To drink or to drown?

Impact of groundwater extraction on subsidence in the Mekong Delta, Vietnam

Universiteit Utrecht
Deltares Enabling Delta Life
TNO innovation for life
DWRPIS

P.S.J. Minderhoud[1,2], G. Erkens[2,1], V.H. Pham[1,2,3], B.T. Vuong[3], E. Stouthamer[1]

1 Department of Physical Geography, Utrecht University, The Netherlands
2 Department of Subsurface and Groundwater Systems, Deltares Research Institute, Utrecht, The Netherlands
3 Division of Water Resources Planning and Investigation for the South of Vietnam (DWRPIS), Ho Chi Minh city, Vietnam

Introduction

Land subsidence rates of ~1-4 cm yr^{-1} are measured in the low-lying Vietnamese Mekong Delta (Fig. 1 & 3). These relatively high subsidence rates are attributed to groundwater extraction. On daily basis over two million m^3 of groundwater is extracted and as a result, hydraulic heads in aquifers are dropping, on average 0.3-0.7 m yr^{-1}, triggering further land subsidence.

With over 50% of the delta surface elevated less than 1 meter above sea level, land subsidence poses a real threat to this delta, increasing flood risk and salt water intrusion. Combined with decreased sedimentation, the long term survival of the delta is at stake. To assess future land subsidence, we need to go from measurements to predictions.

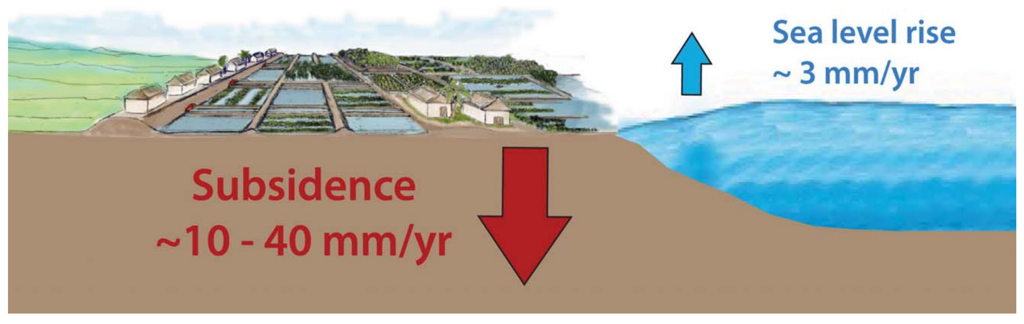

Figure 1. Absolute sealevel rise versus subsidence for the Mekong delta. Subsidence exceeds absolute sea level rise by a magnitude.

