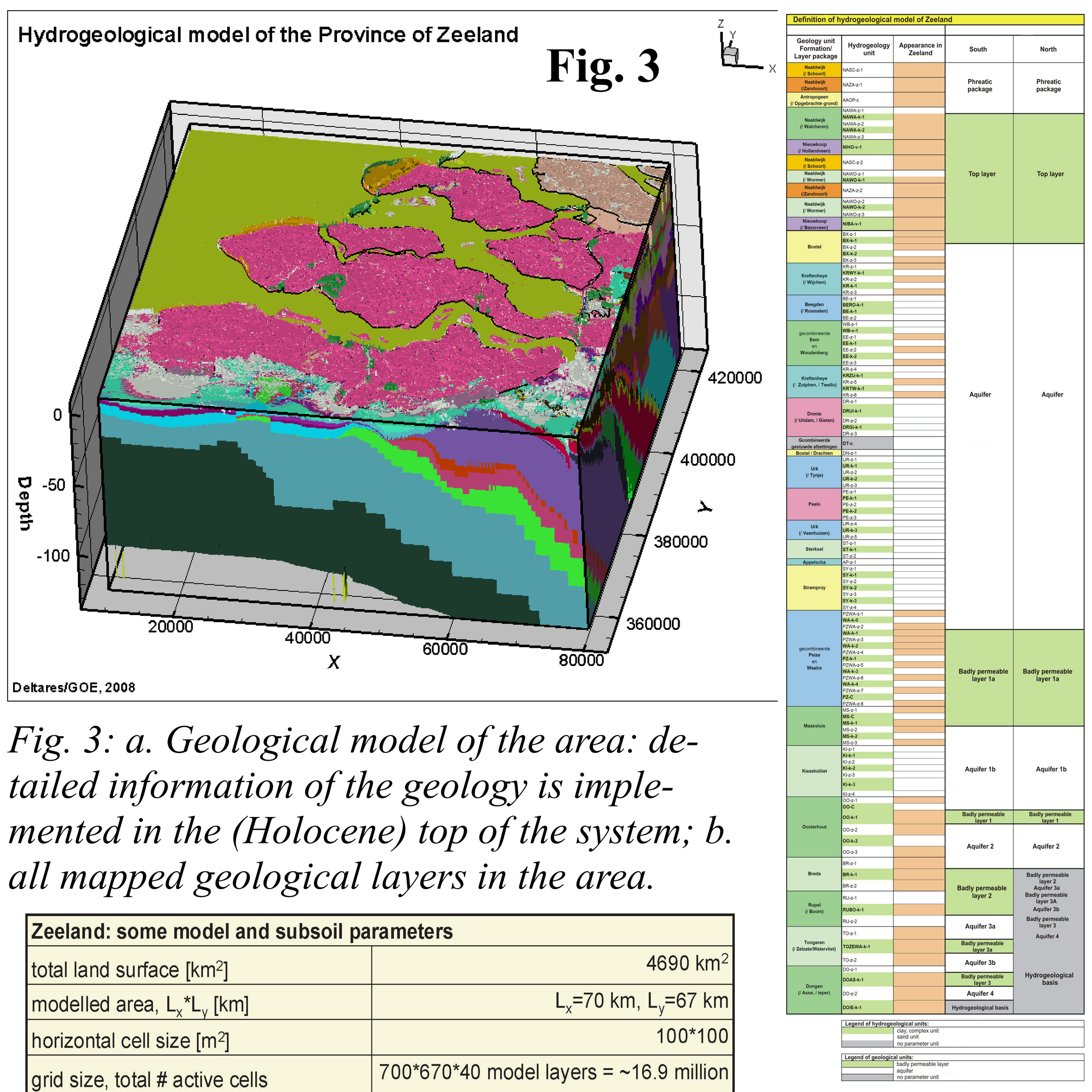

Fig. 3: a. Geological model of the area: detailed information of the geology is implemented in the (Holocene) top of the system; b. all mapped geological layers in the area.

