Full Paper

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Werribee River Ecohydraulics

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Key Points

- Fine scale water quality modelling for water way health
- Using of flushing flows for managing algal blooms
- Integrating data collection, numerical modelling and interpretational analysis

Abstract

Agriculture is the dominant land use in the Werribee River catchment. Flow regime of the river has been dramatically altered to provide water for drinking and irrigation in this area, resulting in a significant depletion of flows in the lower reaches of the river in recent years. As a result, this area is affected by large-scale accumulation of floating weeds and blue-green algal (BGA) blooms. The best approach to manage this problem is to prevent their build up by supplying a large enough flow. This study assessed the performance of a set of environmental flow releases as the mitigation measure for this ongoing issue.

A 2D and 3D hydrodynamic (HD) and advection-dispersion (AD) model of the lower Werribee river, was developed using MIKE by DHI 2D and 3D FM models. Hydraulic control points along the river were identified during a field survey. A series of ADCP velocity profiles were collected across the river by Water Technology during 2 environmental flow release events. Modelled velocities were successfully calibrated and verified against the velocity measurements. The AD model assessed the performance of the flow release for residence time improvement and the prevention of accumulation of blue-green algae blooms.

It was concluded that lower environmental flow releases in the range of 6 to 80 ML/d are not sufficient to achieve satisfactory flushing of the lower Werribee River. An environmental flow of 100-200 ML/d performed best to mitigate algal bloom accumulation.

Keywords

Ecohydraulics, Water Quality modelling, riverine processes, data collection

Introduction

The Werribee River rises in the Wombat State Forest on the Great Dividing Range and flows for about 110 km south-east before discharging into Port Phillip Bay at Werribee South. A substantial portion of flow is extracted from the system as it moves downstream from its headwaters in the Wombat State Forest, where most of the catchment runoff is generated, down to the Werribee Diversion Weir which redirects water purchased by the irrigators at Werribee South. In recent years, only around 10% of the water volume that enters the Werribee River flows into Port Phillip Bay and as a result, flow in the lower Werribee River, downstream of the Werribee Diversion Weir is significantly depleted, particularly in winter and spring when it was naturally higher but is now harvested. In most years, the median daily flow is 1 ML/d, with occasional pulses of up to 100 ML/d for one or two days' duration when releases from Melton Reservoir overtop the weir and/or stormwater runoff is generated from the immediate catchment. Unregulated baseflow now only occurs in the winter and spring of wetter than average years and is of much reduced duration. In 2016 Melbourne Water requested an investigation into the benefits of providing flows to manage accumulation of floating weeds and the occurrence of blue-green algal blooms. The study area has an upstream boundary at Werribee Diversion Weir and the downstream boundary is at Bluestone Ford (shown in Figure 1). The key points for investigation as requested by Melbourne Water were to investigate low flows required to prevent build-up of floating aquatic weeds (Azolla) and to provide mixing of pools to prevent blue-green algae.

The first stage of the study involved the acquisition of a range of relevant data including bathymetric surveys of the river cross-section, available LiDAR, Index of Stream Condition (ISC), River Centreline data and velocity profiling surveys using Acoustic Doppler Current Profiler (ADCP).

In the second stage, a hydrodynamic (HD) model was developed for the lower Werribee river covering the extent illustrated in Figure 1. Modelled velocities for two environmental flow release events were successfully calibrated against the collected velocity measurements. Consequently, an advection-dispersion (AD) model was coupled to the calibrated HD model to model a range of environmental flow events to investigate the maximum velocities and water depth within the different sections of the Lower Werribee River and the associated residence time for each flow event.

Figure 1. Lower Werribee Reaches within the Study Area

Data Acquisition

Topographic Data

In order to verify the hydrodynamic model results in terms of the velocities in different reaches of Werribee River, a comprehensive set of bathymetric data including the available 1m resolution LiDAR was collected which and complemented by the ISC River Centreline data provided by the Department of Land, Water and Planning (DELWP). This data was used to define the top and toe of the river bank.

A series of cross-sections and spot heights including cross-sections at the deeper pools and spot heights at the hydraulic controls such as rock bars and riffles were captured and were applied as a check on the LiDAR data.

The survey data, LiDAR and ISC data was used to generate a Digital Elevation Model (DEM) to give an accurate representation of the river channel profile and the adjacent floodplain. Figure 2 illustrates the developed DEM created for the modelling works.

