19th Annual General Assembly – AGA 2018
International Association of Maritime Universities (IAMU)
M. Grifoll, F.X. Martínez de Osés, M. Castells and A. Martin (Eds)

A SIMULALATION ON TRANSPORTATION OF SUSPENDED SEDIMENT DUE TO THE MAINTENANCE DREDING OF THE CAI LAN INTERNATIONAL CONTAINER TERMINAL, VIETNAM

NGUYEN THI THE NGUYEN *, LE THI HUONG GIANG †

* Faculty of Coastal and Marine Engineering
Thuy loi University
175 Tay Son, Dong Da, Hanoi, Vietnam
e-mail: nguyen.n.t@tlu.edu.vn, web page: http://www.tlu.edu.vn

† Faculty of Hydraulic Engineering
Vietnam Maritime University
484 Lach Tray, Le Chan, Hai Phong, Vietnam
e-mail: gianglh.ctt@vimaru.edu.vn, web page: http://www.vimaru.edu.vn

Keywords: Maintenance dredging, Cai Lan, Deflt3D

Abstract. Maintenance dredging of Cai Lan International Container Terminal (CICT) is expected to be undertaken every three years and generates about 50,000 m^3 of dredged material. All dredged material is disposed at an offshore disposal site, which is about 42 km far from the Terminal and 20 km far from Ha Long Bay. The purpose of the study is to assess the impacts of the maintenance dredging of the CICT on the environment of the World Natural Heritage Site - Ha Long Bay. The 2D tidal current – wave, and dispersion and transportation of suspended sediment modeling were developed. The dispersion and transportation of dredged soil were simulated during dredging and after dumping. The results of the study showed that the suspended substance concentration in the core zone of Ha Long Bay was still lower than that of the Vietnamese standard. However a part of the buffer zone that was about 2-3 km far from the dredging site was locally polluted. At the dumpsite, the dumping soil did not cause any problem to the water quality of Ha Long Bay. According to the modeling results, the offshore dumpsite could be moved landwards 7 km to reduce transportation cost.

1 INTRODUCTION

Many ports throughout the world suffer from siltation of their berthing and maneuvering areas, requiring maintenance dredging activities to safeguard required depths [1]. In addition, the depths of most navigation channels gradually decrease over time due to sedimentation, since these channels behave as a sediment trap. Maintenance costs are a critical element in the economic feasibility of a port, particularly when a relatively long access channel requires frequent dredging.

The mixing and transport of sediments (suspended load and bed load) are a function of water properties that include depth, temperature, viscosity, stratification, and salinity; sediment properties include background levels of suspended solids, material composition, density, size, particle size distribution individual grains or flocks), and solids concentration of the slurry. Hydrodynamic forces include currents, waves, turbulence, all of which cause horizontal and vertical mixing; and other influences include buoyancy (entrapped air or gas), initial momentum on entering the water body from hopper bottom [2].

One of the main concerns over dredging and dumping is the temporary increases in turbidity. Increased turbidity may also lead to short-lived effects on organisms that are light-dependent, but these are generally considered to be negligible. Dumping sediments on the seabed may smother and crush organisms living on the seafloor and may cause changes in benthic habitats and biological communities. Changes in community structure are restricted to within 5 km of the dumpsite. Continuous maintenance dredging often takes place where navigation channels to ports have high sedimentation rates, such as in estuaries. Areas that are frequently dredged have a permanently changing benthic environment. Dredging in estuaries to create a new harbor, berth or waterway, or to deepen existing facilities, can affect tidal characteristics which may affect sensitive habitats. Dredging and dumping activities also contribute to underwater noise. Therefore, it is necessary to study the sediment fate and transport mechanism (dispersion) under the action of coastal currents and waves. The investigation for locating suitable disposal site can be done by using mathematical models.

Currently, there are a number of models that can be applied to simulate the fate and the dispersion of sediment due to dredging and dumping. In a study by Shukla et al., numerical simulation of the sediment dispersion is carried out using the MIKE – 21 software for reproduction of the bed load movement of the dredged material near Karanja Creek, Mumbai, India [2]. The U.S. Army Engineer Research and Development Center (ERDC) applies the Particle Tracking Model (PTM) to quantify the fate of dredged material released during the harbor expansion project to accommodate transient nuclear powered aircraft carriers. The results of this modeling effort quantify exposure of the nearby coral reefs to turbidity and sedimentation [3]. García uses the IH-Dredge model in a dredging operation in the Port of Marin, Spain [4]. Deltares uses the Delft3D model for predicting sedimentation in navigation channels and harbour basins [1].

