WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

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8/3 Westside Avenue
Port Melbourne VIC 3207

Our Ref: 3985-01L01v02.docx

Dear Sam,

Portarlington Harbour Water Quality Modelling

The following letter provides a discussion of the results obtained in this initial assessment of water quality impacts associated with the proposed Portarlington harbour development.

1. SCOPE OF WORKS

Water Technology has been commissioned by AW Maritime Pty Ltd to provide preliminary information to Parks Victoria to assist in determination of the need for a full Environmental Effects Statement (EES) for the project. The preliminary assessment included the undertaking of the following tasks:

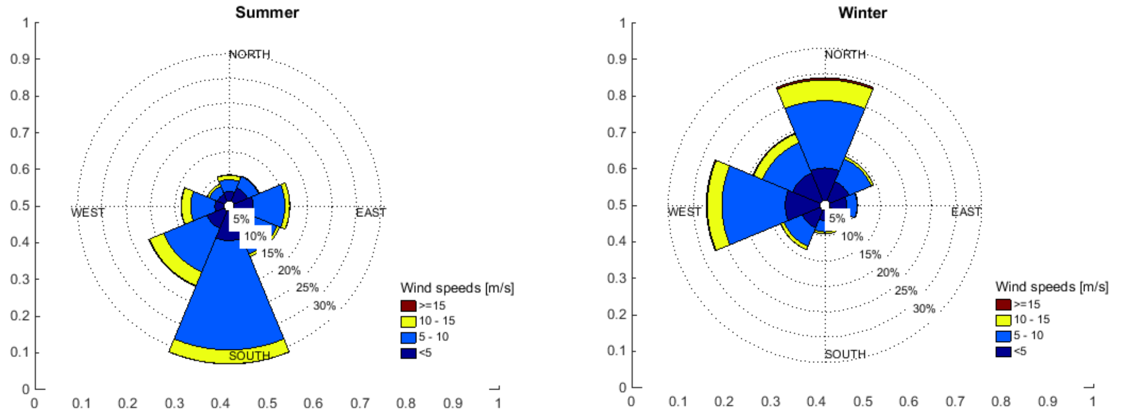
- Analysis of historical wind data from Point Wilson, and adoption of representative summer and winter periods;
- Adaption of a flexible mesh hydrodynamic model of Port Phillip Bay for assessment of the hydrodynamic and flushing conditions around Portarlington harbour;
- Modelling of typical summer, winter, and no wind simulations; and
- Analysis and presentation of the results of the modelling.

2. WIND ANALYSIS

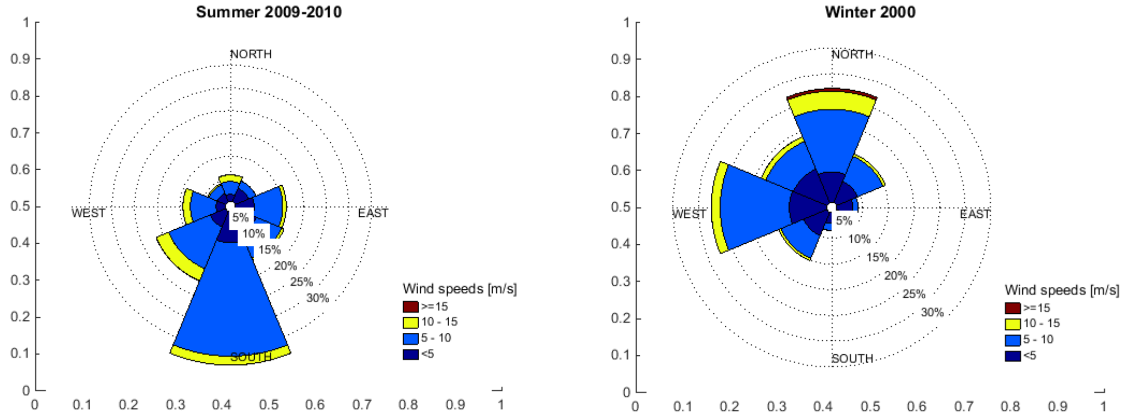
A 17 year period of wind data from Point Wilson was analysed to determine representative wind conditions for summer and winter. The data consisted of wind speed and direction at 6 minute intervals from October 1997 to July 2014.

Wind roses for each season in each year of the record were developed, along with overall seasonal wind roses utilising the entire period of record, Figure 2-1 (A). A representative seasonal period was then selected by matching the individual seasonal records, in terms of the wind direction and magnitude, to the overall seasonal results. The summer of 2009-2010, and winter of 2000, as shown in Figure 2-1 (B) were observed to provide a good representation of the long term summer and winter conditions.

During summer winds measured at Point Wilson predominantly come from the south, while in winter winds measured at Point Wilson are predominantly northerly to westerly. The winter period also has a higher proportion of wind speeds in the range from 10 to 15 m/s.



(A) Summer and Winter Wind Roses (1997-2014)



(B) Representative Wind Roses

Figure 2-1 Seasonal Wind Roses (A) and Adopted Representative Periods (B)

3. MODEL DEVELOPMENT

3.1 Bathymetry

An existing flexible mesh model of Port Phillip Bay was adopted and modified for the hydrodynamic modelling assessment (Figure 3-1). The mesh consists of triangular and quadrilateral elements of varying sizes allowing details of bathymetry, coastlines, and structures to be well defined while minimizing the required computational power for calculations. The mesh has a resolution at the deep offshore boundary of around 2 km^2, element sizes reduce to around 0.0072 km^2 through The Rip, then back to around 0.72 km^2 in the middle of the bay.