Zeeland: some model and subsoil parameters	
total land surface [km^2]	4690 km^2
modelled area, L_x*L_y [km]	L_x=70 km, L_y=67 km
horizontal cell size [m^2]	100*100
grid size, total # active cells	700*670*40 model layers = ~16.9 million
vertical cell size [m]	1x4m, 10x0.5m, 10x1m, 11x4m, 8x10m
# particles/cell, total number particles	4, ~68 million
porosity	0.3
convergence head criterion	10^{-4} m
total time [yr]	100 yr
longitudinal dispersivity α_L [m]	0.05 m

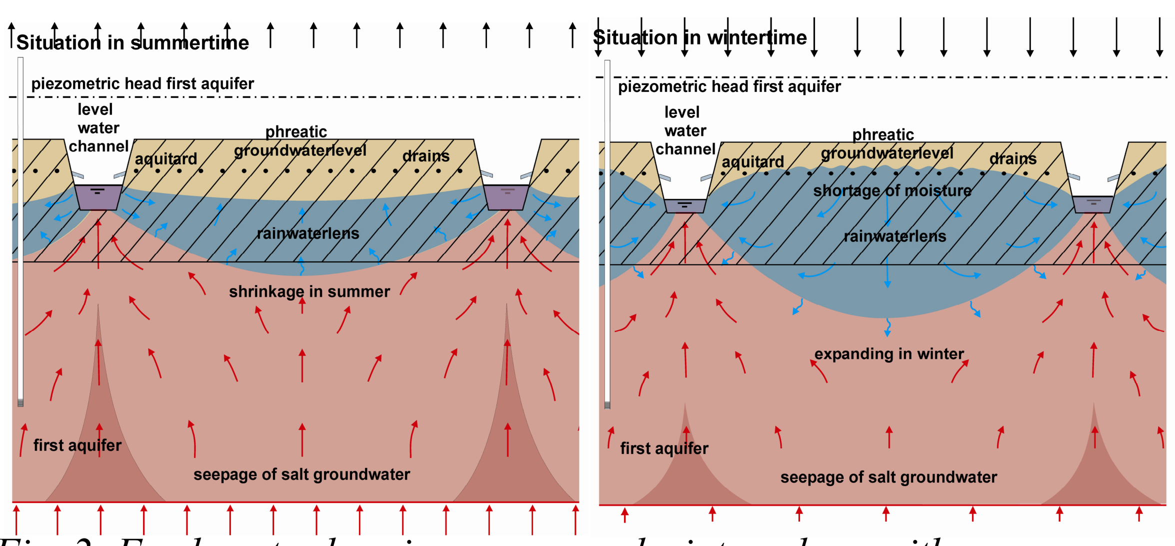

Fig. 2: Fresh water lens in summer and winter, along with ditches containing salt water (Oude Essink et al., 2009)

Fig. 2

METHODS

A 3D numerical regional model is constructed with the code MOCDENS3D (Oude Essink, 1999) to consider fresh, brackish and saline groundwater. With a 64 bit compiler, a large number of model cells can be used to merge two necessary features:

- to simulate details in the top groundwater system (to get enough detailed information for salt damage to crops)
- to determine changes on a regional provincial scale.

See table 1 for details of the numerical geometry. The latest results of geological modeling was implemented, using very detailed information of the Holocene lithology (Fig. 3). The model is calibrated with measured head corrected to freshwater heads (Fig. 4). As we are interested in the salinity at the top system, we modeled this top part of the system with very thin model cells, which causes relatively long computation times to simulate 100 years. Moreover, one of the most difficult parts of modeling variable density groundwater flow and coupled solute transport on this regional scale is the determination of the initial fresh-brackish-saline distribution. Here, we were able to combine various (geophysical) techniques, such as groundwater samples, geo-electrical borehole logs, electrical CPT, Vertical Electrical Soundings (VES), EM31, EM34, groundwater extractions, CVES and TEC probe data, to improve the first estimate of the distribution (Fig. 5).

