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Building a water quality model for Receiving Environment Digital Twin (REDiT)

Caroline Lai [a], Kalyan Chakravarthy [b], Cameron Jackson [c]

[a] DHI Perth, Australia, [b] DHI Auckland, New Zealand, [c] Urban Utilities, Brisbane, Australia
Email: lai@dhigroup.com

Abstract: This paper provides an overview of the development and calibration of a water quality model built for Receiving Environment Digital Twin (REDiT). Committed to improving waterway health and environmental stewardship, Urban Utilities partnered with DHI to develop REDiT, a science-based decision-support system designed to assess pollution impacts and support more informed infrastructure planning and management. The foundation of REDiT is a set of numerical models, which integrates hydrodynamic (including the distribution of salinity and temperature) and water quality to define the bacteria and nutrient transport and dispersion. The 2D model was calibrated to water level and current measurements between 2016 to 2018 in Brisbane River. Over the model building process, challenges were resolved with satellite-derived bathymetry, salinity and temperature derived from 3D ocean model and script-based model setup method.

Keywords: *Numerical modelling, water quality, calibration.*

1. INTRODUCTION

In 2021, Urban Utilities and DHI initiated the development of a Receiving Environment Digital Twin (REDiT) platform for quantifying pollutant loads entering waterways and assessing the relative impacts of diffuse discharges (catchment contribution) and point source discharges (localised STP discharges) on the receiving environment. The online system is based on the hydrodynamics and water quality models of the Brisbane River Estuary and Moreton Bay. The software package applied was MIKE21 by DHI, including the hydrodynamic (MIKE21 HD), water quality (MIKE ECO Lab) and transport (MIKE21 AD) modules.

2. MODEL SETUP

The model was set up based on a flexible mesh approach, with approximately 190,000 elements and covering an area of above 20,000 km². Grid resolution along the offshore boundary is about 3 km and gradually reduces to 15 metres in the vicinity of the sewerage discharge locations (DHI 2024).

The 2D hydrodynamic model computes the water level and flow in response to the forcings of bottom shear stress, wind shear stress, barometric pressure gradients, Coriolis forcing, momentum dispersion and sources from river discharges and sewerage discharges. Three offshore boundaries are driven by salinity, temperature, oceanic and tidal forcings. Atmospheric parameters, including wind, air temperature, humidity, precipitation, cloud cover and solar radiation were also added to the model.

The 2D water quality model (including ECOLAB and transport modules) simulates the movement and fate of water quality variables (Enterococci, Total Nitrogen, Total Phosphorus, and their fractions, and Total Suspended Solids). These state variables are transported by advection-dispersion processes based on the flow condition in the 2D hydrodynamic model.

3. CHALLENGES AND RESULTS

High resolution bathymetric data in Brisbane river tributaries and port area were sourced from the Brisbane River Catchment Flood Study model (BRCFS) and Port of Brisbane NCOS Online model. However, some sewage treatment plant outfall points are close to shallow water areas, where bathymetric data are limited. In this case, satellite-derived bathymetry is a good option to fill in the gap. Figure 1 shows the comparison of bathymetry before and after satellite-derived bathymetry around Luggage Point. With the redefined bathymetry, nutrients tend to flow further north into the Moreton Bay than being trapped in the northern shallow water area.

Salinity and temperature are vital factors for the water quality model. They define the water density, circulation and fate of nutrients in water bodies. Bi-monthly salinity and temperature measurements were subscribed from the Ecosystem Health Monitoring Program, run by Healthy Land and Water (HLW). This provided reliable salinity and temperature information in the Brisbane River. Other than the inland fresh water, we also needed to bring the offshore sea water into the model correctly. To achieve this goal, the offshore boundaries were extended beyond Moreton Bay into the coverage of an existing 3D ocean model. In this case, the 3D ocean model Bluelink was applied. Model outputs were calibrated against salinity and temperature measurements in the upper, middle and lower Brisbane River Estuary from July 2016 to June 2017. A full year calibration was carried out to ensure the model captures the seasonal patterns in summer and winter properly. Water level calibration statistics show good performance against field measurements, with correlation coefficients above 0.95 at most stations.

