Assessing the impact of sewage overflows on oyster harvest areas: Hastings River estuary technical summary

WRL TR 2025/05, May 2025

By D S Rayner, A J Harrison, M Mason, Y Doherty and B M Miller

UNSW Water Research Laboratory

UNSW SYDNEY

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Contents

List of tables

List of figures

1 Introduction

1.1 Project overview

The Water Research Laboratory (WRL) of the School of Civil and Environmental Engineering at UNSW Sydney was engaged to undertake an extensive study titled “Assessing the impact of sewage overflows on oyster harvest areas in NSW”. This study was funded through a Department of Regional NSW Storm and Flood Industry Recovery Program (SFIRP) – Sector Recovery and Resilience grant with support from local councils and wastewater authorities.

The study seeks to understand the fate of contaminants and the potential exposure of oyster leases following overflow events under different environmental conditions including tides, wind and catchment runoff. The results of this study provide decision makers with quantitative data to assess exposure risk to specific harvest areas on an individual sewer overflow event basis. These outcomes allow for increased confidence in ensuring consumer safety, and more targeted harvest area closures to reduce the economic impact of widespread closures on local industry.

Sewage overflows into estuaries occur under a range of conditions, often due to malfunctioning or overwhelmed infrastructure. As a result, the environmental conditions in the estuary at the time of an overflow can vary. While experimental data (such as large scale dye release experiments) can be useful to understand contaminant transport in a single set of conditions (or a small number of conditions), it is impractical to collect such data for the broad range of conditions possible across multiple sewage overflow locations. Therefore, the approach of this study is to combine desktop numerical modelling and site-specific field investigations as a cost-effective means to gain sufficient understanding of contaminant transport.

For a detailed background to the study, refer to the User Guide (WRL TR2024/26).

1.2 Report context

This report is focussed on the Hastings River estuary. It provides technical details of the available data, data collection undertaken, model development and the capabilities of the predictive model. This report provides specific details for the Hastings River estuary and should be read in parallel with User Guide WRL TR2024/26 and Technical Summary Report WRL TR2023/32 (Table 1-1). The other reports for each specific estuary are listed in Table 1-2.

This report is an update of a previous study, WRL TR 2022/26, which was done earlier, as part of an project funded by Port Macquarie Hastings Council (PMHC) through the then NSW Department of Planning and Environment (DPE) Coastal and Estuary Grant Program as part of the PMCH Coastal Management Program. The report has been updated to follow a similar structure to the other estuary specific reports listed in Table 1-2, and to incorporate the learnings from the broader study across the state into the numerical scenario modelling. No additional fieldwork or calibration of the model was completed in this update. As a result, some methods used were slightly different, which is highlighted throughout the report. Similarly, where aspects of the study were updated based on new findings, this is also flagged in this report.

Table 1-1 Summary of project reference documents

Report number	Intention
WRL TR2024/26	Project overview and user guide
WRL TR2023/32	Technical summary of fieldwork and modelling methods

Table 1-2 Summary of estuary specific reports

Estuary	Technical summary
Tweed River	WRL TR2023/18
Nambucca River	WRL TR2023/19
Hastings River	WRL TR2025/05 (this report)
Camden Haven River	WRL TR2023/20
Wallis Lake	WRL TR2023/21
Port Stephens	WRL TR2023/22
Clyde River	WRL TR2023/24
Shoalhaven/Crookhaven Rivers	WRL TR2023/23
Wagonga Inlet	WRL TR2023/25
Merimbula Lake	WRL TR2023/26
Pambula Lake	WRL TR2023/27

1.3 Hastings River site description

The Hastings River estuary is a coastal river in NSW, Australia, located 300 km north of Sydney. Major towns in the area include Port Macquarie, Wauchope and Telegraph Creek. Major tributaries include the Maria River and Limeburners Creek. The estuary has a catchment of approximately 3,600 km^2 with a waterway area of 17.3 km^2 (MHL, 1999). The tidal extent of the Hastings River is 37 km upstream of the estuary entrance, and the extent of the Maria River is 43 km upstream of the junction with the Hastings River. The tidal prism of the estuary on a spring tide in 1999 was 21.3 x 10^6 m^3 (MHL, 1999). The entrance to the Hastings River was artificially trained more than a century ago, and extensions and upgrades to the training walls have been undertaken since then. The estuary has five oyster harvest areas: Rawdon Island, Riverside, Big Bay, Upper Limeburners Creek and Lower Limeburners Creek, shown in Figure 1-1.