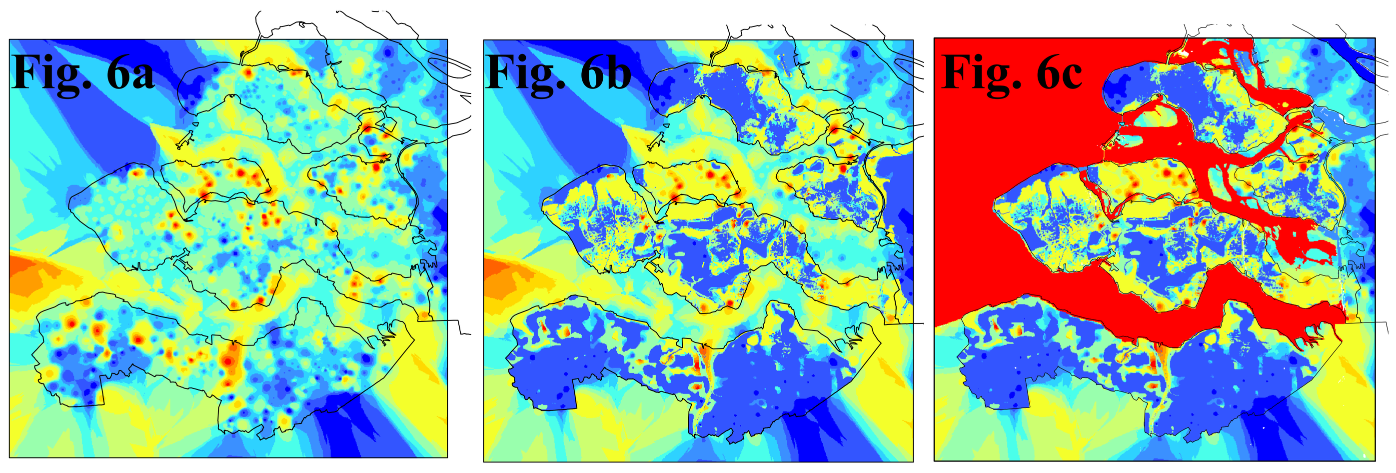

Fig. 6: Three steps in the chloride distribution determination: a. interpolating data, b. including mapped brackish-saline interface; c. including surface water.

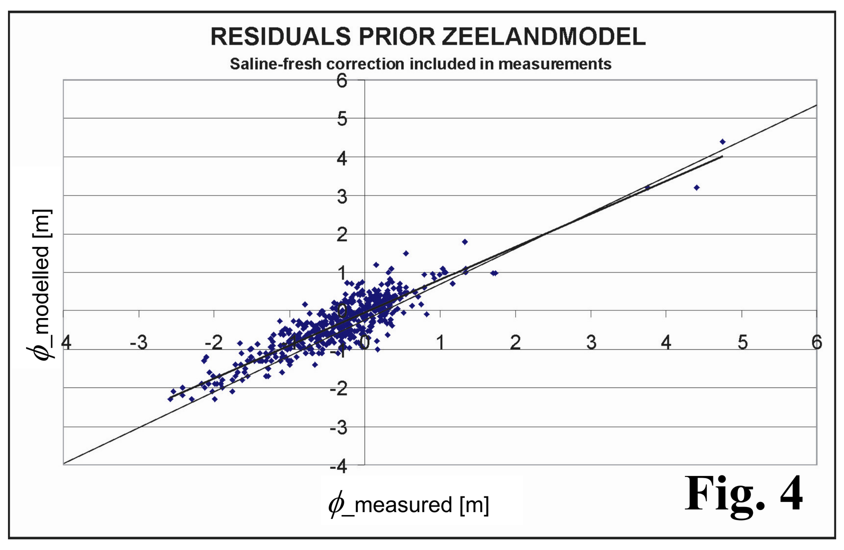

Fig. 4: Modelled versus measured freshwater head.

SOME PRELIMINARY RESULTS

Up to now the following steps were executed to determine the initial fresh-brackish-saline distribution (Goes *et al.*, 2009): a. 3D interpolation of analyses, VES and borehole measurements via geostatistical procedures (Fig. 6a); b. penetrating this 3D distribution with a mapped brackish-saline interface (of 1000mg Cl^-/l), (Fig. 6b); c. implementing salinity values of open surface water. Fig. 5 shows the result in various profiles. In a later phase, shallow low-lying rainwater lenses areas via empirical relation (De Louw et al, 2010, see this SWIM21) and for the near future, helicopter-borne geophysical systems from Interreg IV-B CLIWAT project are implemented to improve this distribution.