Delft3D is an open source, flexible, integrated modeling framework, and developed by Deltares. It can simulate two and three-dimensional flow, waves, sediment transport, morphology, water quality and ecology, and is capable of handling many of the interactions between those processes [1]. The sediment transport module includes both suspended and bed/total load transport processes, as well as morphological changes for an arbitrary number of cohesive and non-cohesive fractions. It can keep track of the bed composition to build up a stratigraphic record. The suspended load solver is connected to the 2D or 3D advection-diffusion solver of the FLOW module (density effects may be taken into account). An essential feature of this module is the dynamic feedback between the FLOW and WAVE (SWAN) modules, which allow the flows and waves to adjust to the local bathymetry changes as the simulation progresses [7].

The purpose of the study is to assess the impacts of the maintenance dredging of CICT on the environment of the World Natural Heritage Site - Ha Long Bay. The Deflt3D-Flow model was applied to simulate the transport of suspended sediment at the dredging site and the dumpsite.

2 MATERIALS AND METHODS

2.1 Study area

CICT is located in Quang Ninh Province, Viet Nam. The Terminal fully completed its construction in February 2013. It is expected to cost $US155 million for the first phase with the container handling capacity started from 520,000 twenty-foot equivalent unit (TEUs) in 2012, and has increased to a capacity of 1.2 million TEUs at its full capacity. CICT holds a 50-year license to develop, design, finance, construct, equip, and operate berths 2, 3 and 4 at Cai Lan Port. CICT has a 10 meter access channel draft at low tide, a 13 meter draft at the berth, a total quay length of 594 meters, and a 25 hectare container yard [5]. CICT offers shipping lines significant cost savings by enabling the deployment of larger container ships which cannot call at Hai Phong Port due to draft restrictions. This provides much needed capacity to the market, improves Vietnam’s competitiveness and supports the expected growth in Vietnamese exports.

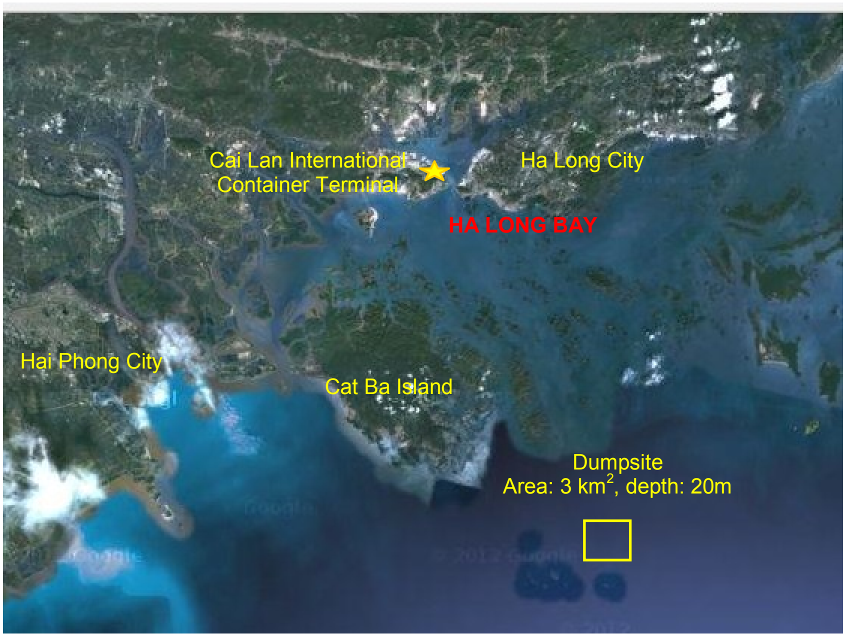

Figure 1: Locations of CICT and the dumpsite

The maintenance dredging at CICT is undertaken every three years and generates about 50,000 m^3 of dredged material. All dredged material is disposed at an offshore disposal site designated by the responsible government authority. The disposal site is about 42 km from CICT, outside Ha Long Bay, and near Long Chau Island (Figure 1). The disposal site is 20 m depth and has a capacity to take 12 million m^3 of deposit. CICT has characterized the chemical quality of dredged material to be disposed at the designated site to confirm that it conforms to the allowable quality. In addition, CICT performs water quality monitoring of suspended solids, turbidity and benthic community before, during, and after dredging operations.