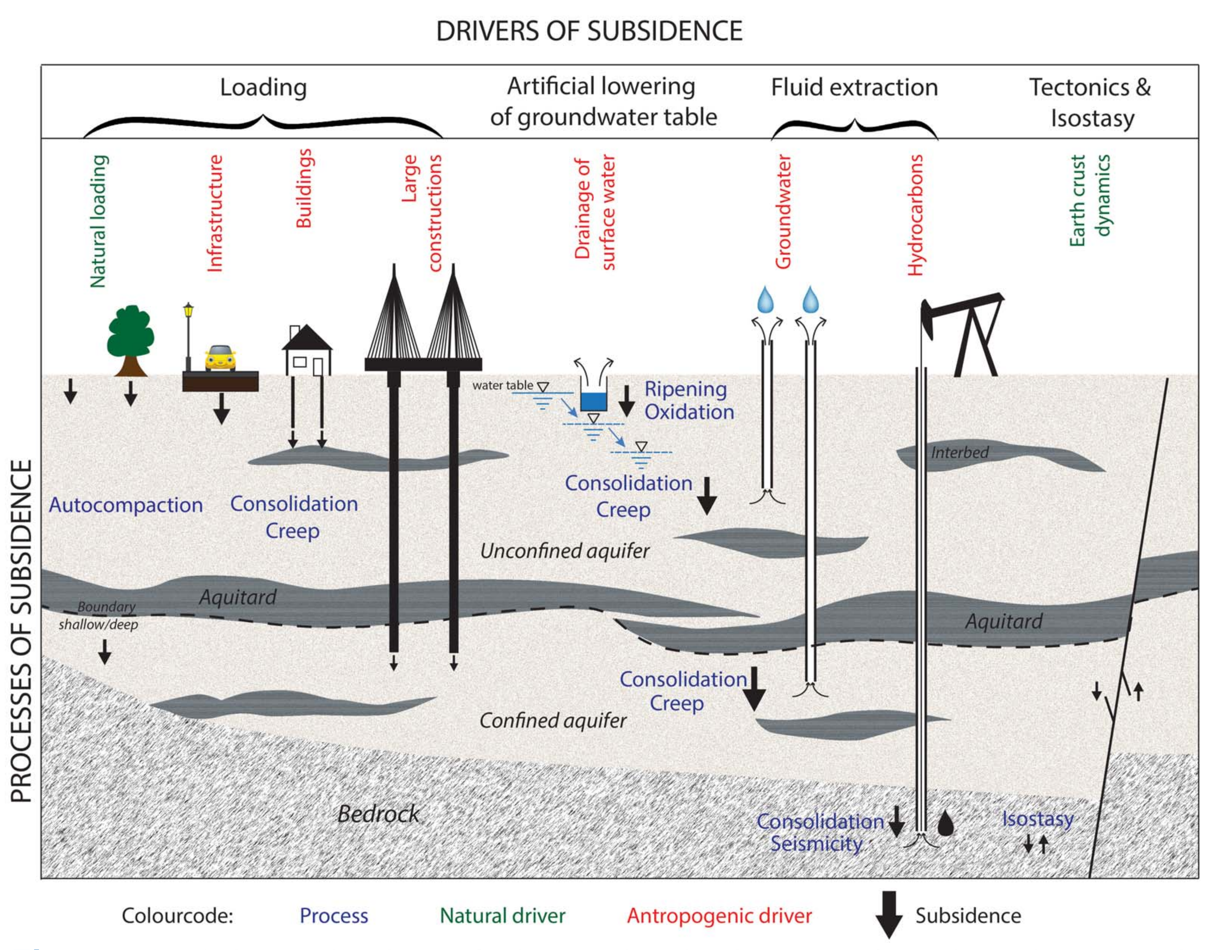

Figure 2. Schematization of the main, both natural and anthropogenic, subsidence drivers and corresponding processes within the upper (phreatic) aquifer and deeper (confined) aquifer(s) (after Minderhoud et al., 2015).

