Managing acidity movement in the coastal land with acid sulphate soils: a modeling approach

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Abstract
A new acidity module has been developed and coupled successfully into an existing hydraulic and salinity model for simulating acidity movement in canals under the controlled marine water intake in the coastal land with acid sulphate soil (ASS). The model allied with the Camau peninsula, Mekong Delta, Vietnam indicates that the most suitable option for improving the acidity condition is to open main sluice gates one day every week when difference of tide amplitude of between the East and West seas is highest and to widen the canals connected to the West sea.

Key Words
Modeling, acid sulphate soil, coastal, salinity, acidity.

Introduction

The study area located in the Camau peninsula, Mekong delta, Vietnam (Figure 1) is a coastal land with a total area of 950,000 ha of which the acid sulphate soils (ASS) occupied 63%. Before 2000, the study area had been adversely affected by acidic pollution from ASS when it was protected from salinity by sluices along the East sea for rice production (Hoanh *et al.* 2003). However, land use changed to shrimp or shrimp-rice system that requires brackish water has reduced the acidity in the fields significantly. Powell and Martens (2005) explained that in the ASS area saline water creates the suppression of the hydrological transport of aqueous acidic products and supports the *in-situ* reformation of solid phase iron-sulfide minerals. Other studies (Indraratna *et al.* 2002; Johnston *et al.* 2005; Åström *et al.* 2007) also indicated the reduction of acidity impacts through the hydrological suppression, neutralisation or dilution of acidic products. A study on applying the inundation by marine water for a large ASS area was also carried out at East Trinity, New South Wales (Johnston *et al.* 2008). In the study area severe acidic pollution in the canal network usually occurs at the beginning of rainy season due to acidity leached out from the dredged acid soils deposited along canal bank. Therefore this study focused on simulation of acidity movement in canal network when saline water is intaken through sluices to find out the most suitable option for water quality management.

Methodology

Developing a new acidity module

The new acidity module was developed (Figure 2) and coupled into an existing hydraulic and salinity model, the Vietnam River Systems and Plains (VRSAP) model (Dong 2000). The acidity module (Figure 3) simulates the acidity transport in canals by flow, diffusion of lateral acidity input along canals and reaction between saline water and acidity. The two latter components were quantified from laboratory and field experiments (Phong 2009). The new acidity module was calibrated and verified by Phong (2009).

Delineating zones for model analysis

Land uses in the study area vary from 2 shrimp crops in the southwest part (zones So to S3) where saline water is dominant to three rice/upland crops in the eastern part (zone F) where fresh water is dominant (Figure 1). Two rice crops or one shrimp crop in the dry season followed by one rice crop in the rainy season are cultivated in the zones with alternate brackish and fresh water (B1, B2 and S1, S2). To simplify the water quality requirement, salinity of 5 ppt is used as a threshold for rice crop. At Ninh Quoi (NQ), salinity should be less than 5 ppt throughout the year to allow 3 rice/upland crops in zone F.