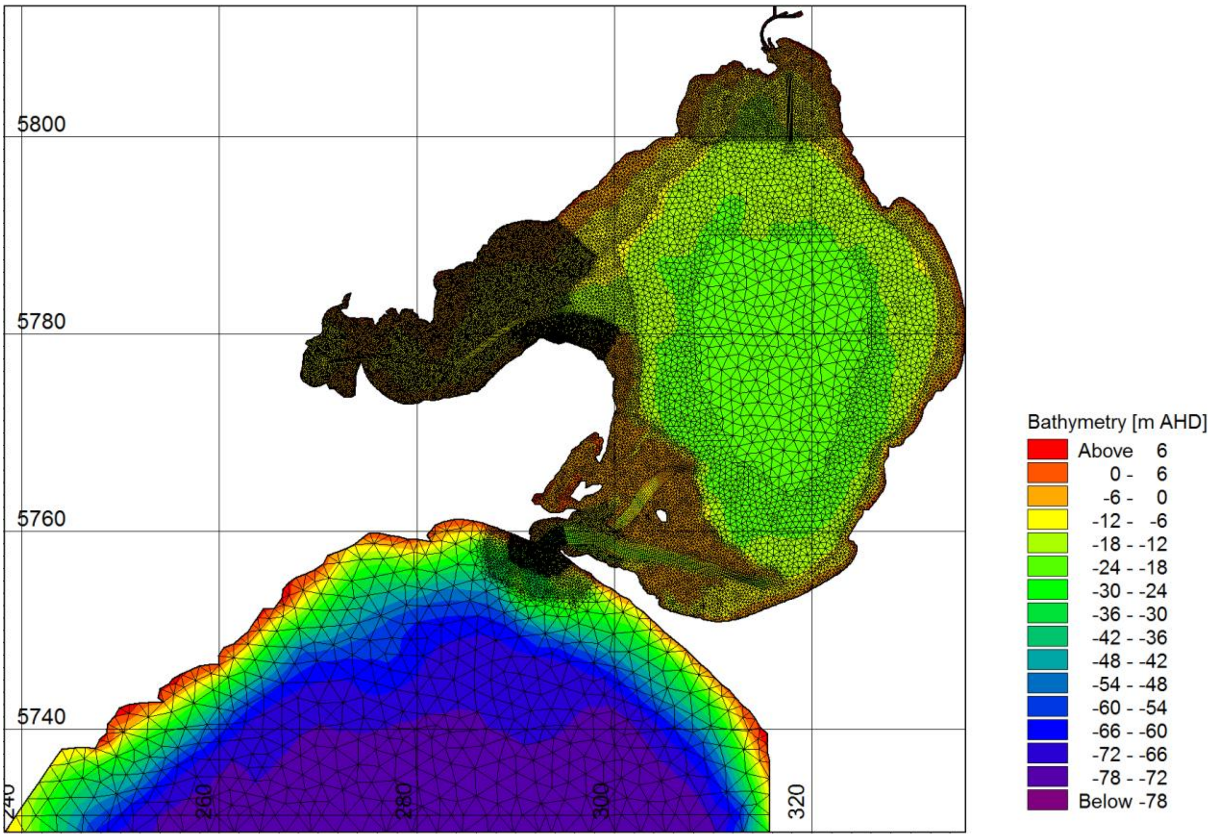


Figure 3-1 Port Phillip Bay Flexible Mesh Extent

Details of the proposed harbour design were incorporated into the model and the resolution around the harbour increased. The design includes an enclosed harbour with two (10 to 15 m) openings on the west, and the main entrance (30 m wide from toe to toe) in the north eastern corner. The northern breakwater extends from the current location to the north then east, a breakwater on the eastern side bends westward to provide an entrance channel approximately 80 m long. The elements within the harbour have an area of approximately 200 m^2, and elements not exceeding 3000 m^2 extend along the coast 3.7 km.

The bathymetry for the proposed harbour design was modified within the harbour for two additional simulations to test the impact on flushing conditions of a local scour hole forming in the harbour, and assuming blockage of the western openings. The local scour hole has been included by lowering the elements in the area indicated to -5 m CD to account for prop wash from the proposed ferry operations (Noelker S, pers. comm. 10-Jun-2015). The mesh and bathymetry used are shown in Figure 3-2.

The different conditions tested are summarised below:

- Mesh 1: Existing design
- Mesh 2: Existing design plus scour hole
- Mesh 3: Existing design western openings removed

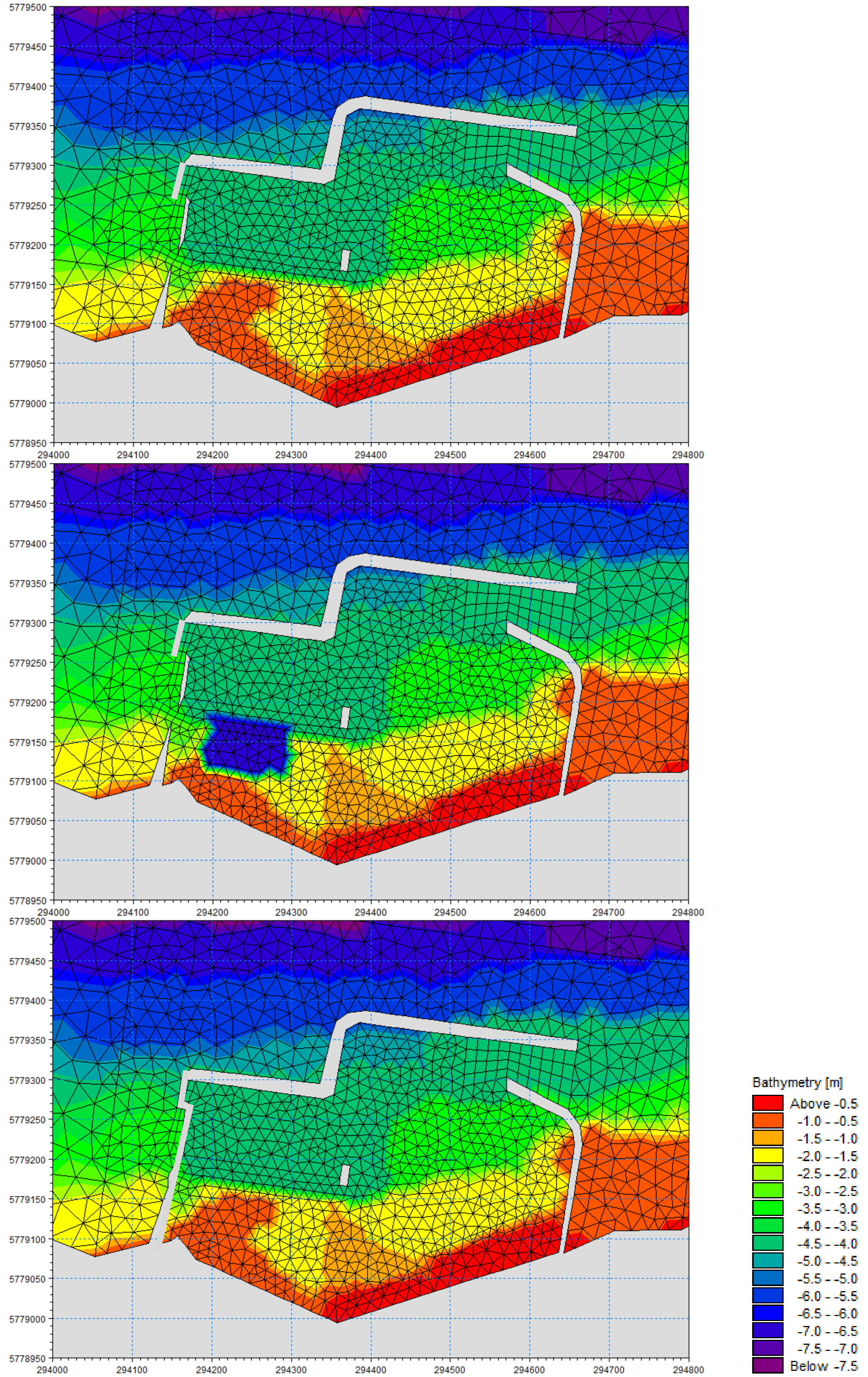


Figure 3-2 Mesh 1; (top), Mesh 2 (middle), Mesh 3 (bottom)