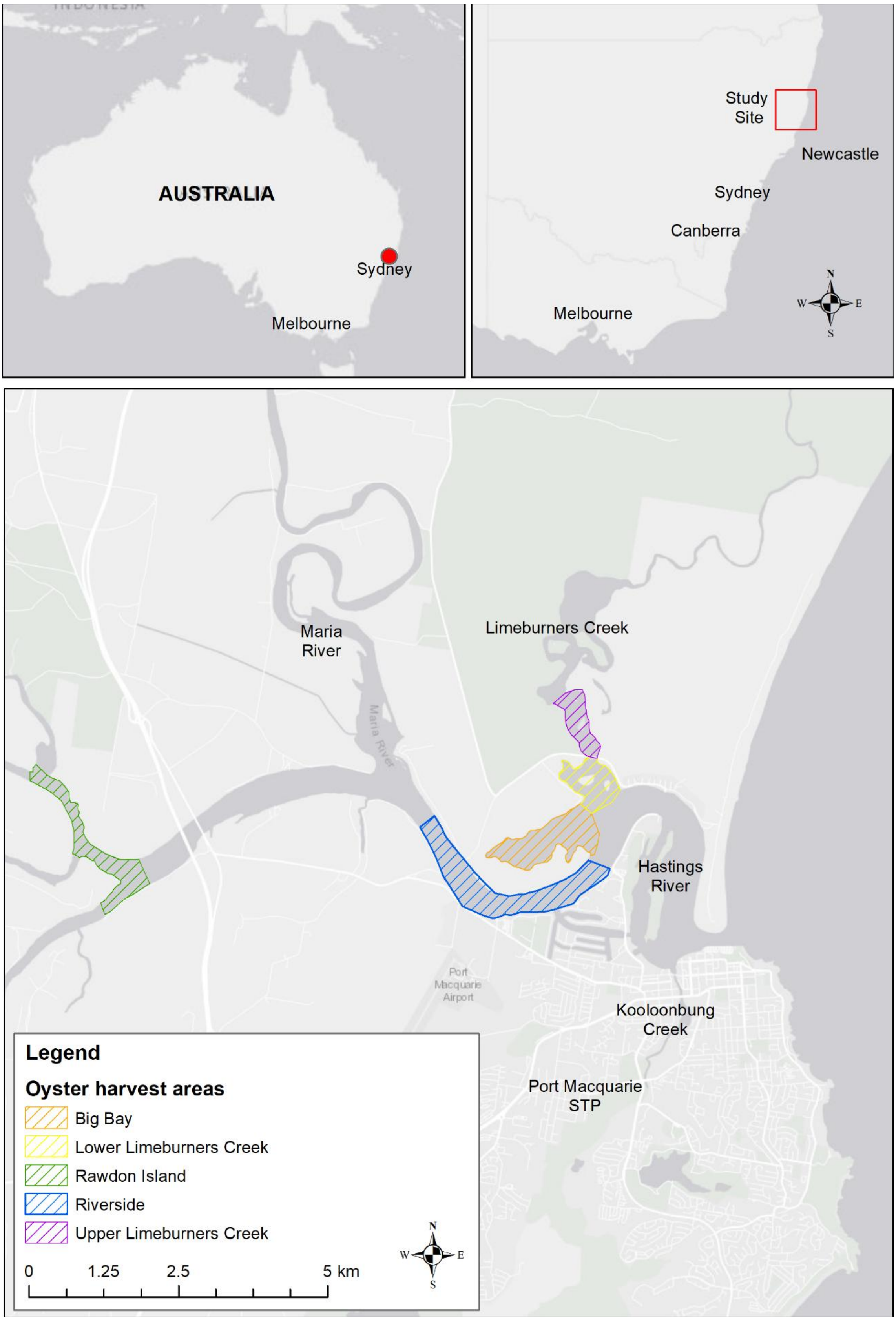

Figure 1-1 Oyster harvest areas in the Hasting River estuary

1.4 About this report

This report includes the following sections:

- **Section 2: Data collation** – summarising the relevant existing data available to assist in calibration and verification of the numerical model of the estuary, including information on historical sewage overflow locations.
- **Section 3: Field data collection** – summarising the outcomes of a field data collection campaign on the estuary.
- **Section 4: Model development** – outlining the development of the numerical model of the estuary.
- **Section 5: Scenario modelling** – describing the suite of scenarios run for the estuary.

The following appendices are included which provide additional detail:

- **Appendix A: Field data collection**
- **Appendix B: Model calibration and verification**

2 Data collation

2.1 Preamble

Table 2-1 summarises the preexisting available data relevant for development of the numerical hydrodynamic and water quality model.

Table 2-1 Summary of data collated for this project

Data type	Primary sources	Comments	Report section
Long term water level data	MHL (2023a) MHL (2023b)	Long term water level data available in 7 locations, at minimum from the 1990's to present	2.2.1
Tidal flow and water level	MHL (1999)	Tidal flow gauging at 20 locations in October 1999, plus additional water level locations	2.2.2
Catchment discharge	WaterNSW (2023)	Two long term catchment flow monitoring locations on the Hastings and Wilsons Rivers	2.3
Sewage overflow	PHMC NSW Food Authority	Data provided on overflows reported to EPA and NSW Food Authority, closure actions pursued and some information on duration and volume	2.4
Bathymetry	OEH (2006) Advisian (2018) DPIE (2018) NSW Spatial Services (2012)	Bathymetry primarily sourced from OEH 2006 single beam survey and 2018 NSW Marine LiDAR Topo-Bathy survey, with supplementary data from Advisian flood model and 2012 Digital Elevation Model (DEM)	2.5

2.2 Hydrodynamic data

2.2.1 Long term water level data

Manly Hydraulics Laboratory (MHL) monitors the water level at several locations across the Hastings River estuary, shown in Figure 2-1. All seven water level gauges have been operational since the mid-1980's to early-1990's to present, and records at a 15 minute time interval. Data from all relevant loggers have been supplied for use on this project.