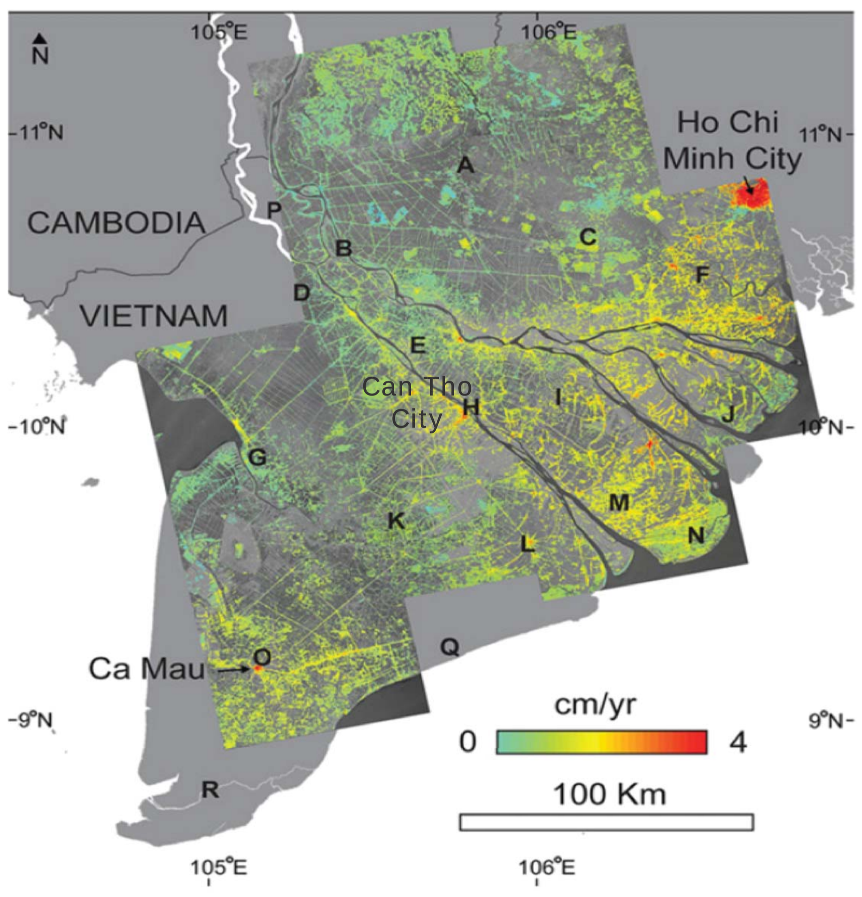

Figure 3. Satellite based (InSAR) subsidence rates measured between 2006-2010 for the Mekong Delta. Data © JAXA, METI 2011 (Erban et al., 2014).

Objective

We aim to model subsidence corresponding with 25 year of groundwater overexploitation in the Mekong delta (Fig. 4).
Furthermore, we test our new model setup, which will be used at a later stage to create subsidence predictions.

Approach

We develop a 3D groundwater flow model to simulate groundwater flow. The multi-aquifer subsurface is reconstructed based on interpreted borehole data (Fig.5). Hydraulic heads are modeled following groundwater exploitation during the past 25 years. Last, corresponding subsidence is calculated.