Catchment rainwater runoff and corresponding nutrient discharges were provided by Urban Utilities. The total number of catchment discharge points increased from 34 in the first model iteration to 101 in the latest model iteration. Each discharge point has water discharge, salinity and temperature, and water quality and is split into baseflow and overflow. Eleven STP treated effluent and bypass discharge data was also considered as source. This resulted in more than 2,000 input files, which was unmanageable by person. Therefore, scripts were written to prepare inputs, model setup and post processing. A script-based method for model set-up is time efficient and minimises human error.

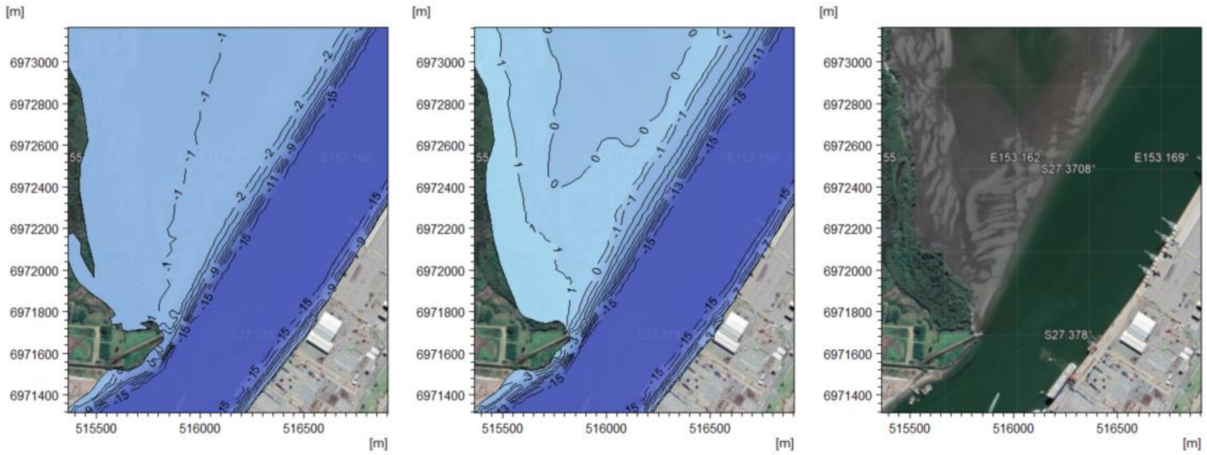

Figure 1 Comparison of bathymetry before (left) and after (middle) satellite-derived bathymetry. With Google Earth image (right) as reference.

4. DISCUSSION

REDiT was developed to provide a user-friendly platform for spatial visualization, specified location time series visualization and scenarios comparison. Users are able to manipulate the input parameters, run the model and view results within the platform. This paper gives an overview of the model setup and presents the calibration outputs.

Recognising the importance of bathymetry to a model, more efforts should be made to cross-check data from different sources. A smaller grid resolution dataset may or may not lead to more accuracy. In this case, redefining the shallow water area influences the flow patterns significantly. Building a 3D water quality model is more complicated than just adding vertical layers and putting 2D boundary forcings. Other considerations should include but not limit to the model objectives, thermocline in ocean water, reliability of fresh and sea water boundaries. Or sometimes, a 2D water quality model will do the work too. As more powerful machines become available, larger and more complex models could be built. A free, open-source Python library for MIKE data file processing and automation is available to support this.

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Bluelink. Established in 2001, as a partnership between CSIRO, Bureau of Meteorology, and the Royal Australian Navy, with the goal of developing an operational forecasting system for the global ocean circulation around Australia. http://wp.csiro.au/bluelink/global/

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