WATER QUALITY MONITORING AND MODELING FOR GARDENS BY THE BAY, SINGAPORE

By

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in partial fulfilment of the requirements for the degree of

Master of Science

in Hydraulic Engineering and Water Resource Management

at the Delft University of Technology and National University of Singapore

to be defended publicly on Monday January 18, 2016 at 9:30 am (CET)

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Summary

Inland surface water quality is of increasing concern worldwide due to surplus contaminants introduced by industrial, agricultural, commercial and residential sectors. Issues with excess nutrients that enter the water bodies are in particular challenging as they contribute to one of the most prevalent problems in surface water bodies: eutrophication. The lake system in Gardens by the Bay (GBTB) is a water body that faces risk of eutrophication, as it is located in one of the most urbanized catchments in Singapore, and receives stormwater runoff from the highly fertilized gardens. The lake water is discharged back to Marina Reservoir, which serves as a drinking water source and recreational water body. Public health is thus a concern when managing water quality in GBTB. Besides, GBTB is one of the busiest tourist attractions in Singapore, so aesthetic values are of great significance. As part of a research-based evaluation of the water quality in GBTB, several objectives are specified for this study:

(1) to evaluate current trophic state of the lake system;

(2) to obtain baseline information for water quality modeling;

(3) to build a simplified water quality model, as a quick-scan tool for reproduction of ecological responses to nutrient input in the lake system, based on available data;

(4) to suggest prevention and mitigation methods for eutrophication and sustainable development of the lake system.

A monitoring plan was designed in addition to routine measurements at Kingfisher Lake and Dragonfly Lake. Spatial variation of the water quality along flow direction was investigated for a two-month period. Assessments were made in accordance with local and international guidelines for the designated uses of the lake system as well as its receiving watercourse: Marina Reservoir. The water in the Gardens was aesthetically good, except occasional odour and high turbidity. However, water flowing back into Marina Reservoir did not all time reach the expectations of preserving a good water quality as the water intake from Marina Reservoir. Amongst all changes in water-quality parameters along the flow direction, increase in
concentration of phosphorus and chlorophyll-a were most prominent. Measurements of the two parameters indicate a transfer in trophic state from eutrophic (or mesotrophic) to hypereutrophic.

A scrutiny was given to location Dragonfly2 (abbreviation for ‘Part 2 of Dragonfly Lake’), as it is immediate upstream of the outlet to Marina Reservoir. In comparison with the allowable limits for trade effluent discharge to controlled watercourse, higher pH and true color were measured at Dragonfly2. Chlorophyll-a concentrations were also sometimes too high for recreational uses.

Growth of phytoplankton can be limited by availability of sunlight, or energy. On average, 54% of the light was attenuated within the first 0.5 m, but on May 14 the percentage increased to 80%. For six out of seven days of measurements, light was abundant for maximum growth rate of non-cyanobacterial phytoplankton at the depth of 1.5 m, and some cyanobacteria even at the lake bottom. Exception was again observed on May 14 when the depth was reduced to 0.5 m for non-cyanobacterial phytoplankton, and 1.5 m for some cyanobacteria (such as Microsystis). Phytoplanktonic biomass and other suspended matters both contributed to light attenuation (and thus clarity) in the water column with greater influence from the latter.

Different rainfall patterns may cause changes in runoff quality from catchment and hydrological conditions in the water body. Drastic increase (to the peak) in turbidity concentration was observed during intensive rainfall events with a long preceding dry spell. Concentrations of total phosphorus and chlorophyll-a showed some delays in ascent and peaks, compared with turbidity.

Chlorophyll-a concentration was in general positively but weakly correlated with total phosphorus, pH, turbidity, and dissolved oxygen at Dragonfly2. The correlation analysis supports the finding that particulates other than phytoplanktonic biomass attribute more in the quantification of turbidity.

The study of spatial variation of nutrient and chlorophyll-a from 29th of April to 19th of June revealed that concentration of phosphorous was higher at Stream2 and downstream locations. This, together with favourable growth conditions such as longer hydraulic retention time, may have led to a dramatic increase in phytoplankton population at these locations.
A simplified water-quality model with necessary processes was developed for the lake system, including the interactions between water column and top sediment layer. The lake system was divided into six segments based on the monitoring results of spatial variation. Flows from one segment to another were calculated from daily water balances in each segment. Sensitivity tests and calibrations were carried out using data obtained in 2013, and validation of the model was done for 2015.

The model simulations correspond reasonably well to field measurements before mid-April 2015 in most segments of the lake system. Inaccurate modeling of runoff qualities caused drastic deviation in some segments towards the end of simulation.

The scenario study suggests that, there is some 21.2 kg of phosphorus entering the lake system from downstream Stream1 during the period 26th of April to 19th of June. The estimation is likely higher than the real load, but the result of scenario analysis suggests a good load-eutrophication response in the receiving water. Usefulness of the current model is thus justified as a quick-scanning tool for nutrient-related management practices.

Recommendations are given accordingly for both future researches and water-quality management in Gardens by the Bay.