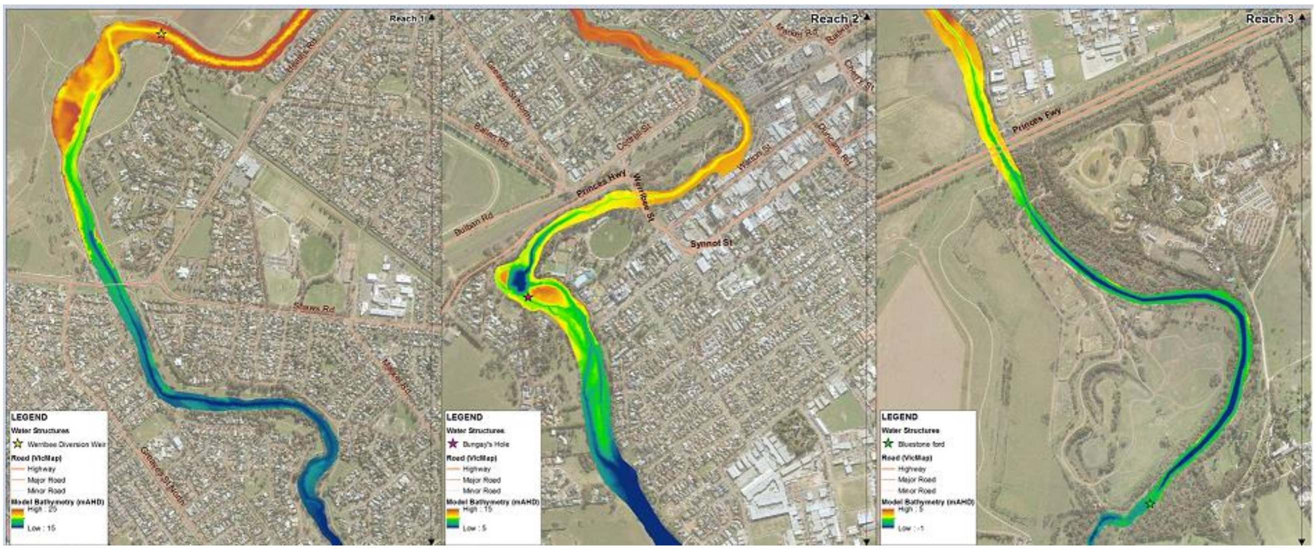

Figure 2. Model DEM in Reach 1 (left), Reach 2 (middle) and Reach 3 (right) of Lower Werribee River

Velocity Measurements

Hydraulic calibration of the model was conducted against two sets of velocity measurements collected by Water Technology in March and May 2017. These measurements were scheduled to coincide with a 20ML/d and 200ML/d environmental flow release events. A 1200 kHz RiverPro ADCP was used for collecting current velocity data. The RiverPro ADCP is designed specifically for shallow river applications. The imbedded GPS sensor enables positioning of each ensemble. The ADCP was mounted on a Riverboat survey vessel which was pulled or towed across the river to collect data. Three transects were collected at each location to allow for a more accurate representation of the velocities. The survey vessel repeatedly navigated the selected transect locations while the ADCP continuously collected velocity data.

Figure 3. RiverPro ADCP, measuring velocities in Werribee River

Figure 4. Location of ADCP Transects for 20 ML/d (left) and 200 ML/d (right) Flowrate Events

Monitoring Data

A range of water quality data was collated from the available resources including the Water Measurements Information System instream water quality data and DELWP's data on blue-green algae across several locations in the study area.

Numerical Modelling

Hydrodynamic Model

The MIKE by DHI Flexible Mesh (FM) model was utilised for this study. MIKE 21 FM HD was used for the flow component of the numerical modelling while a transport module for assessing flushing processes was coupled to the HD model for the evaluation of the algal transport and mixing within the lower section of the river. The model was run in 2D for the majority of the analysis, where the flow parameters are depth averaged, while

3D simulations were undertaken to further refine the flushing analysis in reach 3 to provide an understanding of any stratification and corresponding algal blooms.

Model Setup

Setting up the HD model was comprised of the following components: generation of the model grid or mesh, defining boundary conditions and calibrating the model. Using the developed DEM, a flexible mesh model domain was generated (Figure 5) with 219,708 nodes. To account for complex flow patterns in the model, model mesh was refined to 1m triangular elements in the main channel while upstream and downstream of the study area 20m elements were generated.

