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Master Plan Jakarta, Indonesia: The Giant Seawall and the need for structural treatment of municipal waste water

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ABSTRACT

In order to take actions against the annual flooding in Jakarta, the construction of a Giant Seawall has been proposed in the Master Plan for National Capital Integrated Coastal Development. The seawall provides a combination of technical solutions against flooding, but these will heavily modify the mass transports in the near-coastal area of Jakarta Bay. This study presents numerical simulations of river flux of total nitrogen and N,N-diethyl-*m*-toluamide, a molecular tracer for municipal waste water for similar scenarios as described in the Master Plan. Model results demonstrate a strong accumulation of municipal wastes and nutrients in the planned reservoirs to extremely high levels which will result in drastic adverse eutrophication effects if the treatment of municipal waste water is not dealt with in the same priority as the construction of the Giant Seawall.

1. Introduction

The municipalities of the Jakarta Metropolitan Area are facing a great challenge to deal with the issues of overexploitation of groundwater, land subsidence and annually reoccurring floods, lacking expansion of infrastructure including, among others, sanitation and treatment of municipal waste water (Steinberg, 2007). The uncontrolled flow of untreated municipal waste water has led to a strong deterioration of water quality in the rivers of Jakarta and along the shores of Jakarta Bay (Damar, 2003; Arifin, 2004; Thoha et al., 2007).

Van der Wulp et al. (2016-in this issue) have identified persistently high concentrations of total nitrogen and total phosphorus along the Jakarta shoreline due to high initial river concentrations and sub-optimal flow characteristics in those areas where eutrophication issues are frequently reported.

The Master Plan "National Capital Integrated Coastal Development" focuses on the design and functioning of flood risk solutions incorporated in an integral design for socio-economic urban development (Ministry for Economic Affairs, 2015a). This offshore approach incorporates the phased construction of a Giant Seawall and large storage basins to protect Jakarta City against floods from sea and rivers. Various articles in the Jakarta Post show public concerns expressed about the environmental and socio-economic consequences of the Master Plan including the deterioration of the water quality in the intended storage basins.

In the present study, an existing combination of numerical hydrological and flow modelling techniques as previously described in Van der Wulp et al. (2016-in this issue) was used to simulate river discharges, flow, and dispersion of nutrient flux, in the form of total nitrogen (TN) and total phosphorus (TP), into Jakarta Bay. The flow and mass tracer model was adapted to simulate scenarios similar to the three phases of the Master Plan to illustrate the fate of river bound nutrients and municipal waste water. In addition, the simulation of N,N-diethyl-*m*-toluamide (DEET) flux was introduced as a tracer substance. DEET is an organic compound, which is commonly used as insect repellent. Due to its intensive usage in the study area and its properties, DEET is useful as molecular marker for municipal wastewater discharges (Dsikowitzky et al., 2014).

2. Materials and methods

A number of scenarios were simulated by the adaptation of the existing Jakarta Bay flow model as described by Van der Wulp et al. (2016-in this issue). The development phases A, B, and C, similar to the phases described in the Master Plan National Capital Integrated Coastal Development (Ministry for Economic Affairs, 2015a) were implemented in the flow model (Fig. 1).

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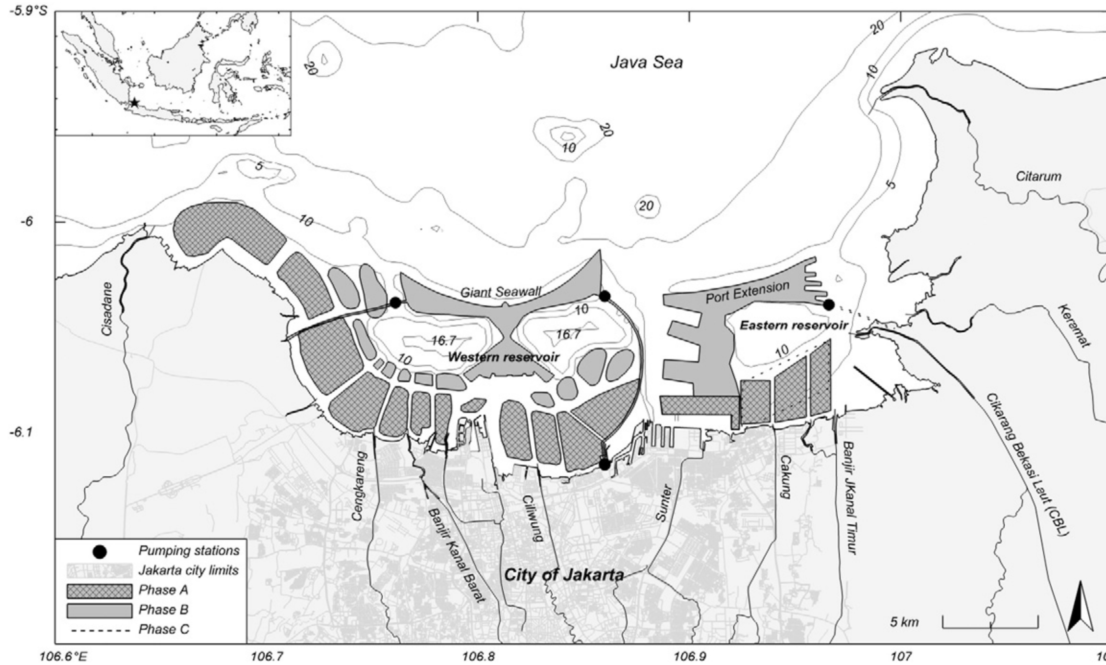