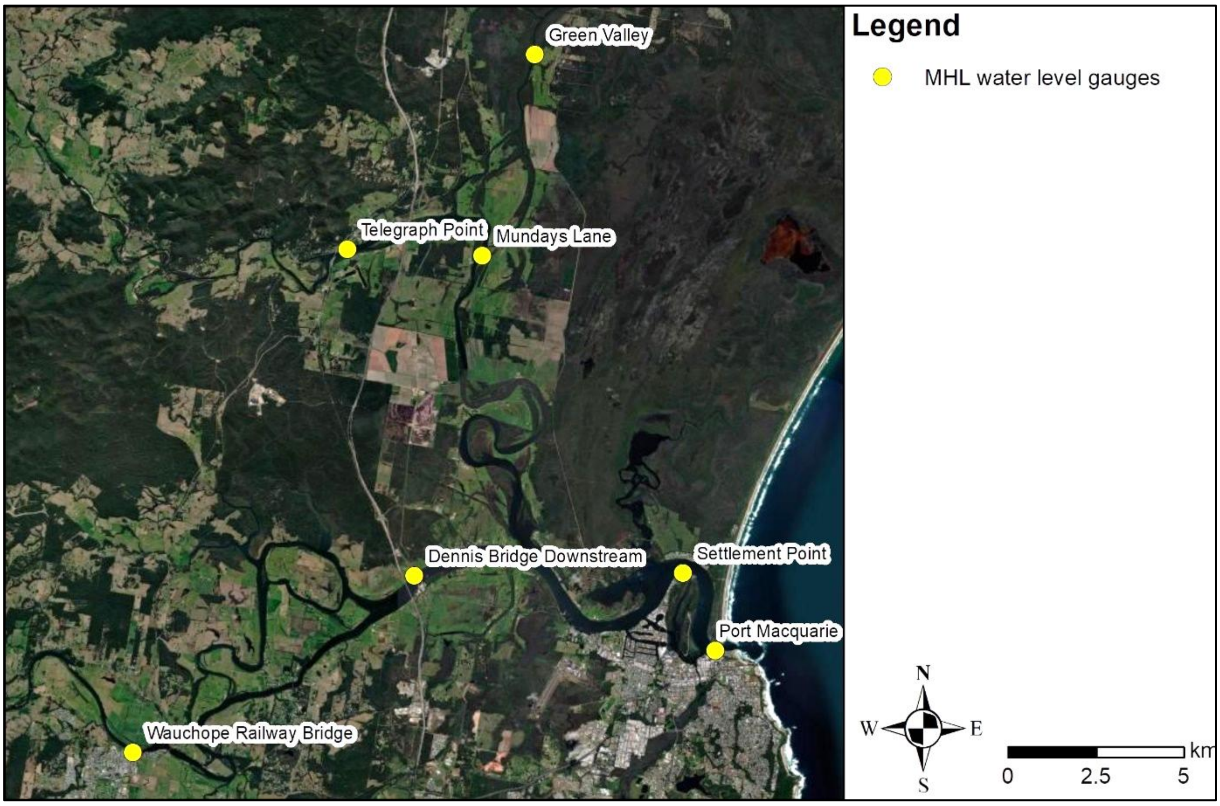

Figure 2-1 MHL water level gauges

2.2.2 Manly Hydraulics Laboratory 1999 data collection

In 1999, Manly Hydraulics Laboratory (MHL) undertook a short term intensive data collection program as part of the Estuary Management Plan (MHL, 1999). The aim of the data collection program was to improve the understanding of the hydraulic processes driving the estuary to aid better decision making. Monitoring was conducted between 23 and 25 October 1993 and included monitoring at 19 locations across the estuary (see Figure 2-2). This data collection campaign included:

- Tidal discharge, measured over a full ebb and flood tide cycle, at 20 locations using either an ADCP or tideboard. The tidal prism was estimated to be approximately 21 x 10^6 m^3 at the entrance to the Hastings River (Site 2) and approximately 4 x 10^6 m^3 at Maria River at the confluence with the Hastings River (Site 21)
- Water levels collected at 16 locations, including the permanent MHL stations (discussed in Section 2.2.1)

Measurements of tidal flow and tidal velocity are essential for good calibration of a hydrodynamic model. Without this data, it is difficult to assess the accuracy of the model at replicating the tidal prism of an estuary (e.g. how much water goes in and out on every tide). While the field data collection campaign completed in 1999 is comprehensive, it is acknowledged that the available dataset is almost 25 years old. In many estuaries geomorphic changes over time, such as scouring or accretion at the entrances, impacts tidal prisms and tidal circulation currents, which may not be reflected in the historical data. While geomorphological changes are not anticipated to be significant, this was verified with additional data collection in the 2022 field data collection campaign.