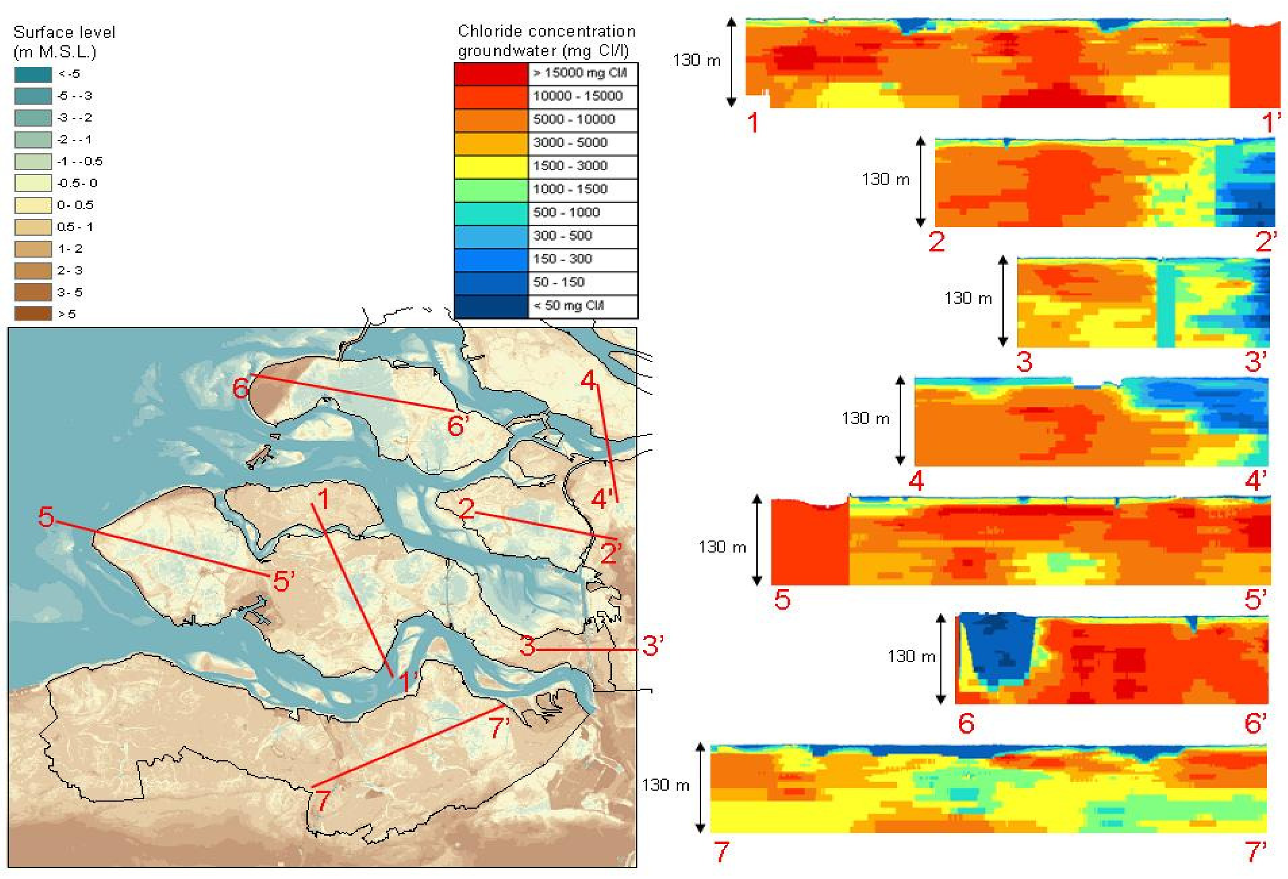

Fig. 5: Groundwater surface and b. fresh/brackish/saline profiles through the 3D chloride distribution.