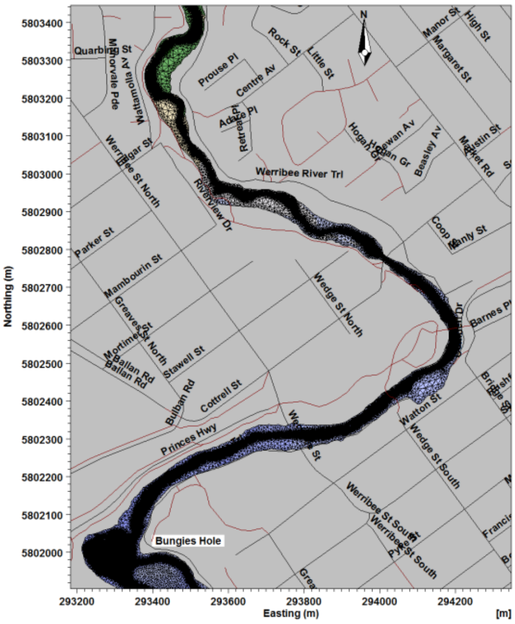

Figure 5. Model Mesh in Reach 2

Hydraulic roughness parameters were adopted using industry standard values that represent the vegetation condition, hydraulic controls and other main features within the study area. A 2D roughness map was developed based on the adapted roughness values.

Boundary Conditions

The hydraulic model has 2 boundaries: the upstream boundary which was located at the Werribee Diversion Weir. Here a point source represented the range of environmental flows investigated in this study. These include 1, 6, 10, 20, 40, 80, 100 and 200 ML/d flows.

The downstream boundary was set at the river mouth where a mean sea level of 0m AHD was assigned to the water level boundary. The study area for this assessment has a downstream extent at Bluestone Ford, and therefore is not under influence of tides. A sensitivity test was set to assess model response to varying tidal levels at the river mouth which showed that the river velocities were independent from tidal variations at the river mouth.

Model Calibration

Calibration of the hydraulic model was mainly achieved by adjusting the model bathymetry at various locations. This included increasing elevation at the weirs downstream of Bungey's Hole, narrowing down the channels with high vegetation on either bank and widening the channel underneath Shaw's Bridge. Comparison of the modelled velocities versus measurements on site demonstrates that overall a good level of calibration was achieved, indicating the suitability of the model to investigate the advection-dispersion processes. Figure 6 demonstrates the comparison of the modelled velocities versus measurements at Site 5 for the 20ML/d flow event.