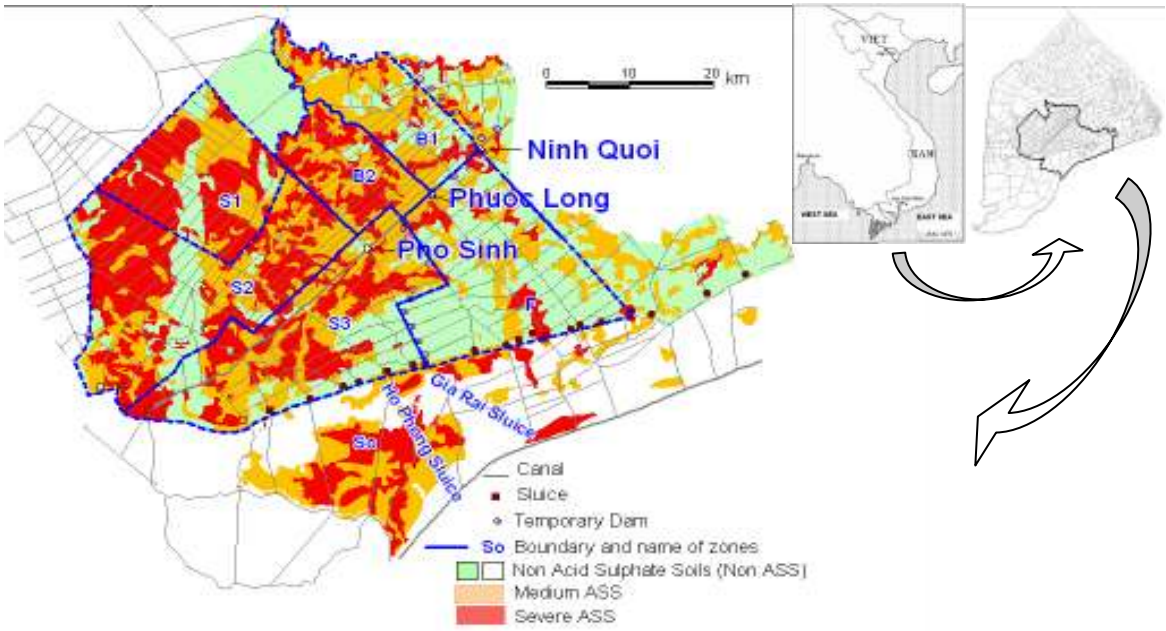

Figure 1. Zoning for water management in ASS area.

Matching salinity with land use requirements while minimizing acidity impacts
The model was applied to explore a suitable water management option for matching salinity requirement in different land use zones while minimizing acidity impacts in the study area. Model results were transferred to GIS for mapping the isohalines and the pH isolines to check the salinity and acidity movement in all land use zones.

Different sluice operation options were studied for managing salinity in the study area (Hoanh *et al.* 2003). In this study, acidity movement in the canal network is investigated in an option of operation of both Ho Phong (HP) and Gia Rai (GR) sluices combined with canal widening to allow easier saline water intake and improving acidity problem.

The expectation of water management is to push out acidity to the West sea direction where the land is still fallow or mainly covered by forest. Among the primary canals that links the East sea side to the West sea side, the Ninh Thanh Loi (NTL) and the Quan Lo-Chu Chi (QLCC), with a width from 10 m to 50 m, are the shortest (20-25 km) canals connected directly to the HP and GR sluices (Figure 4a).

Results and discussions
As a result of field experiment to quantify sources of acidity pollution along canals (Phong 2009), Table 1 shows the total amount of acidity in water leached out by water components (runoff, bypass, percolation and seepage) from canal embankments at the beginning of rainy season are strongly affected by both acid soil type and dredged years and it is extremely high at canal embankment with dredged severe acid soil deposited between 1-2 years (mid).

Table 1. The total amount of acidity leached out from canal embankment (mol H^+ m^{-2} of surface of canal embankment) during field experiment from 15/4 to 30/7/2005.

Age of deposit	Soil type		
	Severe ASS	Medium ASS	non ASS
Old	3.7	3.5	0.3
Mid	19.7	13.2	
New	1.9	2.5	

Note:
Soil type: Severe, medium ASS: Depth of sulphuric horizon are from 0-50 or and >50 cm, respectively.
Age: Old > = 3 years; Mid >1 to 2 years; New <= 1year.

