Subsidence in the Mekong Delta, Vietnam: Impact of groundwater extraction

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

Philip Minderhoud

Introduction

Land subsidence rates of ~1-4 cm yr^{-1} are measured in the low-lying Vietnamese Mekong Delta (Fig. 1). These relatively high subsidence rates are attributed to groundwater extraction. On daily basis over two million m^3 of groundwater is extracted from the upper 500 m of the multi-aquifer subsurface. As a result, hydraulic heads in aquifers are dropping, on average 0.3-0.7 m yr^{-1}.

Land subsidence increases flood risk, and, on the longer term, threatens the delta with drowning.
To evaluate the impact of future land subsidence, we need to go from measurements to predictions.
Here we present our approach to assess the subsidence potential of the multi-aquifer subsurface of the Mekong delta due to groundwater extraction under different groundwater management scenarios.

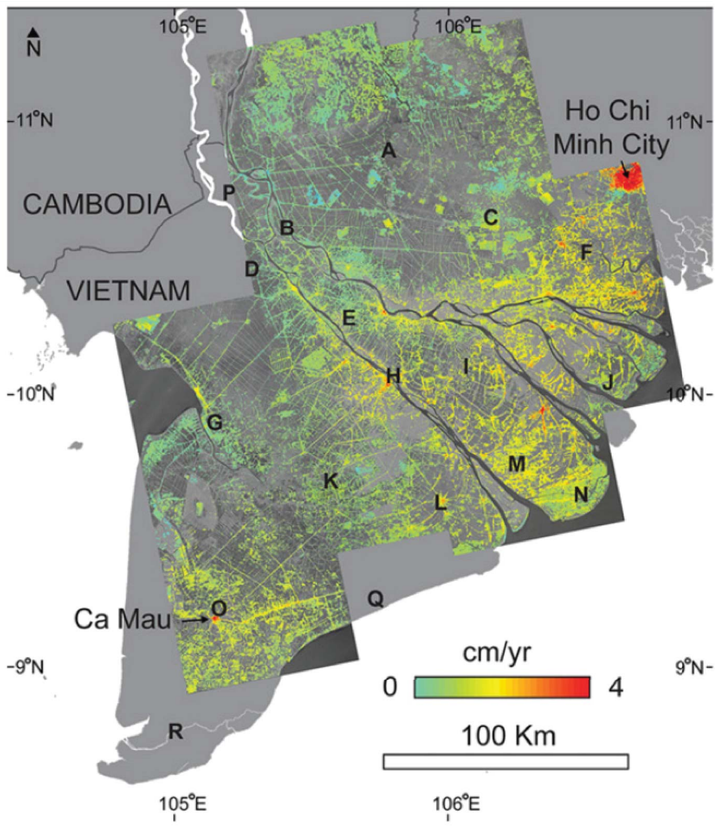

Figure 1. Satellite based (InSAR) subsidence rates between 2006-2010 for the Mekong Delta. Data © JAXA, METI 2011 (Erban et al., 2014).