2.2 Suspended sediment modeling

The 2D tidal current – wave, and dispersion and transportation of suspended sediment modeling were developed for the dredging operation in CICT by applying the DELFT3D model. The dispersion and transportation of dredged soil were simulated during dredging and after dumping. Based on Ha Long Bay map, and available data on bathymetry, water level, tidal harmonic components seaward, the model area was limited as follows: 1) river limitations were at the hydrological stations at Do Nghi, Cua Cam, and Quang Phuc: 2) sea limitation was an arc that has a radius of 75km from the Terminal. Figure 2 shows the model area, and bathymetry condition. The bathymetry data at the deep sea was extracted from the DEM Etopo2 map for the East Sea. Bathymetry data near the coastline was the surveyed data. The hydrodynamic model grid had 378*483 nodes with a minimum grid size of 35 m at the dredging site and a maximum grid size of 500 m at the open sea. Landward boundary conditions were hydrological data as well as suspended sediment concentrations extracted from the observed data. Open sea boundary conditions were tidal water levels, and waves. Initial condition for suspended sediment was uniform value, which was the lowest value derived from the measured data. Wind data was also added in the simulation. To guarantee stability and accuracy of the time integration of the shallow water equations, certain time step limitations need to be taken into account. The accuracy of the model depends on the Courant-Friedrichs-Lewy number (CFL), which generally should be smaller than 10. However, in case time and spatial variations are small, the Courant number can be even higher. In this study, a time step of 60 seconds was chosen. Simulation time was set from 22/9/2016 to 6/10/2016.

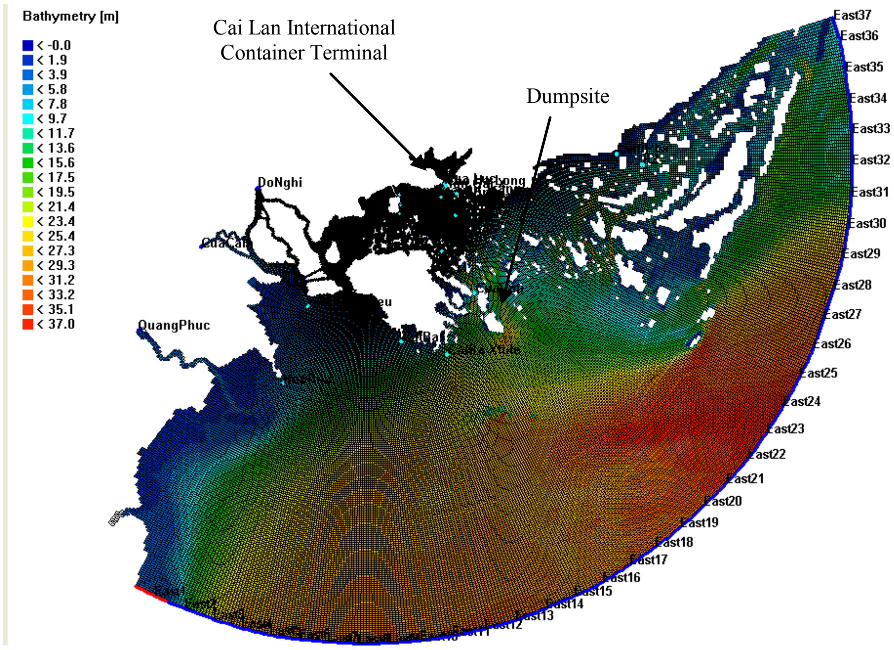

Figure 2: Bathymetry and computational grid

Source term magnitude: The source term magnitude is the amount of suspended sediment entering the environment, and is expressed as a fines flux (kg/s). The spatial and temporal variation should be accounted for through correct implementation on the computational grid. In Delft3D-FLOW, the source term is implemented as a discharge of water, and sediment. For each input cell, a discharge (m^3/s) and a concentration (kg/m^3) have to be specified. The source term flux is a multiplication of the input discharge by the input concentration. The maximum allowed discharge depends on the flow velocity of the ambient fluid, and the size of the computational grid. The maintenance dredging of CICT is about 40 days, leading to 50.000 m^3 for the dredged soil amount, or 1,250 m^3 for dumping soil everyday. Four sets of sediment samples were collected in the vicinity of the project area, and analyzed to determine their sediment size distributions. The results showed that the dredged material consisted of 65,1% sand, and 34,9% fines (23,8% silt and 11,1% clay). Based on these results, the predicted fines flux was about 6.8 kg/s (1,250 m^3 of dumped soil everyday * 34,9% fines * 2,800 kg/m^3) / (24 hours * 3,600s). Concentration of suspended sediment in the working center during the cutter-suction dredger's work was about 250 – 500 mg/L [6].

