A Flexible Predictive Tool for Salt Water Intrusion in the Red River Delta

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SUMMARY
For the management of estuarine water resources, it is necessary to have an instrument to determine the salinity concentration for any given location on the basic of directly measurable parameters such as geometry, river flow, and tide. Such an instrument is called a predictive tool. This can be used to simulate a case, in which one or more of the input parameters are subjected to change.
To date, numerous models for salt intrusion have become available. They are often used to make predictions of changes in salinity distribution under various boundary conditions. It is often implicitly supposed that if a model has been calibrated to reproduce measurements, then it will have some levels of predictive capability (Carter et al. 2006; Gallagher and Doherty 2007). However, this hypothesis is not always reasonable. It appears that a model developed for a specific condition of climate, geology, and hydrology does not represent the physical processes realistically and suitably in different environments (Beven 2000). In other words, the predictability of a model may only be fully achievable for a specific condition at which the model is calibrated, but it may uncertain to some extent.
In many studies involving real world situations, a predominant disadvantage of the models is that they require a large number of measured data before the calibration and prediction can take place. The input data for boundary and initial conditions, such as topography, freshwater discharge, hydraulic conductivity, tidal velocity, and dispersion coefficient are extremely difficult to measure in reality that constrains the accurate modeling of the salt water intrusion.
While the modeling theory seems to favor simple, characterized by a few components and a restricted set of parameters, practical applications often require detailed representation of processes, and predictive models have to address complex environmental problems (Fenicia et al. 2009). However, a predictive model must have complex simulation capabilities, and that model should be supported by the available large datasets (Hunt et al. 2007). As data availability may be much different from one location to another, establishment of model complexity is not always desirable. This requires flexible model structures that can adapt well to different requirements of specific applications. Predictive models should be developed in a way to strike a balance between model complexity and data availability, by keeping models as simple as possible, but complex enough to justify the dynamics of the data (Fenicia et al. 2008; Savenije 2009).
The analytical salt intrusion model of Savenije (2005) is a good example of a flexible modeling approach. This model was originally developed for use in single channel estuaries considering the channel shape under tidally averaged conditions. The model involves two calibration coefficients that can be determined on the basis of an extensive salinity intrusion survey. It also contains some semi-empirical formulas that allow the prediction of the salt intrusion for a wide range of estuaries. However, there is no definitive answer to the question of whether the tidally averaged salt intrusion model can be applied to predict the future salinity distribution in complicated geometrically estuaries, in which the estuary shape

significantly varies as a function of tidal amplitudes. Such estuaries exhibit a narrow and nearly prismatic shape at low tide, but at high tide, they are very broad, and the banks strongly converge upstream.

In this paper, we present a predictive solution for salt intrusion based on the work of Savenije (2005). The proposed method was developed based on the premise that a calibrated model can be used for making predictions of future system behavior if the information content of the calibration data is sufficiently enough to constrain the model parameters. Hence, the parameterizations estimated through calibration for different geometric and hydrologic conditions can ensure the model to reproduce the reality that it is designed to represent. This strategy allows us to utilize the model at a level of complexity that sufficiently represents all processes at which a prediction of interest depends. The method was extended to establish empirical relations for the model parameters as a function of directly measurable parameters such as geometry, freshwater flow, and tide. Thus, changes in boundary conditions and their influences on the salinity distribution can be predicted.

The developed method was adapted for use in the Red River Delta (RRD) in North Vietnam. This delta comprises four estuary branches: Tra Ly, Red River, Ninh Co, and Day (Figure 1). Existing topography, tide, and salinity data during a month in the dry season of 2006, which were measured by the joint project between the Tokyo Metropolitan University and the Water Resources University (Nguyen 2012), were used to calibrate the model parameters. Predicted results of longitudinal salt intrusion profile were compared with collected datasets in 2008 and 2009 to validate the method. A relatively good agreement was found between the model calibrated parameters and those computed from the empirical relations. We also found that the predicted salt intrusion profiles agree well with the measured data. These findings provide a key for the further investigation of salt water intrusion in estuaries.

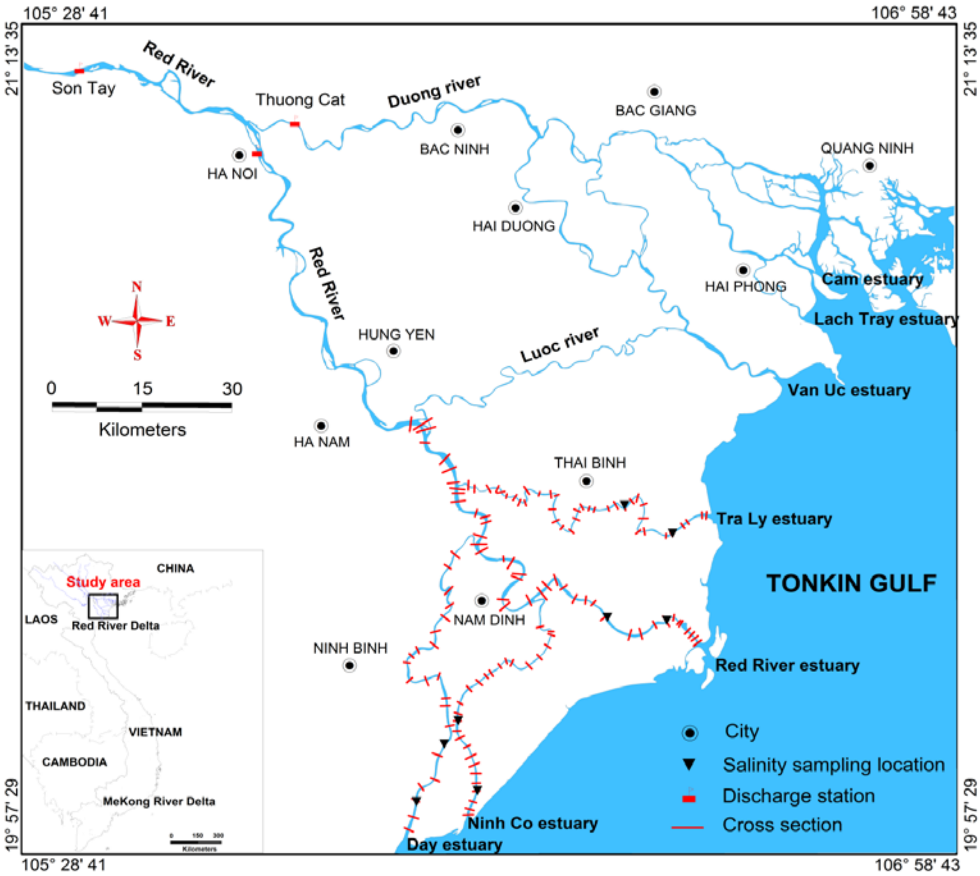

Figure 1. The study area.

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