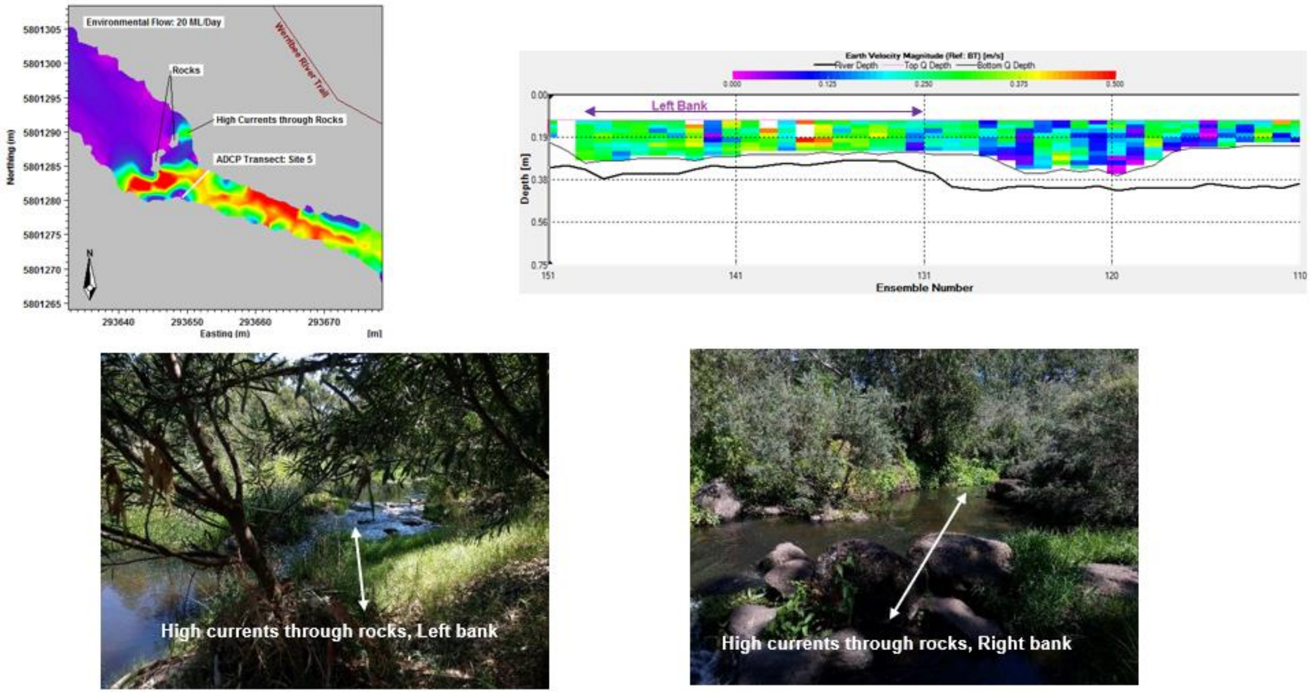

Figure 6. Modelled Velocities (left) and ADCP Transects (Right) for the 20 ML/d event at Site 5

Results Analysis and Discussions

Monitoring Data Analysis

Analysis of the monitoring data shows that the most dominant bloom-forming BGA here is Microcystis, which is a genus of freshwater cyanobacteria. High Microcystis concentrations were generally observed after low rainfall. Additionally, higher concentrations of Microcystis were only found during the periods when there was no flow at the Werribee Weir 7 days prior to the sampling date. It was also found that the size of a Microcystis bloom is positively correlated to the temperature and solar irradiance. No obvious Microcystis biomass was detected when the 7-day moving average air temperature was less than 17 °C or when the 7-day moving average solar irradiance was less than 19 MJ/m^2.

HD Model Results

One of the key purposes of this study was to investigate the flow velocities in different sections of Werribee River, associated with a range of environmental flow releases. An ecological investigation of the Werribee River by GHD (GHD 2016) hypothesized the possibility of preventing an accumulation of aquatic weeds with velocities of 0.03-0.05 m/s which was equated to a flow rate of 6-10 ML/d. The relationship between aquatic weed build-up and velocity (or shear stress) is a knowledge gap that could be addressed through future projects.

The results of the hydraulic modelling here indicate that velocities of 0.05 m/s are reached in some sections of the river only and are not consistently maintained along the entire river. Results indicate that along the river, the 0.05m/s velocities are not consistently achieved for the entire system even for higher environmental flow releases such as 20 ML/d flows. 80 ML/d is the first modelled flow where the center of the channel has velocities greater than 0.05 m/s for the whole reach upstream of princes Freeway, except for the large pool at Bungey's Hole. For the 6 ML/d flowrates, velocities decrease to below 0.001 m/s for a long section of the river from Shaws Bridge to the cross section with Edgar Street. Upstream of Bungey's Hole and within the pool itself, minimal currents persist. For a high flow release of 200 ML/d, velocities within the pool drop to below 0.02 m/s.

Advection-Dispersion Model

2D Model Results

The calibrated 2D HD model was coupled to an AD model to investigate the residence time in Reach 3 (the section with the highest algal blooms) and the flow regime sufficient for the flushing of this section and therefore inhibition of algal blooms associated with a range of environmental flow release events.

An initial tracer concentration of 100 units was assigned to Reach 3, within the 2D model. Modelled tracer concentrations at a point just to the upstream of Bluestone Ford are presented in Figure 7 for each flow event. The results indicate that a minimum of 20 ML/d flow is required to completely flush out the waters in Reach 3 in less than 7 days. For flow rates less than 20 ML/d, it takes longer than 7 days to completely flush out the system. At the upper end of the flow rates modelled, a 200 ML/d flow will replace the waters in Reach 3 in less than a day. This residence time is not sufficient to prevent accumulation of blue-green algae. 6 ML/d is less than 10% of the total volume of reach 3 (total volume of reach 3 is approximately 67 ML) and the velocity generated in this reach is approximately 0.001m/s as a result of a 6 ML/d flow. It is estimated that for the water to travel from Princes Highway bridge to reach Blue Stone Ford at the downstream end of Reach 3 it would take approximately one month. Considering the growth rate of blue-green algae of 0.5/d (Chorus et al., 1999), this is much larger than the rate of water replacement by flushing in the system.