Available data / data processing

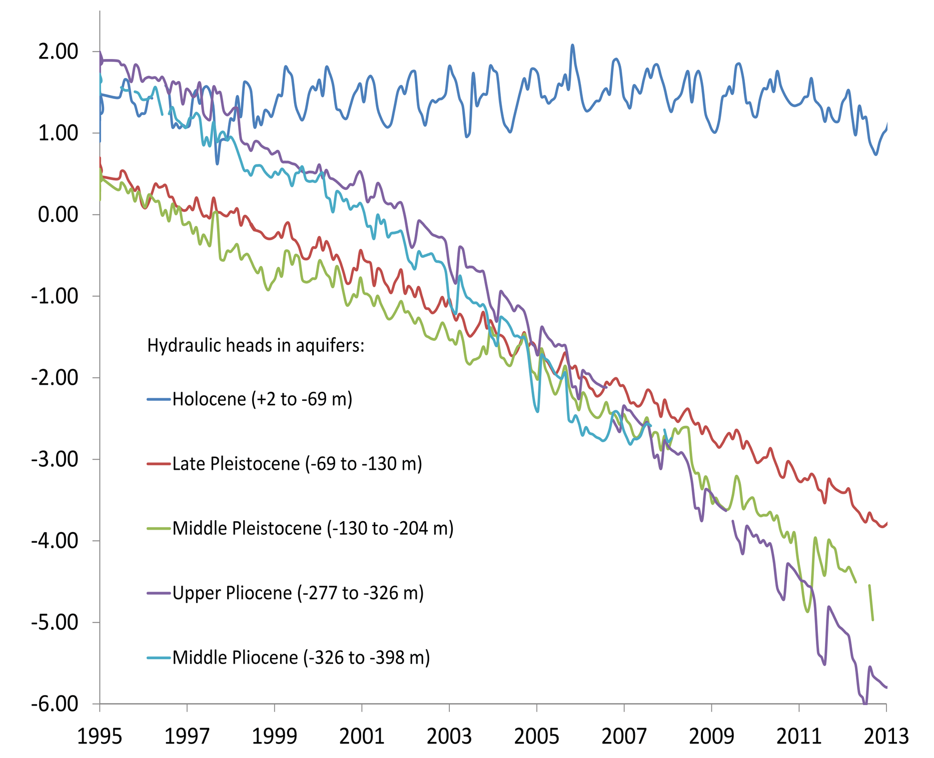

Figure 4. Measured hydraulic head time series from monitoring wells near Can Tho city, central Mekong delta.