Model calibration is crucial part in mathematical modeling. Generally, it is done with dynamic parameters like current speed, current direction, and water levels. Available hydrological data for these processes was the surveyed water level and current data at Hon Dau station, tidal estimated data at Cat Ba, Cua Ong, and Hon Gai. The suspended sediment data for these processes was taken from the survey results in September 2016.

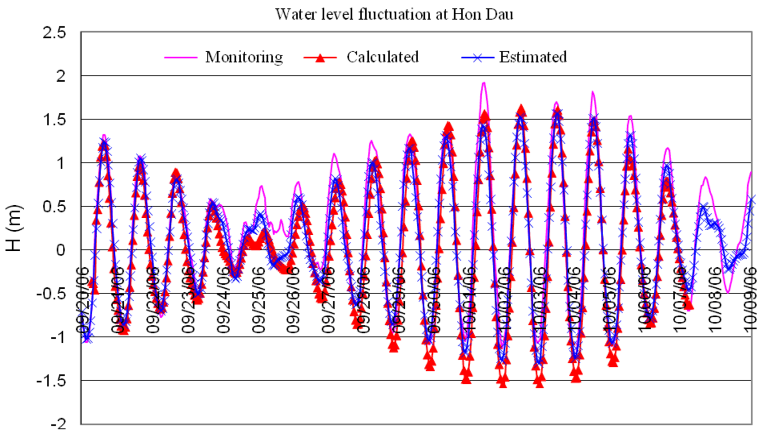

Figure 3: Calibration result on the water level at Hon Dau station

3 RESULTS AND DISCUSSION

The results of the study showed that the study area was not dominated by river flows but the tide from the sea due to its natural conditions. Therefore, the flows in this area go up and down following the tide (see figure 4 and 5). In the figures, the velocity magnitudes are positive and negative. However, the direction and magnitude of the flows in the study area significantly varied because of the complex geometry with the available of many small islands. At the dumpsite, the flow had northeast - southwest direction with the maximum velocity of 0.25 m/s (Figure 4). With this flow direction, suspended sediment was transported from the dredging site to Bai Chay Beach, and then to Ha Long Bay. Contrary to the flows nearby the coast, at the dumpsite, the flow velocities were rather high. A maximum velocity at this location reached 0.45 m/s with north – western north direction.