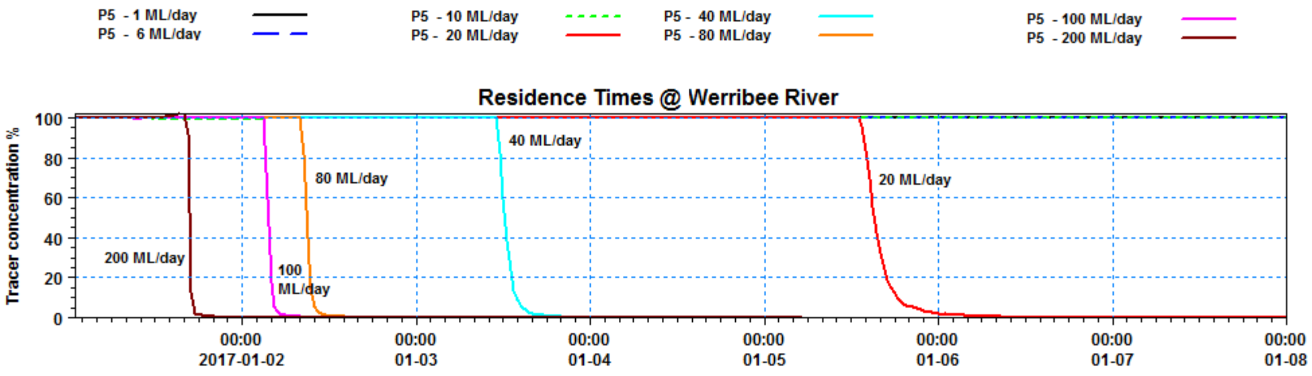

Figure 7. Residence Time for a point upstream of Bluestone Ford

3D Model Results

A 2 layer 3D model was developed to further investigate the flushing related to the release events, for both unstratified and stratified conditions. Stratified models were set up by assigning a temperature difference between the upstream water temperature and initial temperature in Reach 3. Some blue-green algae such as Microcystis can migrate vertically in the water column and travel down to the bottom water to uptake nutrient if the nutrient in the surface water is depleted. Therefore, stratification could play an important role in the return of algae after a flow release event.

The results of the unstratified 3D model are very similar to those of the 2D model. However, model results indicate a significant increase in residence times for stratified conditions as shown in Figure 8.

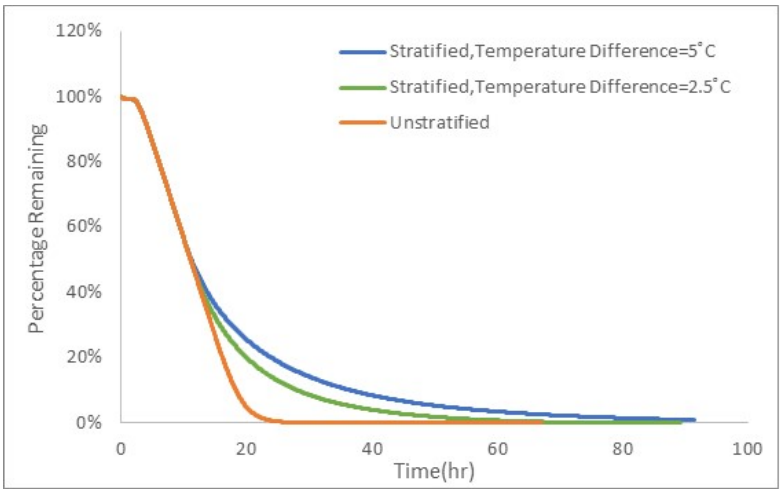

Figure 8. Flushing conditions under stratified and unstratified conditions for the 3D model: 100 ML/d

Conclusions

The aim of the study was to investigate flow velocities and residence times in the lower reaches of Werribee River for a range of environmental flow release events. The calibrated HD model coupled with the 2D and 3D AD models produced the following conclusions:

- A baseflow of 6 ML/d is unlikely to prevent the build-up of floating aquatic weeds between the diversion weir and the Princes Freeway. If feasible, a higher flow of 40-80 ML/d could be used to move aquatic weeds through the system and then collect the weeds at the low energy zones (e.g. large pool at Bungey's Hole). Monitoring is recommended for the determination of the velocity criteria for the movement of the aquatic weed.

- For a flow rate of 6 ML/d, the residence time is not sufficient to prevent accumulation of blue-green algae. An environmental flow of 100-200 ML/d (maintained for a minimum of 2 days) is necessary to flush out the entire lower reaches.

- Stratification dramatically increase the time required to achieve a complete (99%) flushing and therefore, reduction in the occurrence of temperature stratification in the upper reaches of the river could be targeted to assist with management of blue-green algae. Additional monitoring is required to confirm stratifications in the deeper pools and subsequently specific flow recommendations to prevent stratification.

Acknowledgments

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