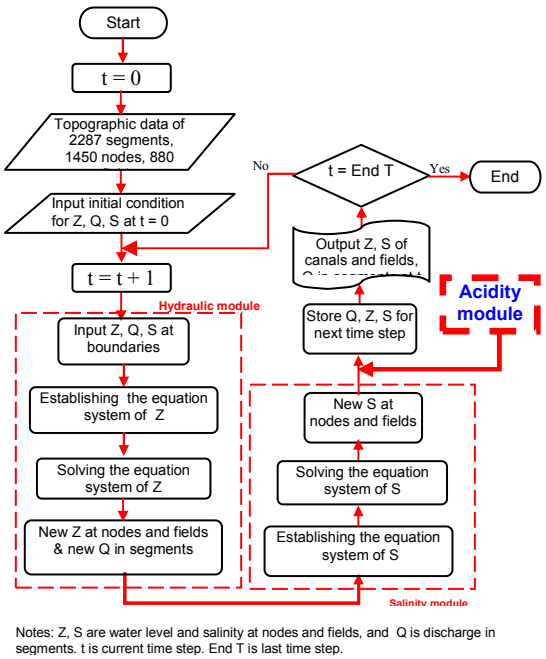

Figure 2. The ACIDITY module in the VRSAP model.

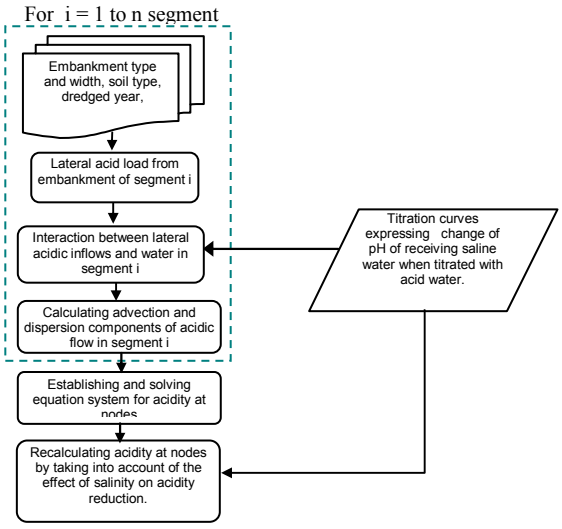

Figure 3: The ACIDITY module

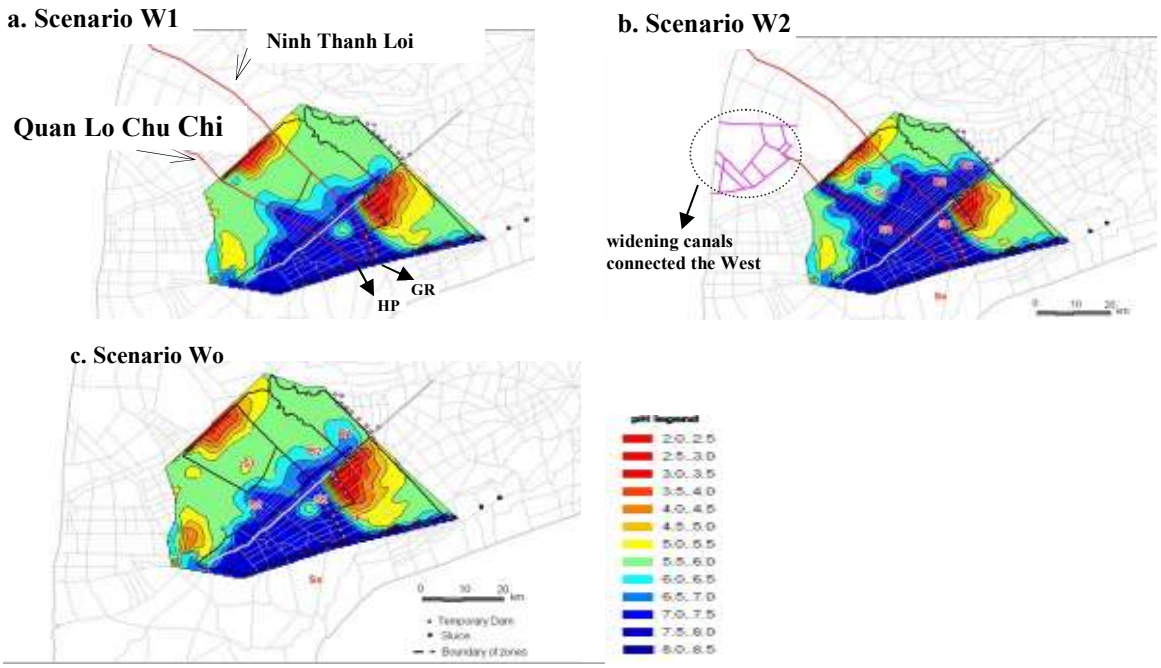

Figure 4 Acidity propagation under scenarios a. W1: sluice operation and widening NTL and QLCC canals b. W2: sluice operation with widening more canals connected QLCC to West Sea; and c. Wo (control scenario) only sluice operation without canal widening.