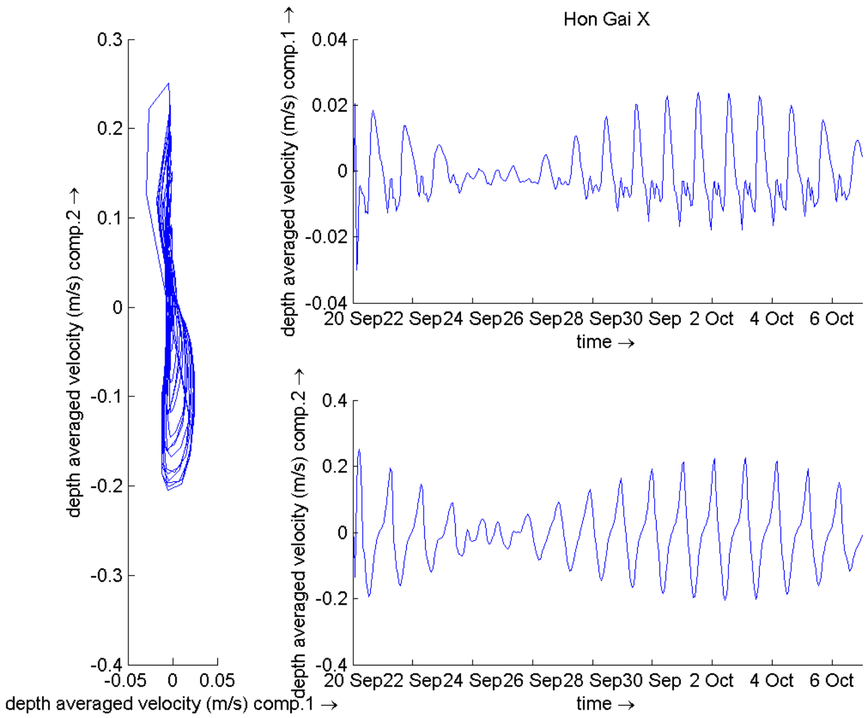

Figure 4: Flow directions and magnitudes at dredging site

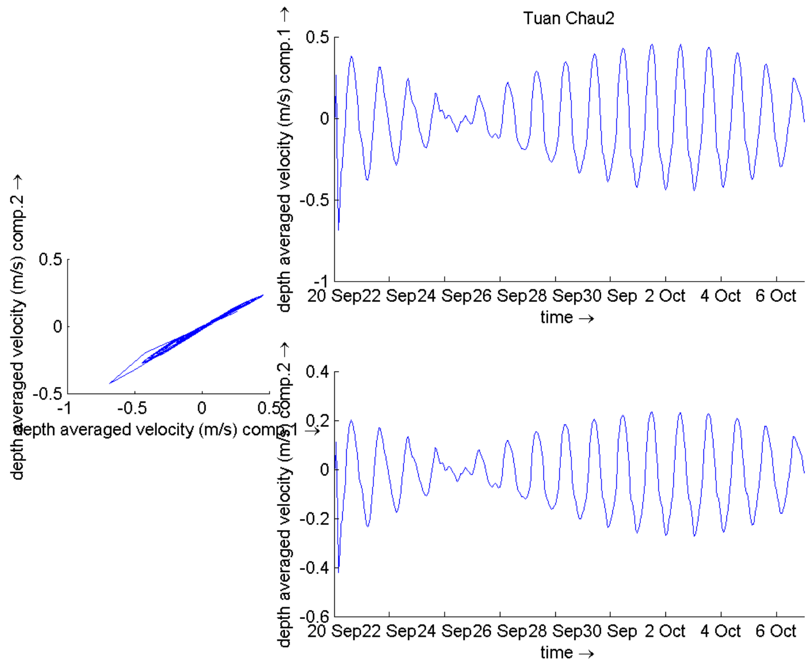

Figure 5: Flow directions and magnitudes at dumpsite

At the dredging site, the dispersion of suspended sediment changed with the tidal flow (Figure 6). The result showed the area of increase high suspended sediment concentration was less during the ebb tide than that during the flood tide. During the ebb tide, the tidal current brought the suspended sediment to Ha Long Bay. For this reason, a part of the buffer zone of Ha Long Bay, where was about 2 - 3 km far from the dredging site, was locally polluted. However, the suspended substance concentration in the core zone of Ha Long Bay was about 10 mg/L, and much lower than that of the Vietnamese standard for marine water quality (50 mg/L). During the food tide, the tidal current pushed the suspended sediment back to Cua Luc Bay. Therefore, the maintenance dredging of CICT polluted the Cua Luc Bay. It took a month for the suspended substance concentration to go back to the initial state after the dredging finishes. Most of the time, Bai Chay Beach was polluted by the suspended sediment from the dredging operation.

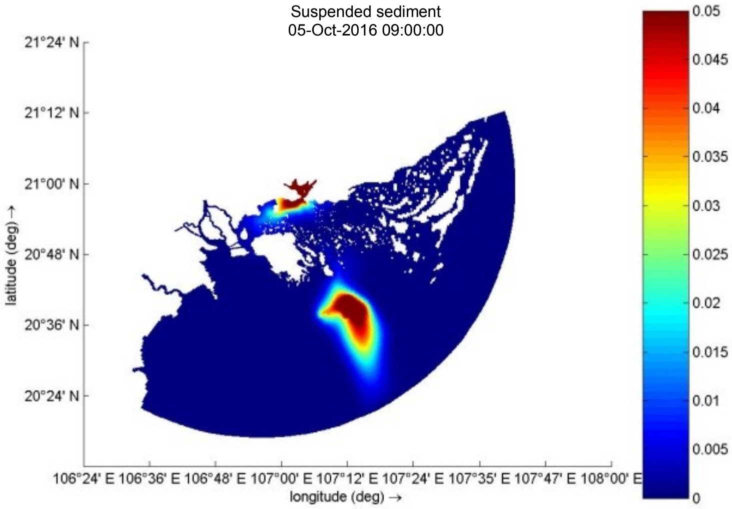

Figure 6: The distribution of suspended sediment concentration (kg/m^3) at the dredging site and the dumpsite during the food tide