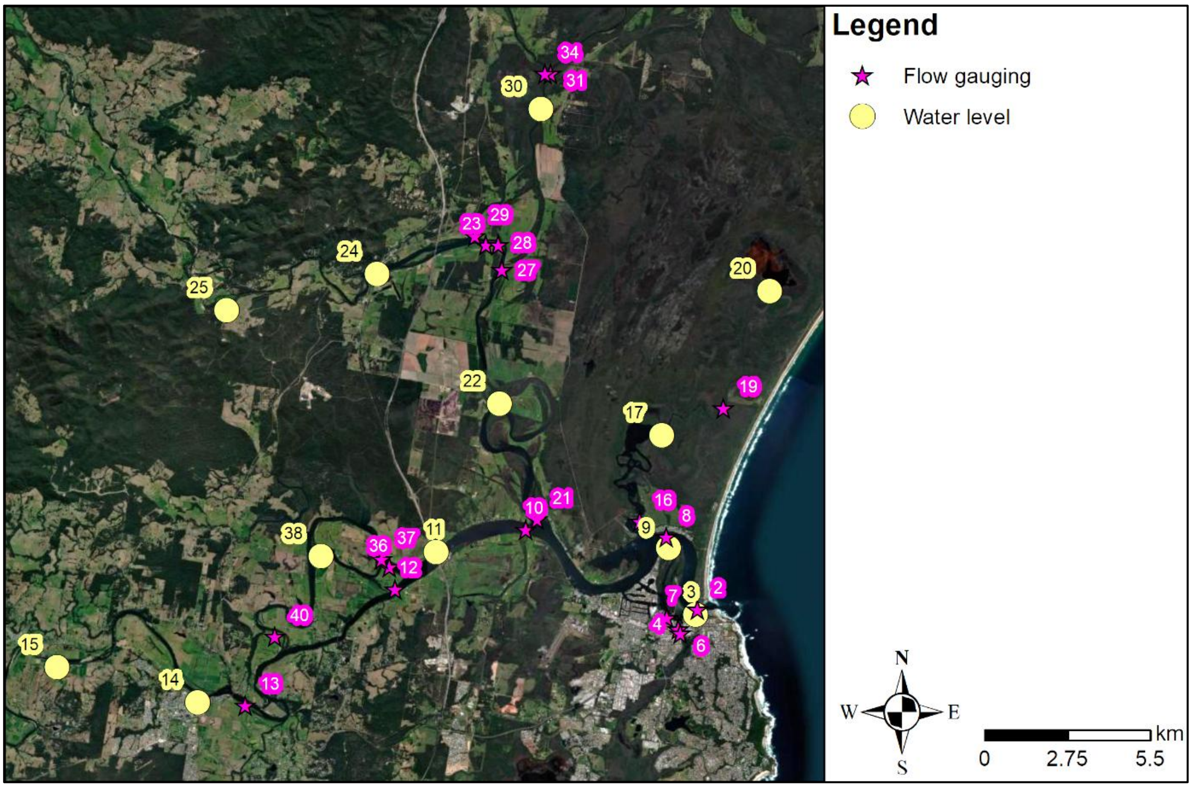

Figure 2-2 MHL (1999) data collection campaign

2.3 Catchment discharges

Gauged catchment inflows were available from WaterNSW. When these were not at the tidal limit (the model boundary), the flows were scaled up proportional to the additional catchment area using the method in WRL TR2023/32 Section 2.4. There are seven model boundary inflows into the Hastings River estuary and continuous flow gauging of discharge and water levels are available from WaterNSW (2023) at three relevant locations: Hastings River Ellenborough (1954 to present), Wilsons River at Avenal (1984 to present) and Mortons Creek at Mortons (2010 to present). Table 2-2 lists the model boundaries, the gauges used and the relevant scaling factor applied. Figure 2-3 and Figure 2-4 show the locations along with the catchment area flowing into each tidal boundary (solid line polygon) along with the associated portion of that catchment that is upstream of each gauge (hatched).

Table 2-2 Summary of scaling factors for model catchment boundaries

Model boundary	Base WaterNSW gauge	Scaling factor
Hastings River	207004	1.478
Wilsons River	207014	1.020
Pipers Creek*	207014	0.307
Connection Creek*	207014	0.307
Kooloonbung Creek*	207017	0.090
Wrights Creek*	207017	0.036
Yippen Creek*	207017	0.104
Settlement Shores*	207017	0.016

*This catchment was ungauged, so the gauge in a nearby catchment was scaled and used.

Flowrates exceeded at various percentiles for each WaterNSW gauge are shown in Table 2-3.

Table 2-3 WaterNSW gauge flow percentiles

Percentile	Hastings River Ellenborough (207004) ML/d *(m^3/s)*	Wilsons River at Avenal (207014) ML/d *(m^3/s)*	Mortons Creek at Mortons Road (207017) ML/d *(m^3/s)*
5th	59 *(0.69)*	4.2 *(0.05)*	0.0 *(0.0)*
20th	164 *(1.9)*	21 *(0.25)*	3.3 *(0.04)*
50th (median)	586 *(6.9)*	114 *(1.3)*	16 *(0.19)*
80th	2,089 *(25)*	620 *(7.3)*	59 *(0.68)*
95th	8,509 *(100)*	4,055 *(48)*	419 *(4.85)*