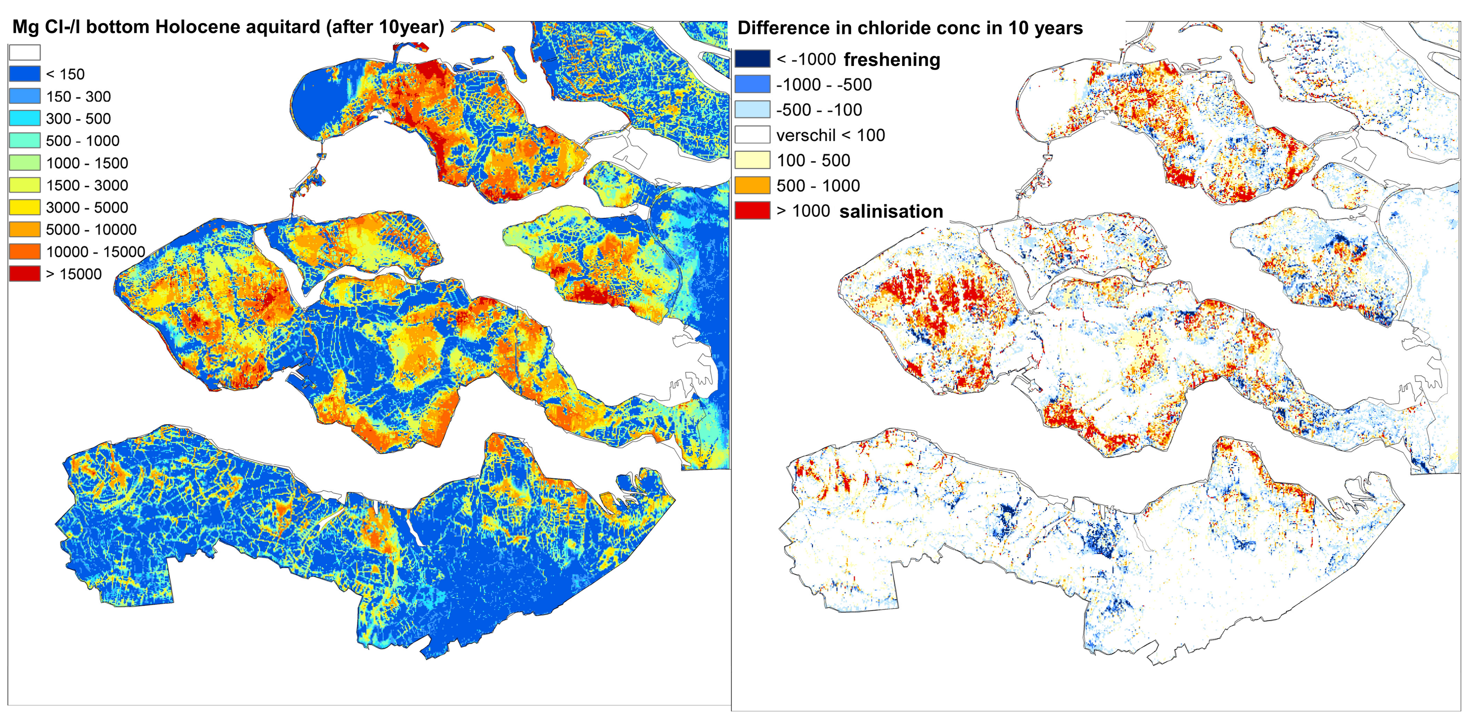

Fig. 7: Chloride concentration after a simulation of 10 years, and the salinsation and freshening results.

References:

- De Louw, P.G.B., Oude Essink, G.H.P., Goes, B.J.M and Sergi, F., 2008. Characterization of Local Rainwater Lenses in Agricultural Areas with Upward Saline Seepage: Monitoring Results. *20th Salt Water Intrusion Meeting, Naples, Florida.*
- Goes, B.J.M., Oude Essink, G.H.P., Vernes, R.W. and Sergi, F. 2009. Estimating the depth of fresh and brackish groundwater in a predominantly saline region using geophysical and hydrological methods, Zeeland, the Netherlands, *Near Surface Geophysics 401-412.*
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- Oude Essink, G.H.P., Louw, de, P.G.B., Stevens, S., de Veen, B., de, Prevo, C., Marconi, V. en Goes, B.J.M. 2009, Monitoring campaign in the occurrence of freshwater lenses in the Province of Zeeland, *2007-U-R0925/A, 132p.*

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CONCLUSION

A modeling tool is developed ready to start assessing the impacts of climate change (changes in precipitation and evapotranspiration, and sea level rise) on the fresh-brackish-saline distribution on a regional scale (Fig. 7), with enough detail to transfer these modeling output to local circumstances (for input to salt damage calculations of agricultural plots). In addition, a procedure has been set up to combine different techniques to get a more reliable fresh-brackish-saline distribution: from various types of (indirect) geophysical techniques using geostatistical procedures, via groundwater sampling, to numerical modeling.