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

P.S.J. Minderhoud1,2, G. Erkens2,3, V.H. Pham1,2, B.T. Vuong1, E. Stouthamer1

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 (DWRPS), 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). These relatively high subsidence rates are attributed to groundwater extraction. On daily basis over two million m³ 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.

DRIVERS OF SUBSIDENCE

Available data
Lithological borehole descriptions
Hydraulic head and extraction well data
Physical and chemical sediment properties
Geological and geochemical cross-sections

Additions to existing models
Conceptual models of delta evolution
Lithostratigraphical analysis
Palaeostratigraphical analysis (Depositional environments & sediment preservation)
3D lithological interpolation

Outcomes
3D lithological subsurface model
Better understanding aquifer–aquifer architecture / properties
Improved distribution of sediment properties
Improved geo-hydrological model

Gain
Hydrological model with subsidence module:
1. Unravel the subsidence balance
2. Evaluate future groundwater management scenarios
3. Support decision-making towards sustainable groundwater management

RESULTS

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

Figure 2. Schematisation 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.

Figure 3. Workflow of the approach to develop the 3D lithological subsurface model and construct an improved geo-hydrological model to enable subsidence modeling.

Figure 4. Measured hydraulic head time series from monitoring wells near Can Tho city, central Mekong delta. Filter depths between 40 meters.

Figure 5. Visualisation of the 3D geo-hydrological model in HKO (MODFLOW shell by Deltares) showing the DEM and subsurface architecture.

Figure 6. Spatial variability of hydraulic head decline of the Middle Pleistocene aquifer after a 20-year model run (1990-2010)’.’

Figure 7. Total calculated subsidence for all layers (1990-2015) modeled using the coupled Si/Al-Cr module in HKO (Men-Bjerrum method)∗.

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