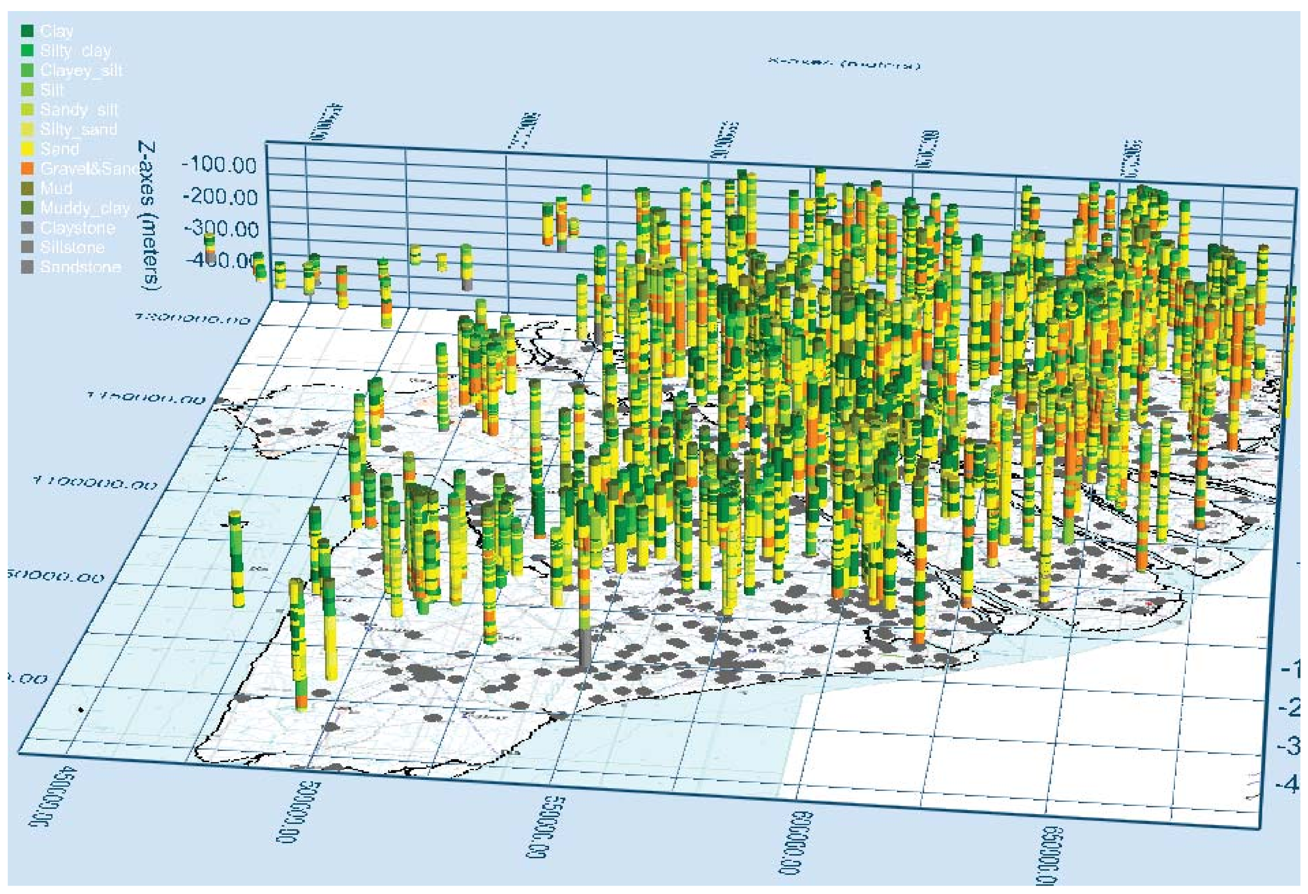

Figure 5. Dataset of lithological boreholes throughout the Mekong delta (>400). Aquifer-aquitard interpretation is based on this dataset.

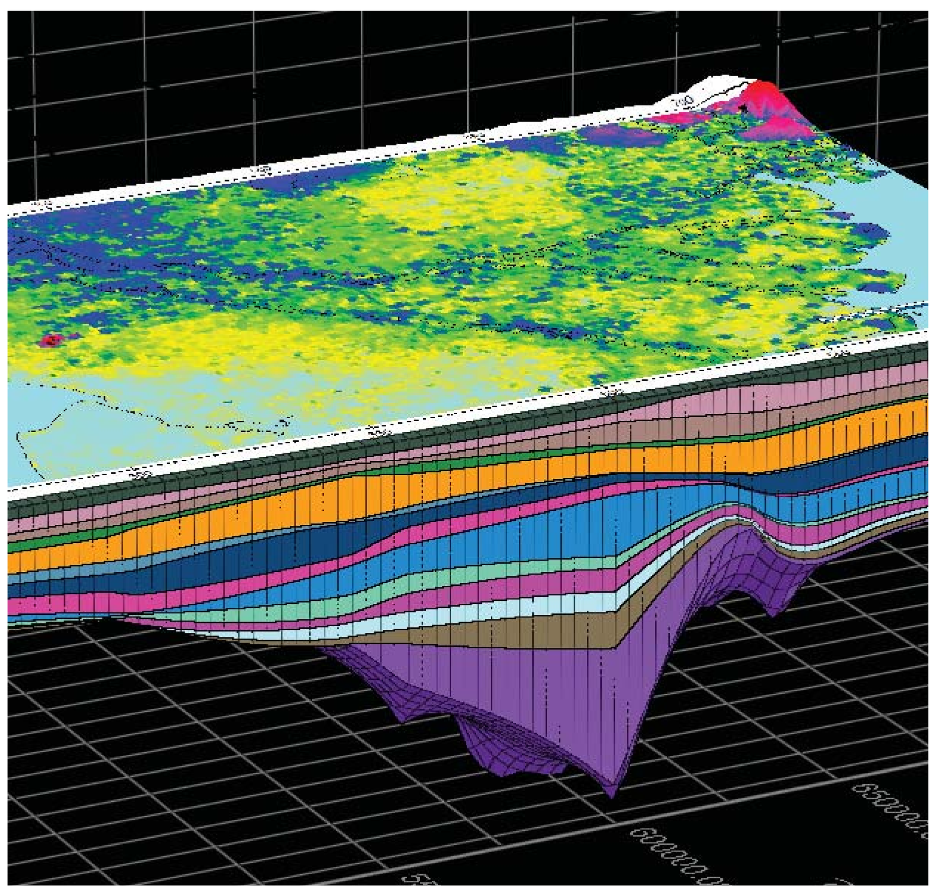

Figure 6. 3D hydrogeological model in iMOD (MODFLOW shell by Deltares) showing the DEM and subsurface architecture.

