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Numerical simulations of river discharges, nutrient flux and nutrient dispersal in Jakarta Bay, Indonesia

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ABSTRACT

The present application of numerical modelling techniques provides an overview of river discharges, nutrient flux and nutrient dispersal in Jakarta Bay. A hydrological model simulated river discharges with a total of 90 to 377 m^3 s^{-1} entering Jakarta Bay. Daily total nitrogen and total phosphorus loads ranged from 40 to 174 tons and 14 to 60 tons, respectively. Flow model results indicate that nutrient gradients are subject to turbulent mixing by tides and advective transport through circulation driven by wind, barotropic and baroclinic pressure gradients. The bulk of nutrient loads originate from the Citarum and Cisadane rivers flowing through predominantly rural areas. Despite lower nutrient loads, river discharges from the urban area of Jakarta exhibit the highest impact of nutrient concentrations in the near shore area of Jakarta Bay and show that nutrient concentrations were not only regulated by nutrient loads but were strongly regulated by initial river concentrations and local flow characteristics.

1. Introduction

Embayments near densely populated areas are vulnerable to eutrophication affecting the coastal ecosystem and coastal uses including fisheries aquaculture. A good example is Jakarta Bay, Indonesia. Jakarta Bay is exposed to a high load of pollutants mainly deriving from land-based sources such as agriculture, industry and domestic waste water from the metropolitan area of Jakarta and the adjoining hinterland. Within the Jakarta Metropolitan Area, untreated domestic waste water from more than 28 million people and sewage from about 2000 industrial branches are discharged into Jakarta Bay. Estimates by Sachoemar and Wahjono (2007) indicate that within the urban area of Jakarta, domestic waste water accounts for 80% of the nutrient pollution. Nutrient loads from rivers have increased substantially over the past two decades and nutrient concentrations in Jakarta Bay increased accordingly (Arifin, 2004). Under the increasing pollution, fish diversity decreased substantially in Jakarta Bay (Thoha et al., 2007). The elevated nutrient levels lead to recurrent microalgae blooms in this region, often associated with fish kill events (Damar, 2003; Thoha et al., 2007). Quantification of river discharges and nutrient loads remains an ongoing challenge. Numerical models have been applied to study circulation patterns of Jakarta Bay (Koropitan et al., 2009; Radjawane and Riandini, 2009; Nurdjaman et al., 2014). One of these models has addressed the discharges of river nutrients in Jakarta Bay (Koropitan et al., 2009). Most of the applied models focus on tides and wind as the predominant driving force behind circulation in Jakarta Bay. The present model approach provides a sequence of numerical simulations regarding river discharges, nutrient flux and driving forces behind the circulation and nutrient distribution in Jakarta Bay. A series of hydrological and flow modelling techniques give a coherent view of the origin of land based nutrient discharges and physical driving forces behind the dispersion characteristics dissolved nutrients, which can be linked to eutrophication occurrences in Jakarta Bay.

2. Materials and methods

A sequence of numerical modelling techniques was applied as summarized in the diagram below (Fig. 1). A hydrological model was setup to simulate river discharges of all significant rivers, channels and streams. Nutrient loads (i.e. total nitrogen (TN) and total phosphorus (TP)) were quantified with the use of simulated river discharges and measured nutrient concentrations for each river. Subsequently, a flow model was set up for Jakarta Bay, incorporating river discharges and nutrient flux to simulate TN and TP gradients in Jakarta Bay. Field measurements were used to calibrate the flow model.

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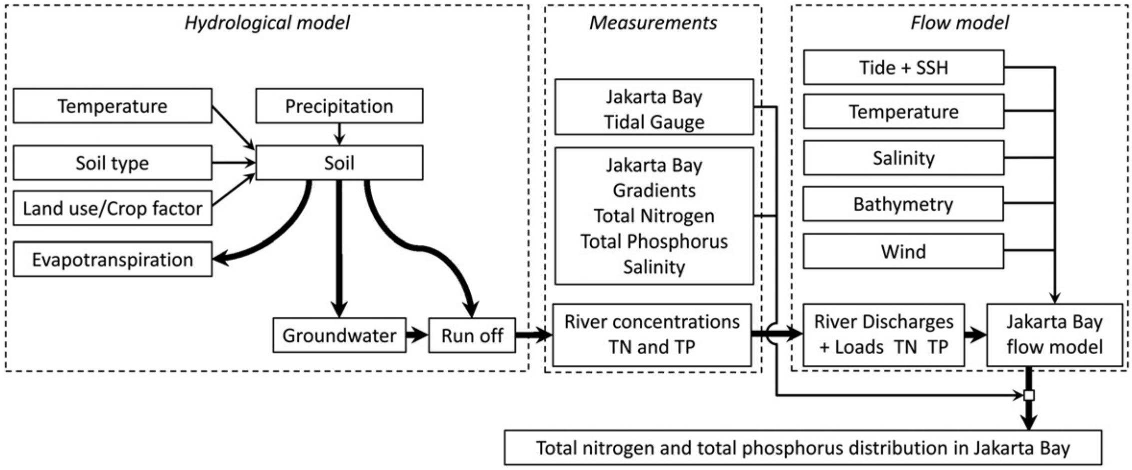

Fig. 1. Flowchart of the modelling approach used for this study. A hydrological- and flow model were used to simulate river discharges, nutrient loads, flow characteristics and nutrient gradients for Jakarta Bay.