At the dumpsite, the suspended substance concentration was higher than the Vietnamese limitation for marine water quality. The dispersion of the suspended sediment also varied with the tidal flow, which is showed as the changing shape in the isoclines of the increased suspended sediment concentration in Figure 7. For example, when the dredged soil is dumped in the flood tide, the largest area of above 50 mg/L concentration of suspended sediment is 8 km^2. Under the influence of the flood tide, the suspended sediment was pushed toward Bai Tu Long Bay, instead of going into Ha Long Bay. In the ebb tide, the suspended sediment transports toward Hai Phong City. The largest area of above 50 mg/L concentration of suspended sediment is 10 km^2. The dump of dredged material did not cause any problem to the water quality of Ha Long Bay. According to the modeling results, the offshore dumpsite could be moved 7 km landwards to decrease the transportation cost.

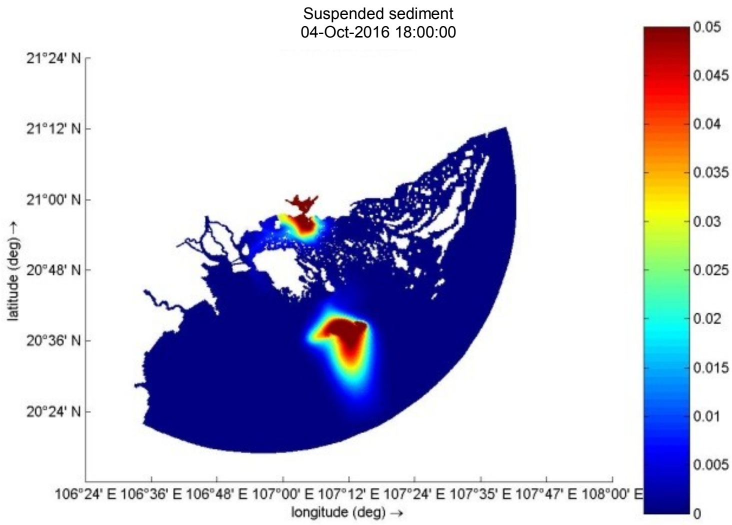

Figure 7: The distribution of suspended sediment concentration (kg/m^3) at the dredging site and the dumpsite during the ebb tide (right).

4 CONCLUSIONS

The hydrodynamics simulations indicated that the peak tidal current in the vicinity of the dredging site was in of 0.25 m/s, which may help in the dispersion of the dredged material comprising of clay and very fine silt. The maintenance dredging of the CICT did not affect the water quality in the core area of Ha Long Bay, but caused water pollution to Cua Luc Bay, Bai Chay Beach, and a part of the buffer zone of Ha Long Bay. The time required to restore the ambient conditions after the dumping ceases would be about a month. The dumpsite could be moved about 7 km landwards in order to reduce the transportation cost.

REFERENCES

[1] Deltares. Sedimentation in Channels and Ports. The Netherlands: Deltares, 2001.

[2] Shukla, V. K. and others. Dredged Material Dumping Site Selection Using Mathematical Models. In: *Proceedings 8th International Conference on Asian and Pacific Coasts (APAC 2015)*. India: Elsevier Procedia, 2015, pp. 109-117.

[3] ERDC. PTM Modeling of Dredged Suspended Sediment at Proposed Polaris Point and Ship Repair Facility CVN Berthing Sites – Apra Harbor, Guam. ERDC/CHLTR-17-16. US: The U.S. Army Engineer Research and Development Center, 2017.

[4] García, Alba J. and others. A 3-D Model to Analyze Environmental Effects of Dredging Operations – Application to the Port of Marin, Spain. In: *Advance in Geosciences*. Germany: Copernicus GmbH, 2014, 39, 95-99.

[5] CICT. Cai Lan International Container Terminal [online]. Vietnam: CICT, 2018. [viewed date 12 April 2018]. Available from <https://www.cict.com.vn>

[6] CICT, Report on Environmental Impact Assessment due to the Dredging of Cai Lan International Container Terminal, Quang Ninh, Vietnam. Vietnam: CICT, 2011.

[7] Nguyen, N.T.N and De Vries, M.B. Predicting Trends in Water Quality in the Coastal Zone of TT-Hue, Vietnam - An Assessment of Impacts of Rice Culture and Aquaculture. In: *Asian and Pacific Coasts 2009*. Singapore: World Scientific, 2009, 4, 148-154.