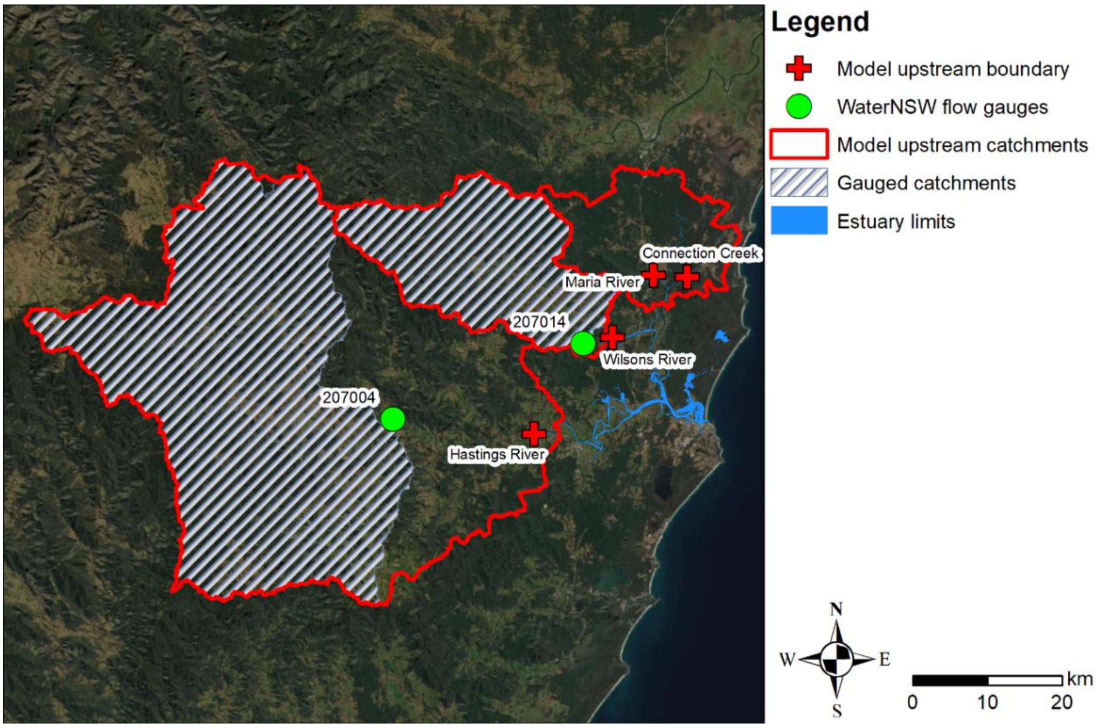

Figure 2-3 Catchment flow gauging stations for large catchments

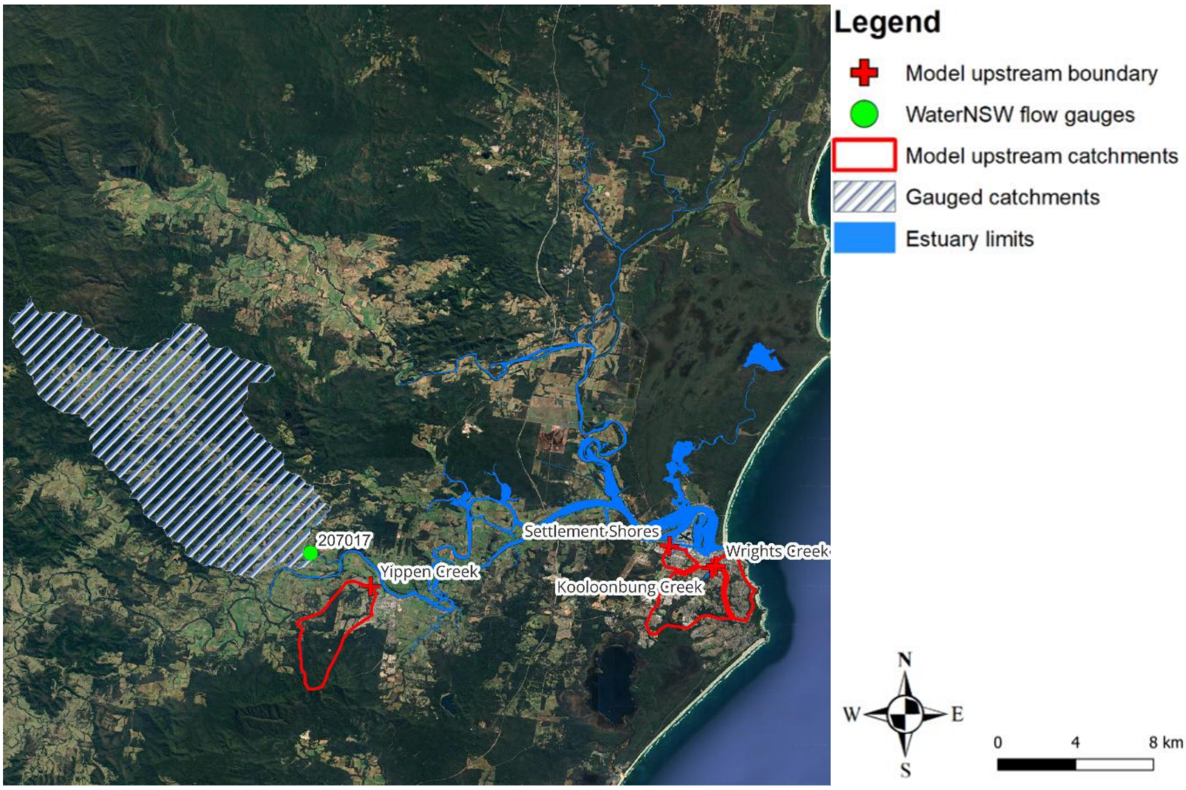

Figure 2-4 Catchment flow gauging stations for small catchments

2.4 Sewage overflow data

PMHC is the agency responsible for wastewater treatment and sewage management in the catchment surrounding the Hastings River estuary. The sewerage system is comprised of a reticulation network of pipes and sewage pumping stations (SPS), in addition to wastewater treatment plants (WWTPs) at Wauchope and Port Macquarie. WRL is aware there are currently investigations into the construction of a third WWTP to support the Port Macquarie WWTP, however the discharge location has not yet been finalised, so it has not been considered in this project. When sewage overflows occur, PMHC is required to notify NSW Food Authority so that appropriate decisions can be made on whether harvest area closures are necessary. Information on sewage overflows between 2016 and 2023 has been provided by the NSW Food Authority and reported overflow locations are shown in Figure 2-5. More information on sewage overflows and why they occur is provided in WRL TR2023/32 Section 2.5.