2.1. Sampling, laboratory analysis and in situ measurements

Water samples were taken in October 2012 at 42 stations forming a grid of seven transects covering Jakarta Bay (Fig. 2). At each station, depth profiles of conductivity were measured by CTD. Additionally, water samples were retrieved at 13 upstream stations of the main rivers and streams entering Jakarta Bay where salinity was zero. Water samples were taken at the water surface. Unfiltered subsamples for the analysis of TN and TP were filled in 200 ml PE bottles and kept frozen at −20 °C. Subsamples for the determination of ammonium (NH_4^+), nitrite (NO_2^-) and nitrate (NO_3^-) and phosphate (PO_4^{3-}) were filtered through Rotilabo© syringe filters of 0.45 μm pore size, fixed with Mercury-Chloride ($HgCl_2$) before being stored in 250 ml PE bottles and stored dark and cool. The samples were analyzed for nutrient concentrations as listed above according to Grasshoff et al. (1999).

A CeraDiver© pressure logger was installed at Onrust Island, situated in the western part of Jakarta Bay, and recorded water pressure and water temperature every 10 min from October 2012 until May 2013.

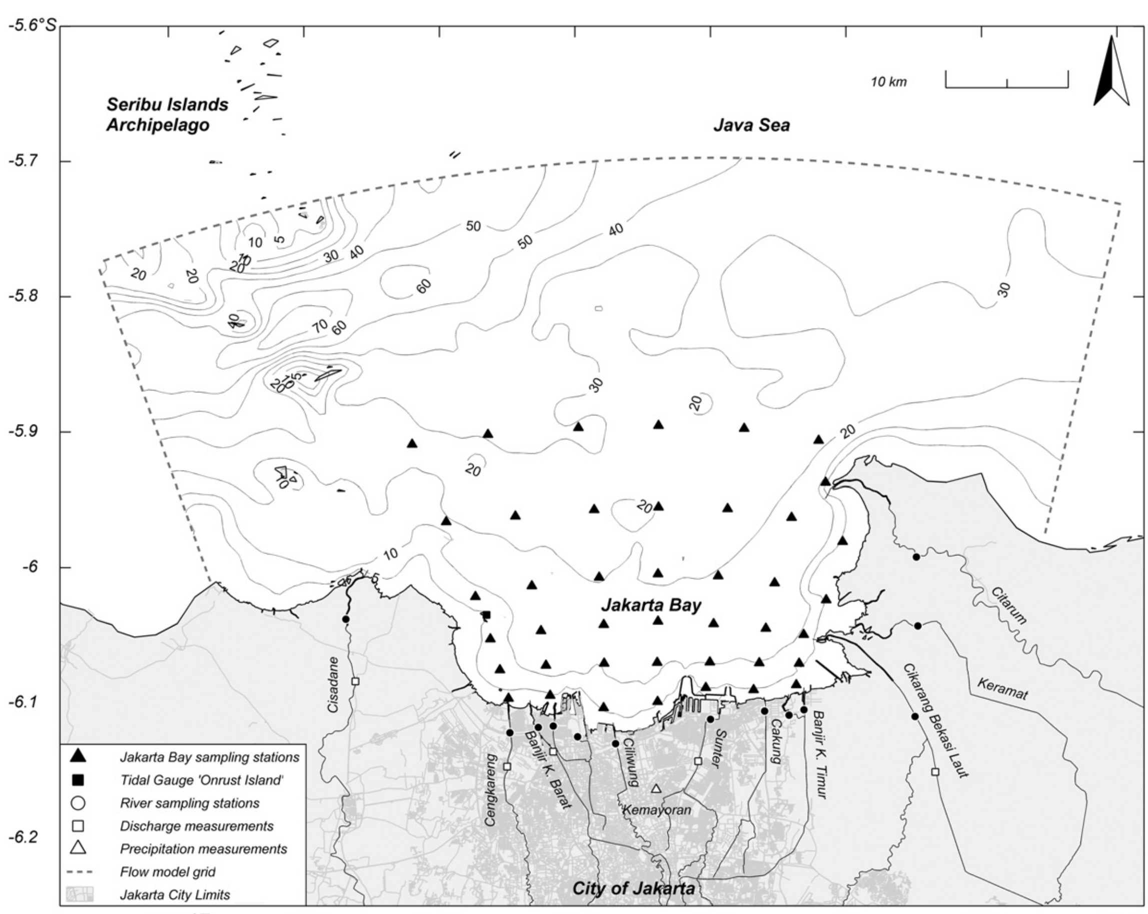

Fig. 2. Jakarta Bay and its adjacent rivers. Points of interest show: Jakarta Bay sampling stations (black triangles), river sampling stations (black dots), tidal gauge (black square), river discharges (white squares), precipitation measuring station (white triangle) and the flow model domain (dashed line).