Preliminary results

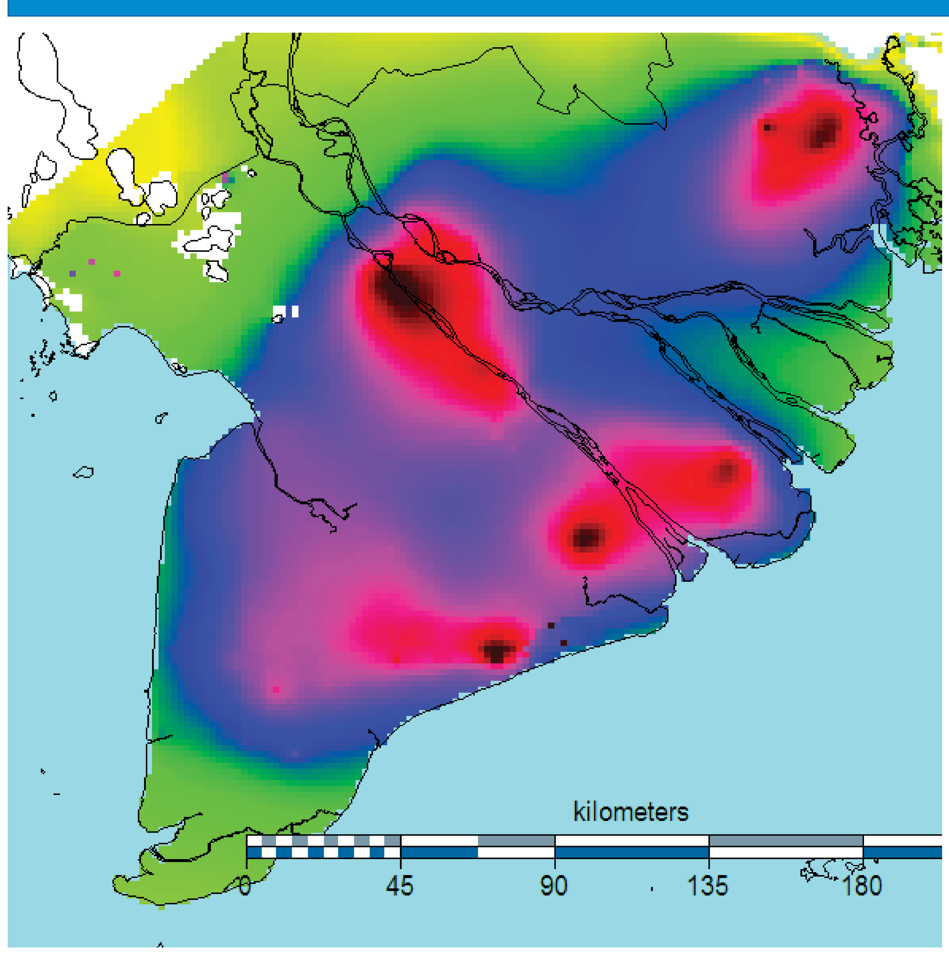

Figure 7. Spatial variability of hydraulic head decline of the Middle Pleistocene aquifer after a 25-year model run (1990-2015)*.