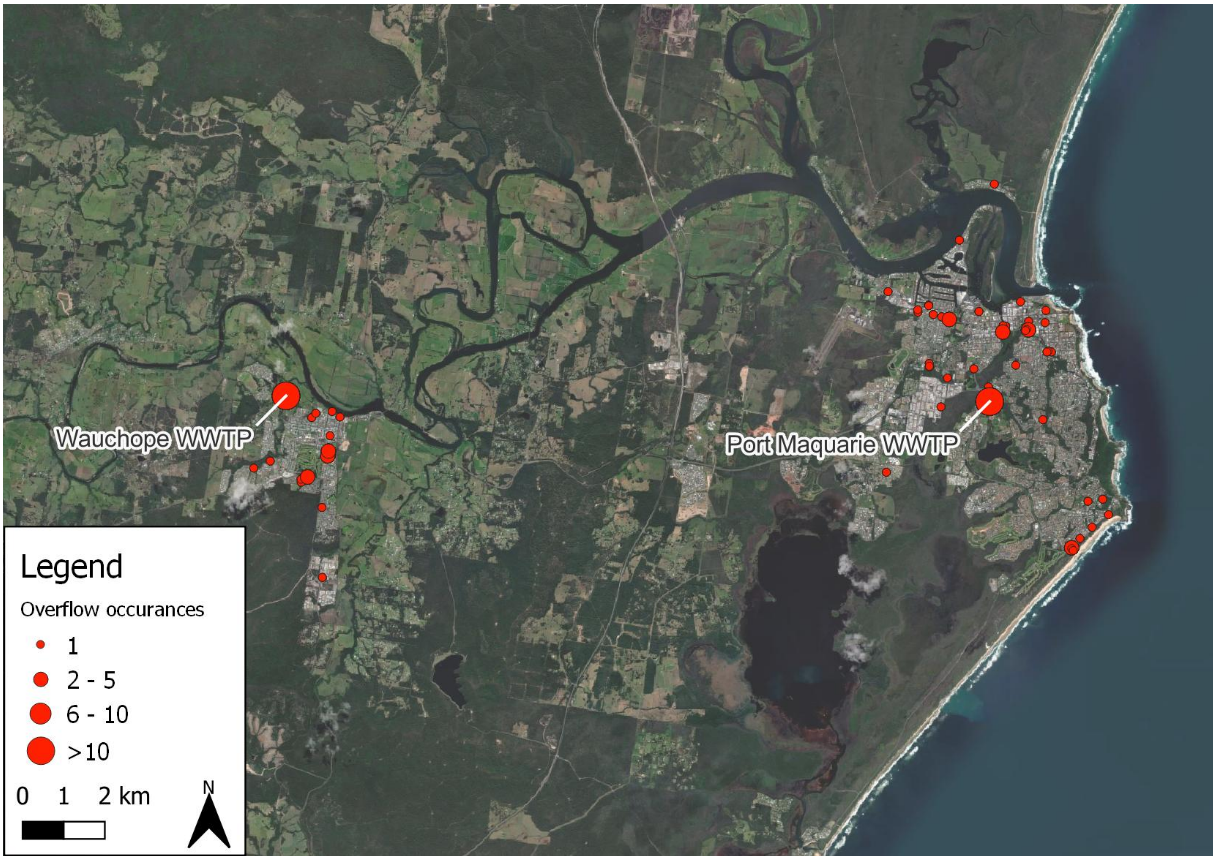

Figure 2-5 Locations of reported sewage overflows on the Hastings River

2.5 Bathymetry

Several existing bathymetry datasets were sourced for this project, including:

- Single beam bathymetry data collected in 2000. This dataset was collated and provided by the NSW Office of Environment and Heritage (OEH, now DCCEEW) and is available on the Australian Ocean Data Network (AODN) portal. This data was collected as a series of transects which cover the vast majority of the model domain, with higher density coverage in the Lower Hastings and Lower Maria Rivers (shown in Figure 2-6). This was the primary source of bathymetry data used in the model:

- 1 x 1 m DEM LiDAR data, available from NSW Spatial Services, used for channel banks and other areas outside the typically tidal range
- Bathymetry data from the Advisian flood model
- Coastal marine LiDAR collected by the former NSW Department of Planning, Industry and Environment (now DCCEEW) in 2018. In the Hastings River this covers the area downstream from Settlement Point at water depths less than 9 m