3.2 Boundaries

A single tidal water level boundary, and spatially constant wind series, were used as boundary conditions for the model. The tidal boundary extended along the southern offshore extents of the model from Lorne to Flinders, where tidal constituent information was available (DoD 2012, Hinwood and Wallis unpublished). The tide applied along the boundary was calculated from tidal constituents at either end (Figure 3-3) with a linear interpolation along its length. The gradient along the boundary improves the representation of currents normal to the boundary. No catchment inflows have been considered in the model as these are not considered to have any significant impact on water levels or currents around Portarlington.

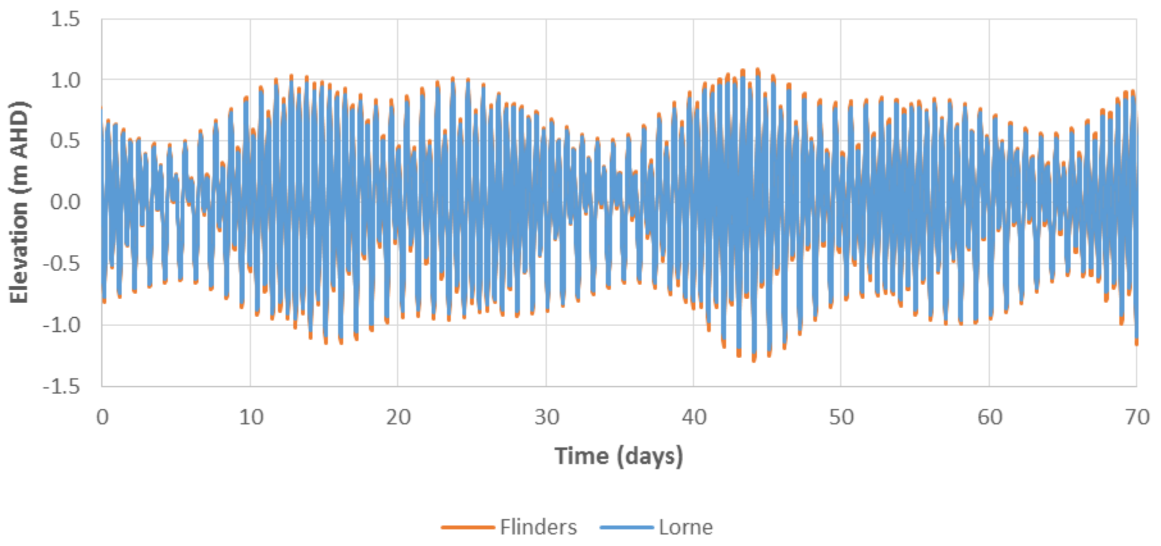


Figure 3-3 Tidal Signals at Lorne and Flinders for Simulation Period

3.3 Model Validation

The Port Phillip Bay model was calibrated for water levels at six locations throughout the bay, shown in Figure 3-4. Water levels predicted by the model were compared against predicted tides generated from tidal constituents at each location (Figure 3-5).

Slight modifications to tidal constituents and the roughness map across the model were made in order to improve the reproduction of predicted water levels at each point. The adopted model roughness map had a global Manning's n of 0.20, with a higher roughness applied through The Rip of 0.33. It was found that changes to the roughness over The Great Sands and the shallow areas west of Portarlington had little impact on the tidal signals at Williamstown and Geelong.

The modelled tidal range and general shape of the tidal signal matches well with predicted tides and is considered suitable for the purpose of water quality modelling at Portarlington.