Two scenario groups of sluice operation and canal widening were analyzed by the model. In the scenario group 1, only sluice operation was considered by analyzing role of each sluice and different combinations of sluices. In the scenario group 2, both sluice operation and canal widening are considered. For example, in scenario Wo (Figure4c) canals are not widened. This scenario is used as control scenario for comparison with two scenarios W1 and W2. In scenario W1 only the NTL and the QLCC canals are widened to a top width of 50m and deepened to elevation of -2.0 m below Mean Sea Level (Figure 4a). In scenario W2 more secondary canals connected the QLCC to the West Sea are widened (Figure 4b).

Sluice operation for controlling saline water intake and drainage has significant effect on acidity propagation. Model results from scenarios in group 1 showed that scenarios with more frequent intake of saline water are more effective in improving acidity condition because of the increase of alkalinity in canal water. The scenario of opening HP and GR one day a week at the highest difference of tide amplitude of between the East and West Seas can be considered as a most suitable option for sluice operation for both purposes of salinity and acidity control. Furthermore, a significant reduction of acidity in the study area occurs when such sluice operation is combined with the widening of primary and secondary canals that connect these sluices to the West Sea (scenario W2).

Conclusion

For managing acidity movement in the study area, the process of land use zoning, matching water salinity with requirement, then simulating acidity propagation under effects of salinity control is suitable. Such process helped in analyzing effects on both salinity and acidity by changing sluice operation and/or widening canals. However, the analysis also showed a trade-off in water quality management: moving acidity out of the study area may cause pollution to the area at the West sea side.

References

Åström M, Österholm P, Bärlund I, Tattari S (2007) Hydrochemical effects of surface liming, controlled drainage and lime–filter drainage on boreal ASS. *WaterAir Soil Pollut.* **179,** 107–116.

Dong TD (2000) VRSAP model and its applications. In 'Proceedings of the Workshop on Hydrologic and Environmental Modeling in the Mekong Basin. Technical Support Division, Mekong River Commission, Phnom Penh, Cambodia'. (Ed RW Al-Soufi).

Indraratna B, Glamore W, Tularam GA (2002) The effects of tidal buffering on ASS environments in coastal areas of NSW. *Geotech. and Geolog. Engineer.* **20,** 181–199.

Johnston SG, Slavich PG, Hirst P (2005) The effects of controlled tidal exchange on improving drainage water quality in ASS backswamps. *Agricult. Water Manag.* **73,** 87–111.

Johnston SG, Keene AF, Bush RT, Burton ED, Sullivan LA, Smith D, Martens MA, McElnea AE, Wilbraham ST, van Heel S (2008) Contemporary pedogenesis of severely degraded tropical ASS after introduction of regular tidal inundation. *Geoderma* **149,** 335–346.

Hoanh CT, Tuong TP, Gallop KM, Gowing JW, Kam SP, Khiem NT, Phong ND (2003) Livelihood impacts of water policy changes: evidence from a coastal area of the Mekong river delta. *Water Policy* **5,** 475–488.

Phong ND (2009) Modelling of canal water acidity due to ASS: a case study of the Camau Peninsula, Mekong Delta, Vietnam. PhD thesis, The University of Melbourne, Australia.

Powell B, Martens M (2005) A review of acid sulfate soil impacts, actions and policies that impact on water quality in the Great Barrier Reef catchments, including a case study on remediation at East Trinity. *Mar. Pollut. Bull.* **51,** 149–164.