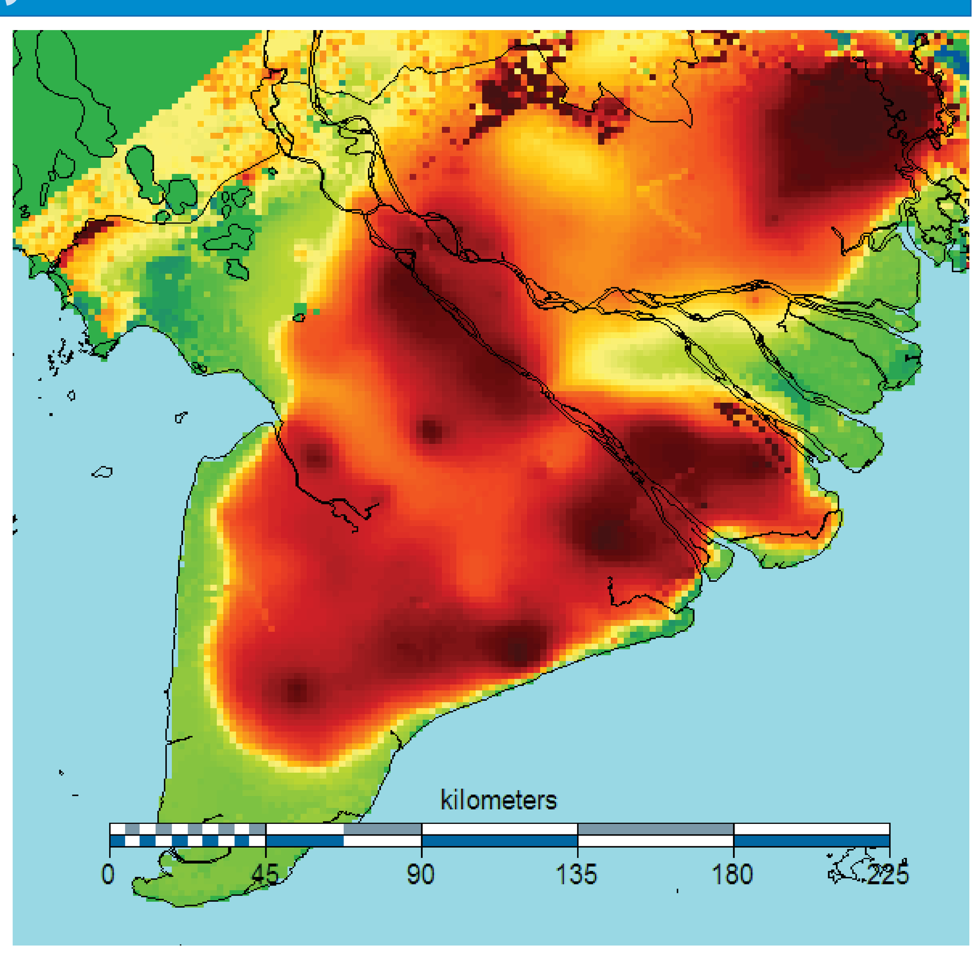

Figure 8. Total calculated subsidence for all layers (1990-2015) modeled using the coupled SUB-Cr module in iMOD (NEN-Bjerrum method)*.

Conclusions

- **The spatial subsidence pattern corresponse with drops in hydraulic head caused by groundwater pumping.**
- **InSAR analysis (Fig. 3) show similar patterns as subsidence calculations, identifying groundwater extraction as a major driver.**

Challenges

- **Model results very sensitive to local subsurface schematization (aquifer-aquitard thickness). How to improve the 3D delta subsurface model?**
- **Geotechnical parameters are unknown for the deep deposits. How to get acceptable subsidence parameterization?**

Acknowledgements
This poster is part of a PhD research carried out by P.S.J. Minderhoud at the Dept. of Physical Geography, Utrecht University, The Netherlands. The PhD project is funded by NWO-WOTRO (W 07.69.105), Deltares and TNO-Geological Survey of the Netherlands. The Division of Water Resources Planning and Investigation for the South of Vietnam (DWRPIS), Ho Chi Minh city, Vietnam is thanked for providing subsurface and hydrological data for this research.

References

Erban, L. E., Gorelick, S. M., & Zebker, H. A. (2014). Groundwater extraction, land subsidence, and sea-level rise in the Mekong Delta, Vietnam. Environmental Research Letters, 9(8), 1–6.
Minderhoud, P.S.J., Erkens, G., Pham, V.H., Vuong, B.T., Stouthamer, E., 2015. Assessing the potential of the multi-aquifer subsurface of the Mekong Delta (Vietnam) for land subsidence due to groundwater extraction. Proc. Int. Assoc. Hydrol. Sci. 372, 73–76.

* The results depicted are preliminary model outputs before model calibration.

NWO Netherlands Organisation for Scientific Research