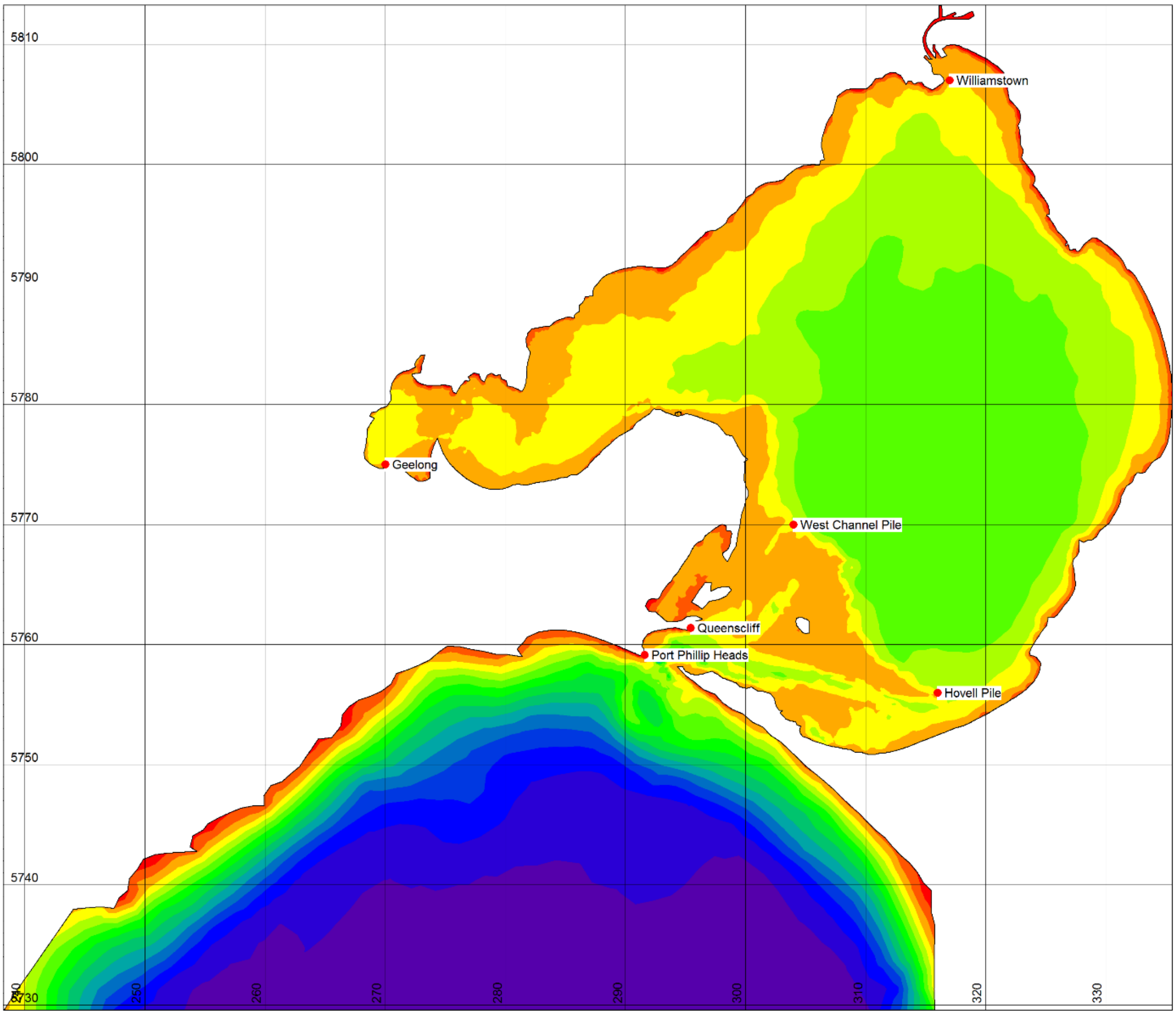


Figure 3-4 Location of Calibration Points

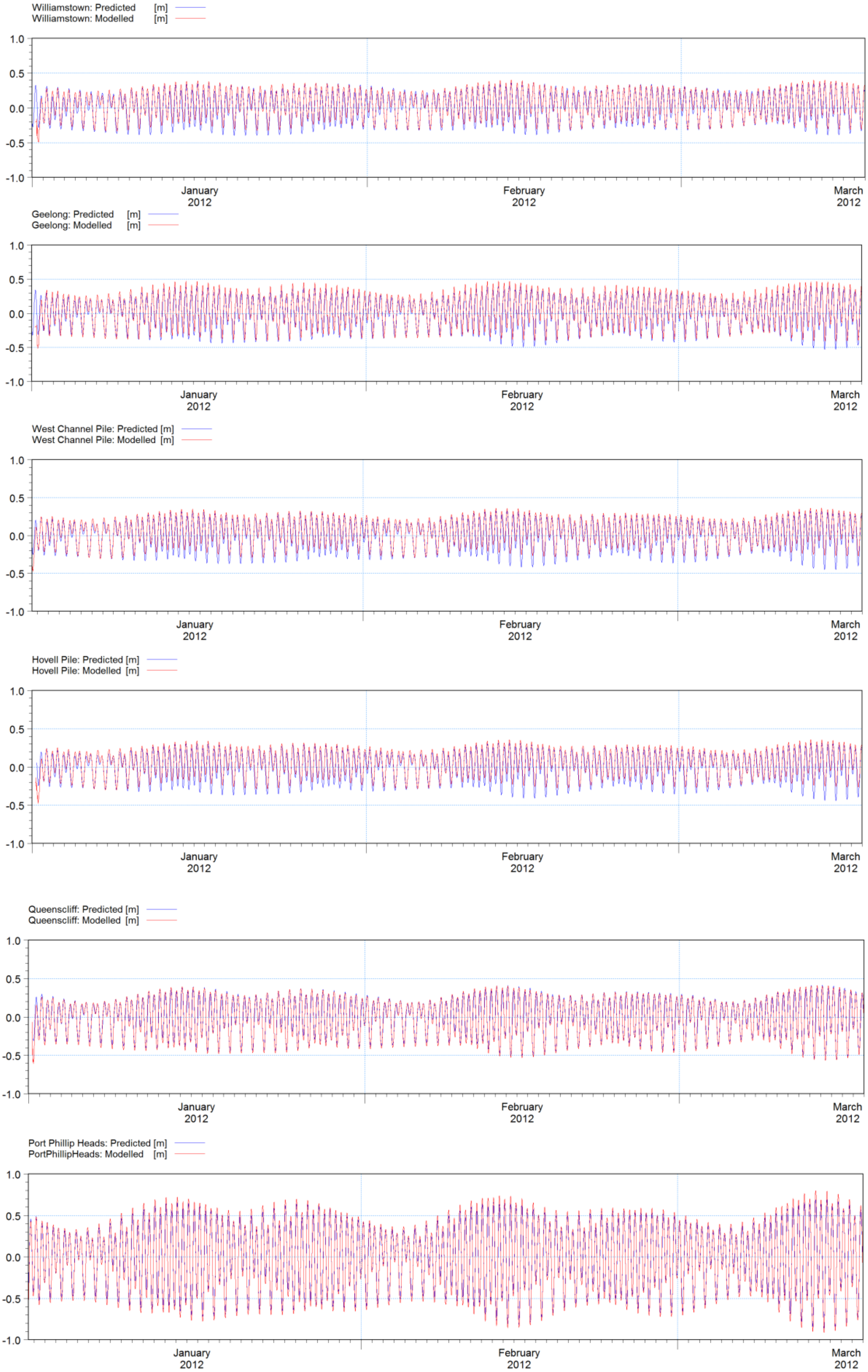


Figure 3-5 Predicted and Modelled Water Levels

3.4 Simulations

Five model simulations were undertaken in order to assess the hydrodynamics of the proposed harbour at Portarlington including the impact of different wind conditions, a local scour hole, and complete closure of the western side of the harbour. The simulations were run over approximately two and a half months, with identical tidal conditions. The only difference between Simulations 1, 2 and 3 was the wind conditions applied. Simulations 4 and 5 were based on Simulation 1 with the noted modifications to the model bathymetry and harbour wavescreen. The simulations undertaken were:

1. No wind;
2. Typical summer winds;
3. Typical winter winds;
4. No wind and area of local scour; and
5. No wind and western openings blocked off.

The flow movement and flushing conditions in the harbour were assessed using model tracers. Model tracer was added to the simulation as both an initial concentration within the harbour of 100% (Tracer 1), and a single point sources discharge within the harbour. These conditions are shown in Figure 3-6. An additional point source tracer was later added to represent a discrete stormwater discharge into the harbour.

The purpose of Tracer 1 is to provide a means of understanding the movement and flushing of the water inside the harbour, how long it takes for water in the harbour to be exchanged (fully flushed), and where the water from the harbour is exchanged to once it leaves the harbour confines.

Tracer 2 represents the release of material such as stormwater outfall via a point source. Tracking the movement of the stormwater discharge can be used to determine the dilution and dispersion of material released into the harbour. The stormwater discharge tracer was added at a very small flow rate with a very high concentration so as to provide a concentration without impacting the volume of water in the harbour.