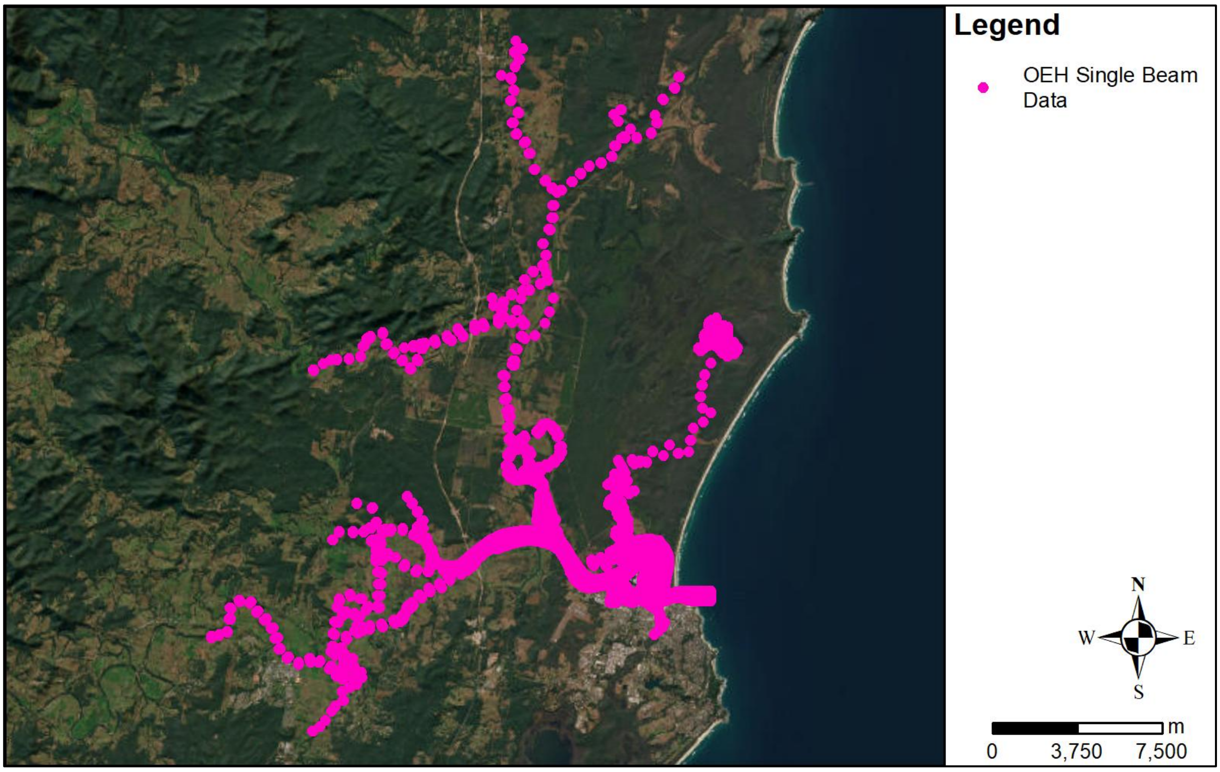

Figure 2-6 Coverage of NSW OEH single beam data

2.6 Existing model

The Hastings River estuary and floodplain have been extensively numerically modelled in recent decades. The model developed for this project was based on existing models from two previous studies:

- The 2018 flood model of the lower Hastings River (Advisian, 2018), built using the RMA modelling suite
- The 2021 Coastal Floodplain Prioritisation Study for the Hastings River (Rayner et al., 2023), which used the flood model as a base (excluding floodplain areas) to improve the understanding of sea level rise impacts. This model was also built using the RMA modelling suite

3 Field data collection

3.1 Preamble

A data collection campaign was completed on 11 and 12 October 2022 by Duncan Rayner, Alice Harrison, Yarran Doherty and Margot Mason. Field data collection included:

- Monitoring of current velocities and volumetric flow using an ADCP
- Monitoring of dispersion and advection using Rhodamine WT dye
- Monitoring of surface current speed and flow paths using GPS drifter drogues
- Collation of data from MHL water level monitoring sites

3.2 Weather and tides

Transport of contaminants in estuaries varies depending on the prevailing weather and tides. Data collection on the Hastings River was targeted across a range of tidal stages (e.g. incoming and outgoing tides). Tides during field investigations were similar both days, with tidal ranges between approximately -0.4 to 0.7 m AHD at Settlement Point, which is representative of the spring tide tidal range (Couriel et al., 2012). The observed water levels at Settlement Point, alongside the timing of key fieldwork components is shown in Figure 3-1.

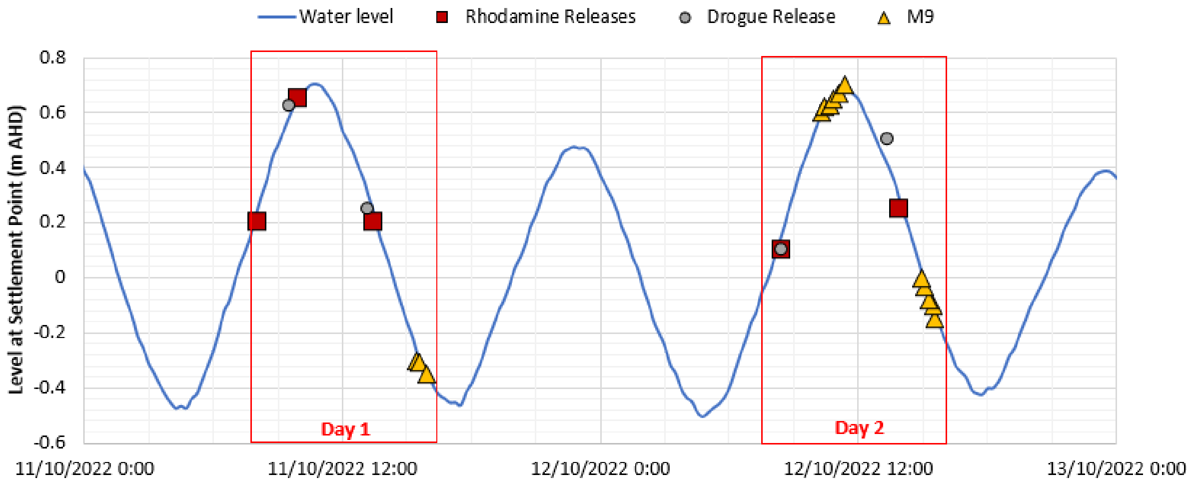

Figure 3-1 Tides at Settlement Point and key data collection

While no rainfall fell on the 2 field days, approximately 30 mm of rain fell in the preceding 5 days (BOM station 060168). Wind speeds were between 15 and 20 km/hour both days from the south to south east.