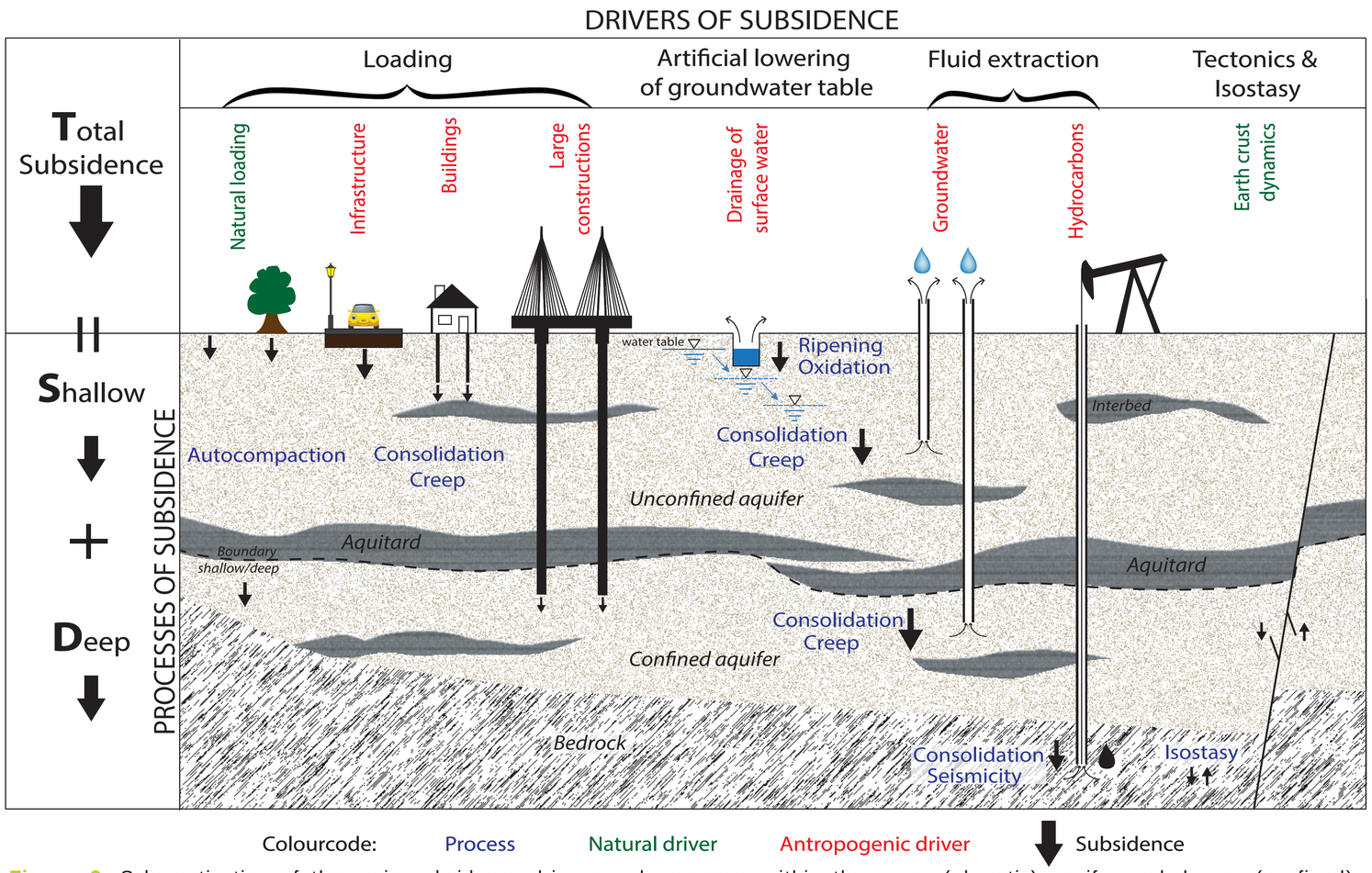

Figure 2. Schematization of the main subsidence drivers and processes within the upper (phreatic) aquifer and deeper (confined) aquifer(s). Both natural and anthropogenic drivers are distinguished. The subsidence balance equation is given on the left side, being the total sum of all shallow and deep subsidence rates.

From monitoring to predicting

Total measured subsidence at the earth surface is the sum of subsidence resulting from all natural and human-induced drivers, the subsidence balance (Fig. 2). We distinguish between shallow and deep drivers and processes of subsidence.
To determine the contribution of groundwater extraction, and to go from measuring to predicting subsidence, the cumulative signal needs to be unraveled. We develop a 3D geohydrogical model hydrology and calculate subsidence to evaluate the impact of groundwater extraction

Available data

Lithological borehole descriptions

SPT[1], LWD[2] and VES[3] measurements

Physical and chemical sediment properties

Geological cross-sections

Geo-hydrological cross-sections

1: Standard penetration test 2: Logging while drilling 3: Vertical electronical sounding

Additions to existing models

Conceptual models of delta evolution

Lithostratigraphical analysis

Palaeogeographical analysis (Depositional environments & sediment preservation)

3D lithological interpolation

Outcomes

3D lithological subsurface model

Better understanding aquifer - aquitard architecture / properties

Improved distribution of sediment properties

Improved geo-hydrological model

Gain

Hydrological model with subsidence module:

1. Unravel the subsidence balance

Identify subsidence drivers and develop mitigation strategies

2. Evaluate future groundwater management scenario's

Supporting decision-making towards sustainable groundwater management

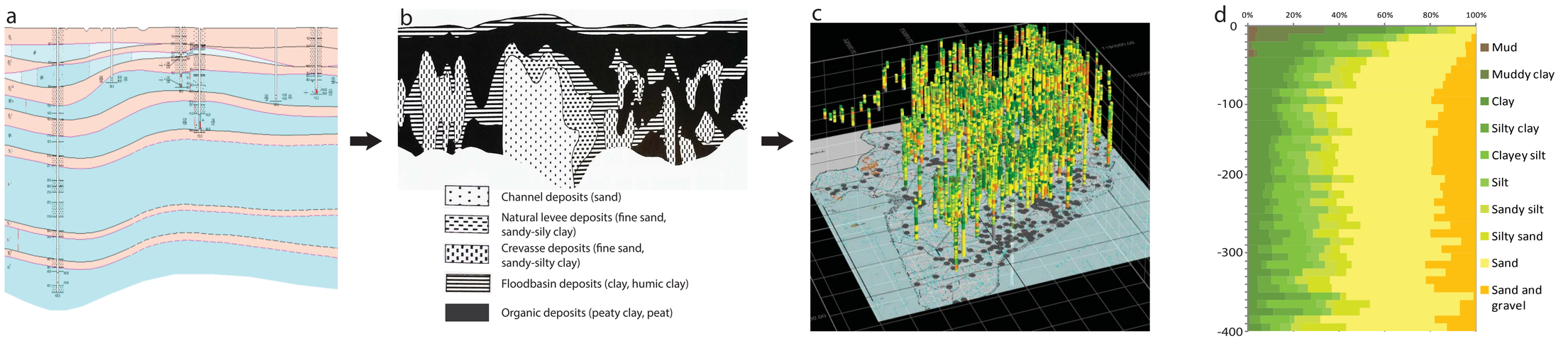

Figure 3. Workflow of the approach to develop the 3D lithological subsurface model a) Cross-section of current geo-hydrological model. b) Example of a cross-section including geomorphological elements (Bierkens & Weerts, 1994). c) 3D view of the available lithological borehole data. d) Depth distribution of lithological classes for the Mekong delta.

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

Bierkens, M. F. P., & Weerts, H. J. T. (1994). Application of indicator simulation to modelling the lithological properties of a complex confining layer. Geoderma, 62(1-3), 265–284.
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.

Netherlands Organisation for Scientific Research