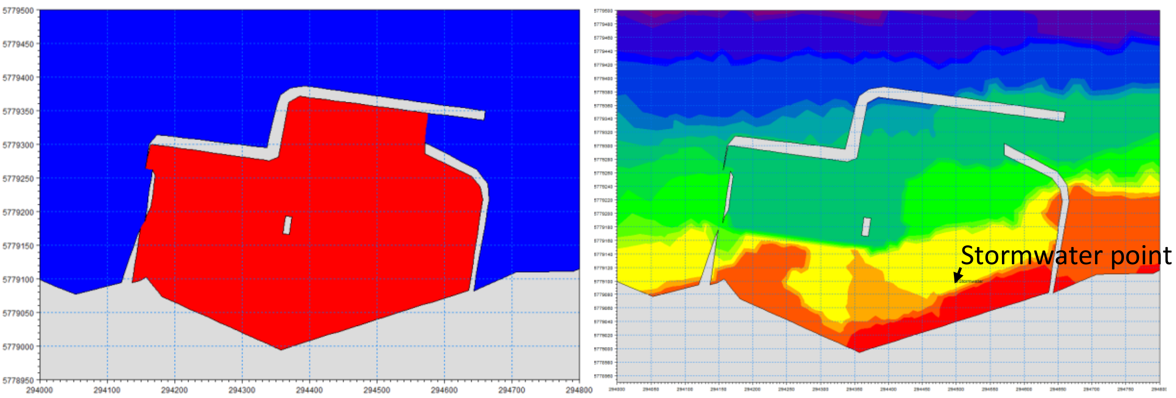


Figure 3-6 Initial Concentration of Tracer 1 (left); and Stormwater discharge source Points for Tracer 2 (right)

4. RESULTS

4.1 Harbour Flushing Times

The "Flushing Time" is a common measure of how long it takes for the water within a harbour or other coastal water body can be exchanged or "flushed". The assessment sets an initial unit concentration of a conservative tracer throughout the harbour and simulates the exchange of water between the harbour and the Bay to determine the time for the concentration within the harbour to drop to 37% (or 1/e) of the original concentration, which is sometimes referred to as the "e-folding" time.

Figure 4-1 shows the flushing of the initial volume of water within the harbour for each of the three simulations, with the red dashed line representing the e-folding value of 37% of the original concentration.

The flushing times for simulation (1) no-wind, and (3) typical winter conditions, are both around 3 days, and the flushing time for (2) typical summer conditions is around 2.5 days. The results indicate the proposed harbour development will have short flushing times of less than 3 days under the typical summer and winter conditions. This will result in satisfactory exchange of harbour waters with the Bay and maintain good water quality conditions inside the harbour.

The inclusion of a local scour hole in simulation (4) resulted in a slight increase in relative mass in the harbour which increased the flushing time to around 4 days. Complete blockage of the western side of the harbour, simulation (5), reduced the rate of mixing and resulted in an increase in flushing times up to 7.5 days. This is however still considered well flushed.

For comparison, a flushing time of 30 days or less for closed or semi-enclosed bodies of water in Port Phillip Bay, has been acceptable to regulatory authorities such as Melbourne Water and the Environment Protection Authority of Victoria for previous projects within Port Phillip Bay (e.g. , Martha Cove; Water Technology 2007, and Wyndham Harbour; Water Technology 2014).

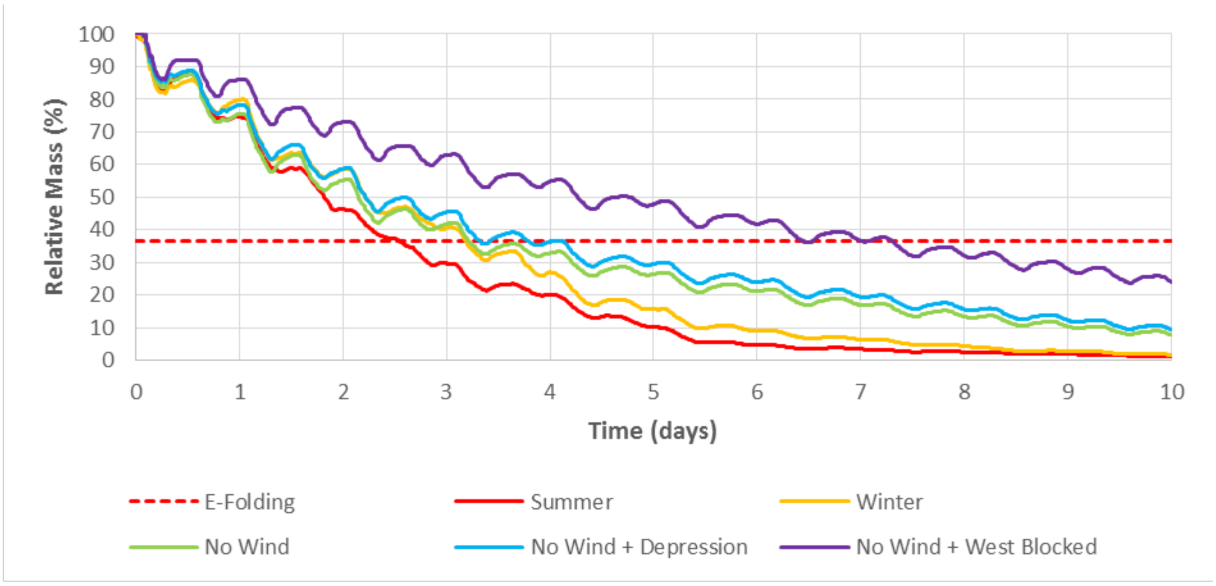


Figure 4-1 Comparison of Flushing Times in the Harbour for Various Simulations

4.2 Stormwater Discharges

The dispersion and dilution of model tracer representing stormwater discharge within the harbour is shown below in Figure 4-2 and Figure 4-3. The figures illustrate the maximum (Figure 4-2) concentration of model tracer during the 40 day simulation, as well as a "typical" (Figure 4-3) plume dispersion during the simulation. The stormwater discharge was assessed for the no wind condition with the western side of the harbour open and closed. A timeseries of concentration at points noted in Figure 4-2 is shown in Figure 4-4 for both simulations.

The 3 figures confirm the good flushing properties shown in Section 4.1 above. Whilst the model tracer can accumulate at the source point, concentration then drops rapidly both within the harbour, and with increasing distance from the harbour.

Concentration of the model tracer both within and around the harbour reaches a stable level and oscillates with the tidal motion within Port Phillip Bay. The concentration 1km to the west of the harbour is below 1% of the stormwater output and less than 6% 1km to the east of the harbour. The addition of wind on the model would lead to similar results, albeit with localised increases and decreases of concentraiton due to wind dispersion.