Fig. 1. An overview of Jakarta Bay and the development phases of the construction of a Giant Sea wall similar to the Master Plan of National Capital Integrated Coastal Development. Differentiation can be made between land reclamations of phase A (cross-hatched), phase B (gray), and the closing of the eastern reservoir in phase C (dotted lines). Pumping stations are placed to control the water level of the western and eastern reservoirs by pumping water from the reservoirs to the sea (black dots). Jakarta city limits topography © OpenStreetMap-contributors.

2.1. Flow model

The Delft3D modelling suite was used to simulate flow characteristics for Jakarta Bay. The computational grid, with a spatial resolution of 300 m, covers Jakarta Bay and stretches out 60 km toward the south tip of the Seribu Islands archipelago. Along the vertical, the domain was divided into 15 fixed layers with a higher resolution closer to the surface to resolve multiple layers for the relatively shallow Jakarta Bay. Bathymetrical data were obtained from nautical charts of the Java Sea and Jakarta Bay. The model incorporated forcing by tides. Tidal forcing was added based on thirteen astronomical tidal constituents extracted from the Global Tidal Model (Egbert and Erofeeva, 2002). Additionally, Sea Surface Height (SSH) and daily, three-dimensional values of salinity and temperature were provided as boundary conditions by the HAMSOM Indonesian model (Mayer et al., 2010, 2015; Mayer and Damm, 2012). Spatiotemporal varying sea surface wind and pressure fields were derived from the GME model (Majewski and Ritter, 2002) and imposed on the model grid to account for wind effects. Simulations were run for the year 2012 with a warm up time covering the last quarter of 2011. A detailed description of the flow model setup and validation is described in Van der Wulp et al. (2016-in this issue).

2.2. River discharges and nutrient loads

River discharges defined for the flow model were taken from the hydrological model as described by Van der Wulp et al. (2016-in this issue). A total average discharge of 205 ± 97 m^3 s^{-1} flow to Jakarta Bay distributed over 13 rivers and streams (Cisadane, Cengkareng, Banjir Kanal Barat, Muara Angke, Muara Baru, Ciliwung, Sunter, Cakung, Blencong, Banjir Kanal Timur, Cikarang-Bekasi-Laut (CBL), Keramat, Citarum) (Fig. 2a). Most of the river discharges enter Jakarta Bay through the Citarum River (137 ± 64.2 m^3 s^{-1}) and the Cisadane River (36 ± 17 m^3 s^{-1}). River TN flux was chosen as the potential driver of possible eutrophication effects. TN loads for individual rivers were quantified based on river discharges, river water quality measurements taken in October 2012 and calibration of simulated nutrient gradients in Jakarta Bay (Van der Wulp et al., 2016-in this issue). TN loads ranged between 39 and 174 tons d^{-1} with an average of 91 ± 45 tons d^{-1}. The highest TN loads entered Jakarta Bay through the Citarum River (46%) followed by the Ciliwung River (18%) and CBL (12%) (Fig. 2b).

Similarly, TP loads ranged between 14 and 60 tons d^{-1} with an average of 31.9 ± 15.7 tons d^{-1}. The highest TP loads entered Jakarta Bay through the Citarum river (51%), followed by the CBL (17%) and the Ciliwung River (13%) (Fig. 2c).

2.3. DEET as tracer for municipal wastewater discharges

The organic contaminant DEET was used as a tracer for municipal wastes DEET was found in exceptionally high concentrations in Jakarta Bay and its adjacent rivers with concentrations in the range of 30 ng L^{-1} in the Citarum River and up to 24,000 ng L^{-1} in the rivers flowing through the central part of Jakarta City (Dsikowitzky et al., 2014). DEET loads were quantified based on river discharges and DEET concentrations in river water sampled in October 2012 as described in Van der Wulp et al. (2016-in this issue). DEET loads were in the order of 44 ± 23 kg d^{-1}, of which the highest loads were found for the Ciliwung River (16 ± 8 kg d^{-1}) and Sunter River (11 ± 7 kg d^{-1}) (Fig. 2c).

2.4. Scenarios

The reference scenario consisted of a simulation covering the period 2012, without land reclamations.

Phase A involves land reclamations in the form of 16 islands situated in the near-shore area of the Jakarta coastline (Fig. 1). In between the islands, a uniform depth of 3 m was specified.

Phase B contained the construction of the Giant Seawall and Port Extension Areas (Fig. 1). The closing of the western reservoir provides a