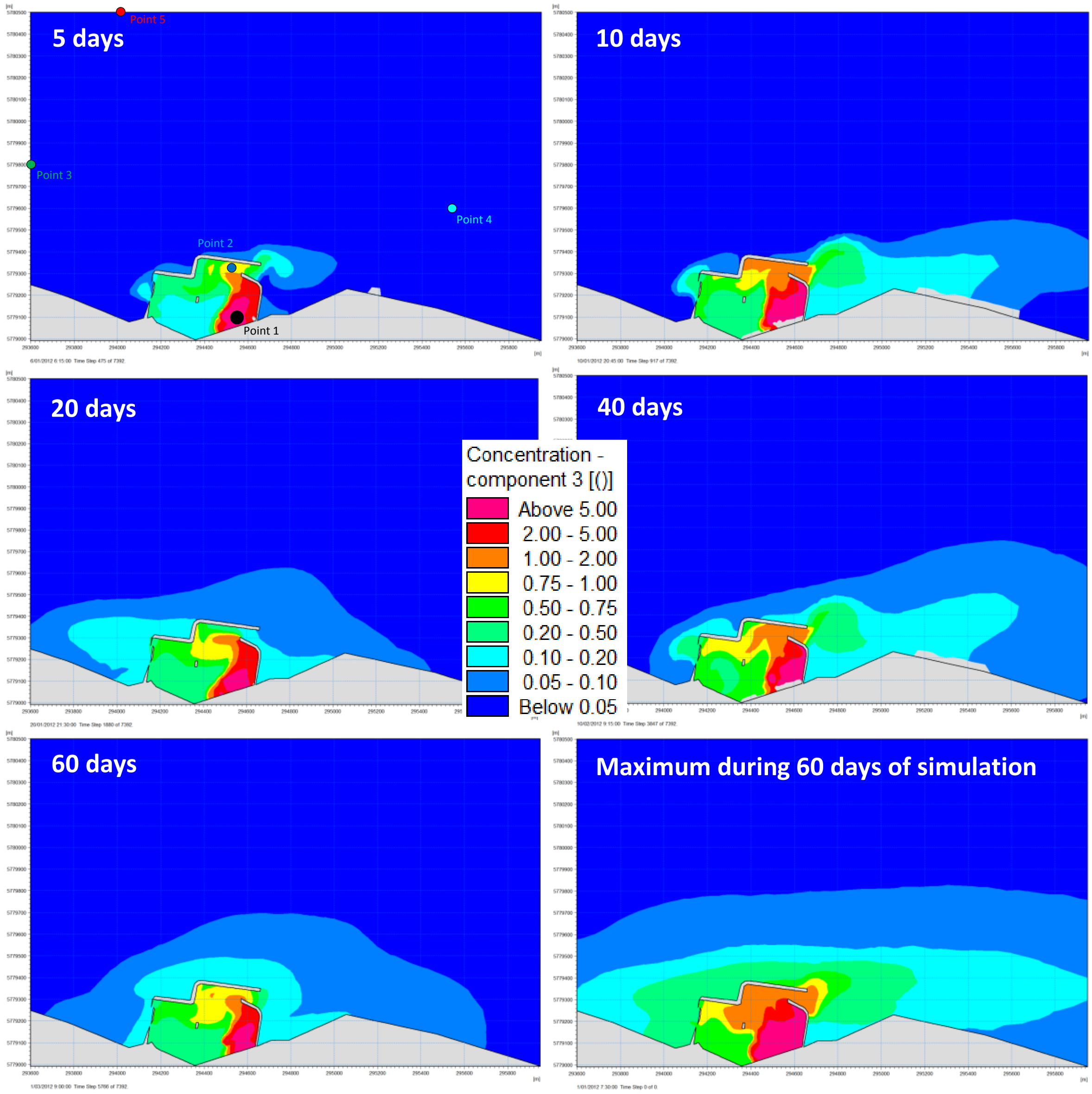


Figure 4-2 Simulation (4) - No Wind and Area of Local Scour, Stormwater Discharge Dispersion and Dilution

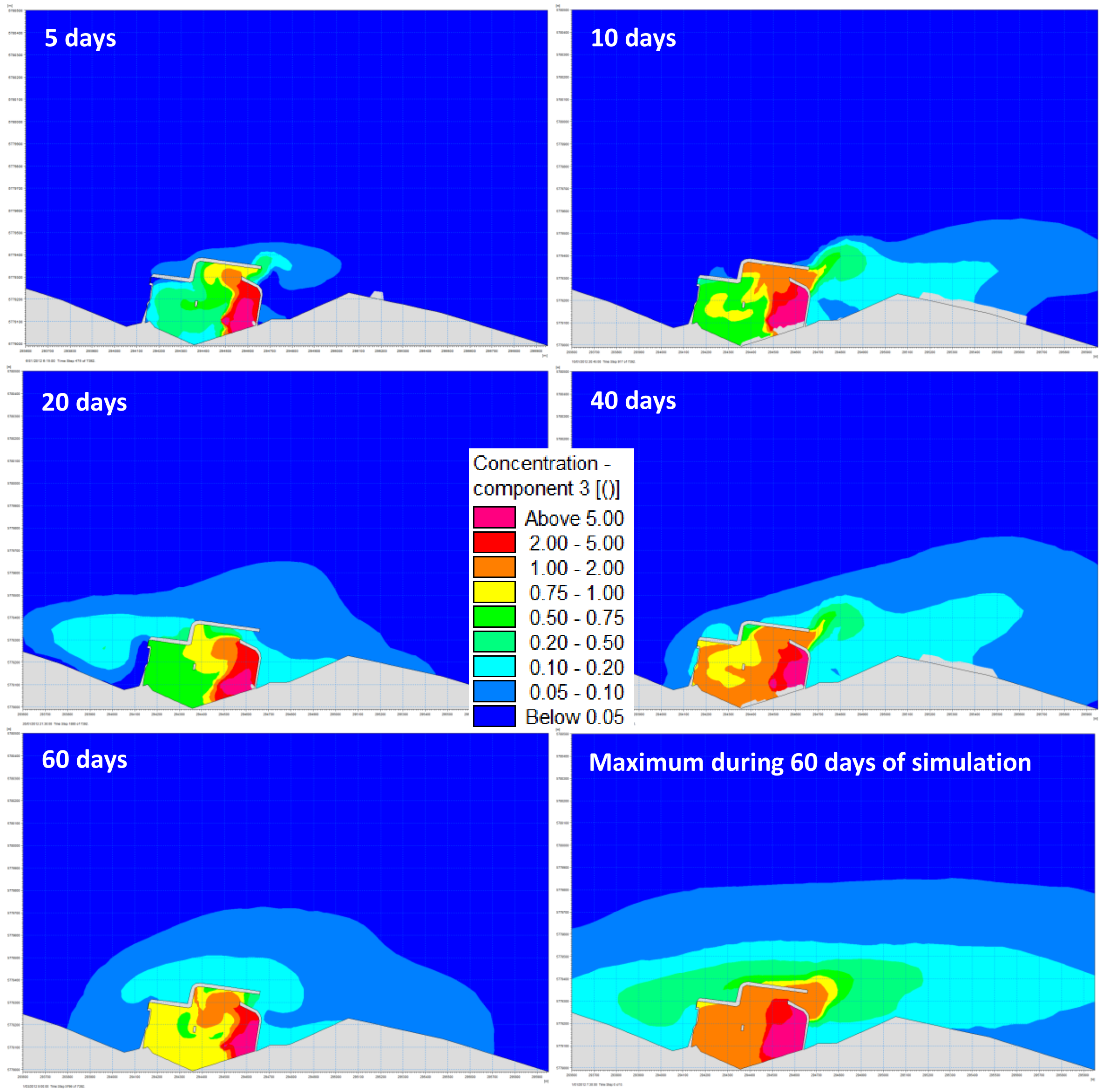


Figure 4-3 **Simulation (5) - No Wind and West harbour blocked, Stormwater Discharge Dispersion and Dilution**

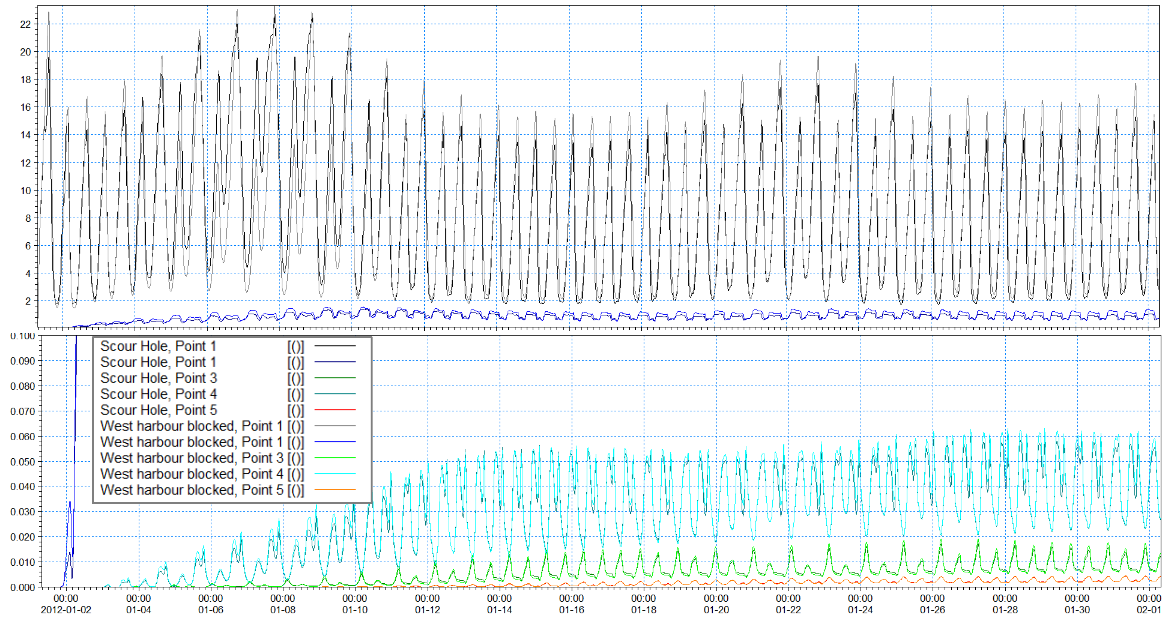


Figure 4-4 Timeseries of model tracer concentration (not different y-axis scales)

4.3 Effect of Opening Western Harbour

As noted above, the openings on the western side of the harbour allow for significant exchange of water between the bay and the harbour, with currents in both directions during the incoming and outgoing tides. Without these openings (simulation 5), as illustrated in Figure 4-1, the flushing time is almost doubled.

Figure 4-5 and Figure 4-6 below show the current speed and direction at four points in the tidal cycle for simulations 1 and 5.

The current patterns representing conditions where the west harbour is open are shown in Figure 4-5 and indicate that:

- Early on the incoming tide there is flow through the harbour east to west;
- As the tide continues to rise, water continues to enter the harbour from the west but ceases from the east;
- Immediately after high tide water flows through the harbour west to east; and
- Towards low tide water flows from the harbour out the western side.

The current patterns representing the harbour closed along with western edge are shown in Figure 4-6 and indicate that:

- Water flows into the harbour from the entrance during the incoming tides, causing some circulation in the north of the harbour;
- On the outgoing tide water flows out of the entrance with low velocities throughout the harbour; and
- Neither the incoming nor outgoing tides cause significant circulation in the south and west of the harbour.

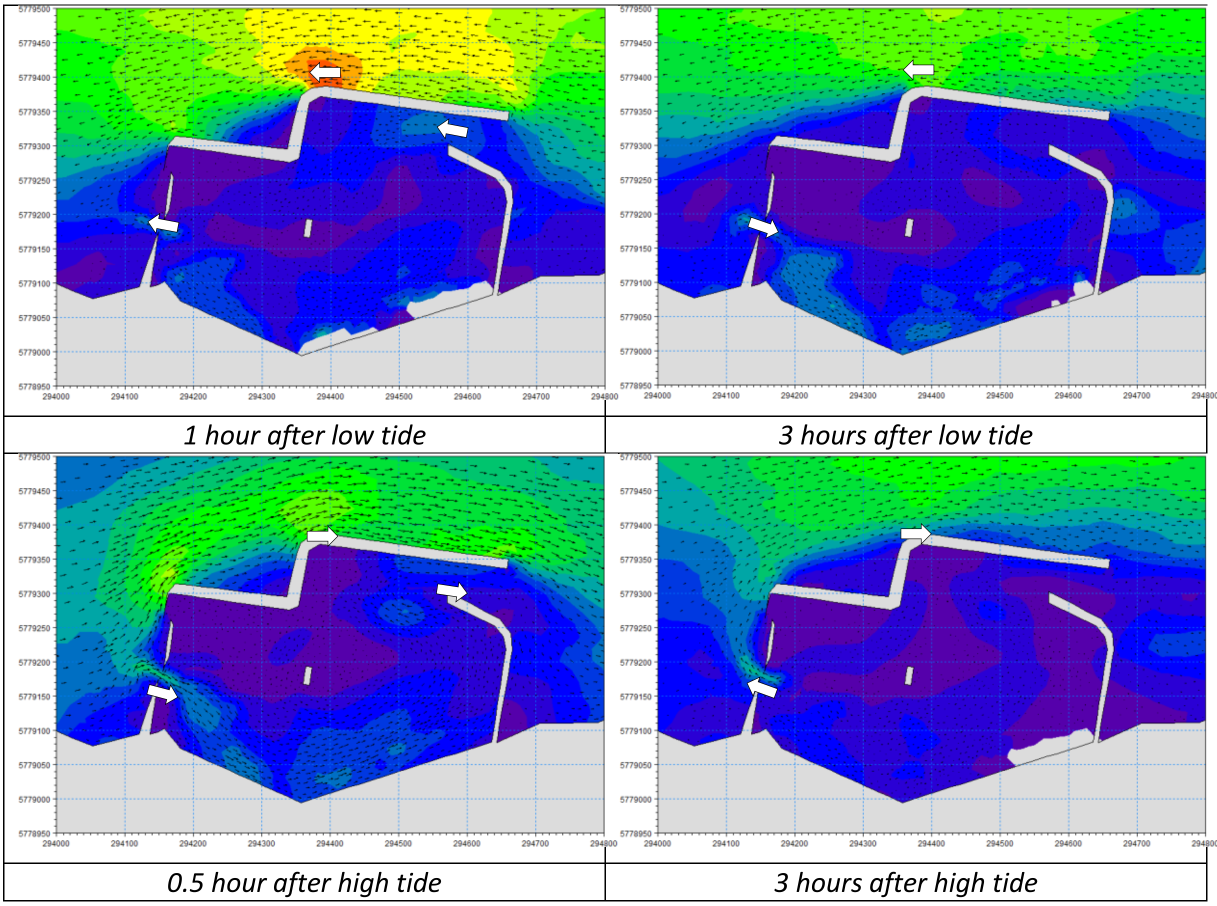


Figure 4-5 Current Patterns in Harbour for Simulation 1 – No Wind

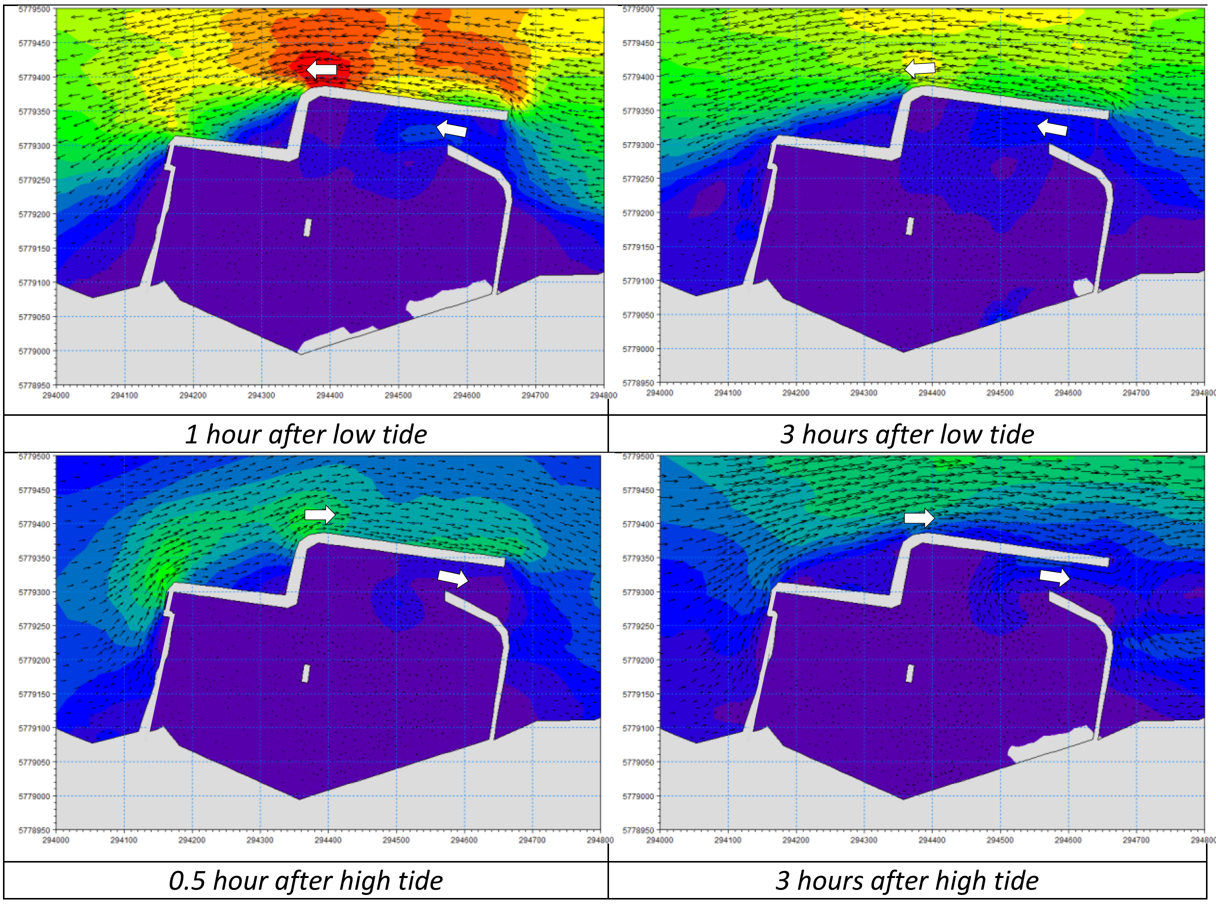


Figure 4-6 Current Patterns in Harbour for Simulation 5 – No Wind and West Blocked

5. SUMMARY

The results of the assessment can be summarised as follow:

- Modelling of the proposed harbour has confirmed there is good tidally driven flushing of harbour waters. Flushing times do not exceed 4 days for any of the three different wind simulations undertaken (Simulations 1, 2 and 3). Once water leaves the harbour it is quickly dispersed and any tracer in the water is rapidly diluted.
- A local scour hole to -5 m CD has a minor negative impact on the flushing, with flushing times increasing to 4 days under “no wind” conditions.
- The openings on the western side of the harbour have a significant impact on currents and mixing in the harbour. Complete blockage of these openings has a significant impact on water quality, doubling the flushing time. However, the resulting flushing of the harbour is still well within the acceptable 30 day range.
- Stormwater discharged in the south-east of the harbour can accumulate within the harbour, however is diluted to low concentrations once leaving the harbour.

If you have any further queries relating to the matter, please do not hesitate to contact me.

Kind Regards,

Elise Lawry

Senior Engineer

6. REFERENCES

Department of Defence (2012). Australian National Tide Tables 2013, Australian Hydrographic Publication 11, Australian Hydrographic Service (AHS).

Hinwood, J, and Wallis, I (unpublished). The Tides of Bass Strait and Tasmania.

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