3.3 Tidal flow gauging

Flow was measured using a boat mounted SonTek RiverSurveyor M9 ADCP at five targeted locations across a range of ebb and flood tidal stages. More information on methods used for tidal gauging can be found in WRL TR2023/32 Section 4.2. Flow measurements in the Hastings River are shown in Figure 3-2 and Table 3-1, with locations shown in Figure 3-3. For plots of tidal flows refer to Appendix B1.4.

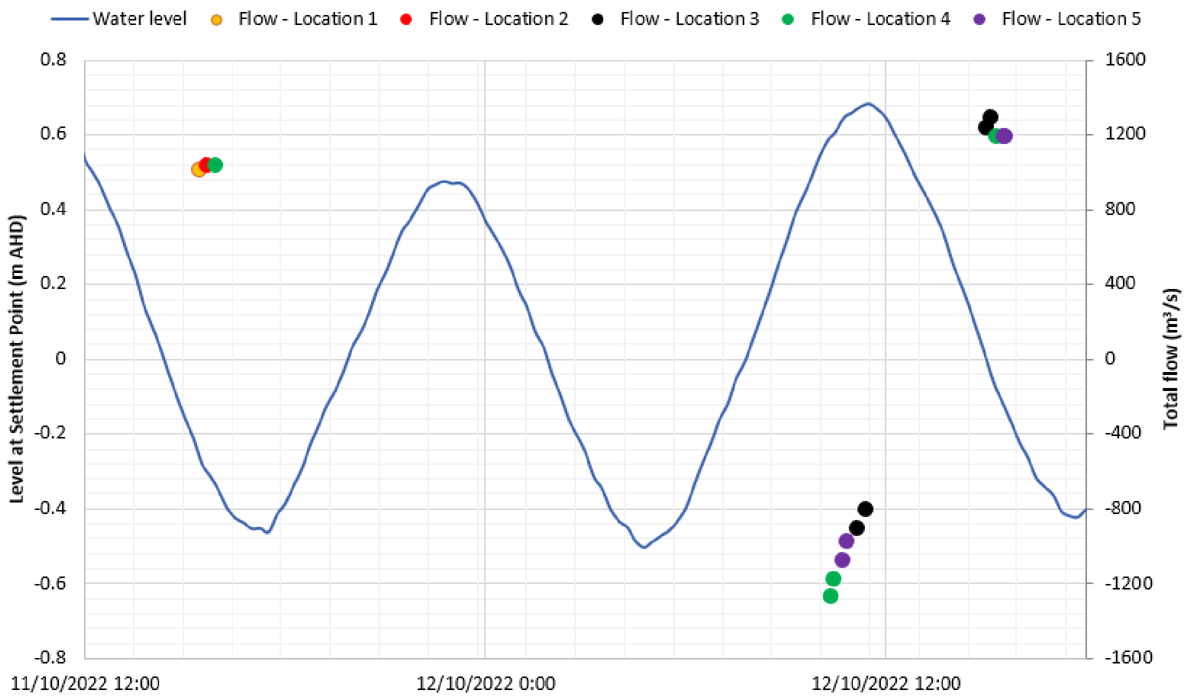

Figure 3-2 Flow data compared to water levels at Settlement Point

Table 3-1 Hastings River flow measurements at all locations

Time start (AEDT)	Transect location	Total flow (m^3/s)
11/10/2022 15:25	1	1,015
11/10/2022 15:36	2	1,039
11/10/2022 15:54	4	1,039
12/10/2022 10:19	4	-1,260
12/10/2022 10:25	4	-1,167
12/10/2022 10:41	5	-1,067
12/10/2022 10:49	5	-966
12/10/2022 11:06	3	-897
12/10/2022 11:23	3	-799
12/10/2022 14:59	3	1,243
12/10/2022 15:06	3	1,296
12/10/2022 15:17	4	1,198
12/10/2022 15:29	5	1,197
12/10/2022 15:33	5	1,201

*Positive flow indicates outgoing ebb tides.

Figure 3-3 Flow data collection locations

3.4 Rhodamine WT dye releases

To simulate pollutant advection and dispersion in the Hastings River, five Rhodamine WT dye releases were performed on the first day of the field campaign (refer to WRL TR2023/32 Section 4.4 for methods). These are summarised in Table 3-2, with locations shown in Figure 3-4. The initial release concentration was 200,000,000 ppb in all instances. These dye release experiments differed from later releases completed on other estuaries in that the boat attempted to follow the peak of the plume, rather than completing transects. This method was changed in subsequent fieldwork on other estuaries as it was found to be difficult to locate the peak of the plume, however, the data collected was still sufficient to meet the needs of this study.

Table 3-2 Summary of dye releases

No.	Date	Time released	Tracked until	Volume of dye released (mL)	Location	Tide
1	11/10/2022	8.08am	9.26am	500	Confluence of Kooloonbung Creek and Hasting River	Flood
2	11/10/2022	9.58am	10.56am	500	Upstream of Settlement Point ferry	Flood
3	11/10/2022	1.27pm	2.20pm	500	Adjacent to Settlement Shore canal estates in Hastings River Channel	Ebb
4	12/10/2022	8.30am	9.58am	500	Back channel, upstream of moored boats	Flood
5	12/10/2022	1.55pm	2.40pm	500	Adjacent to Settlement Shore canal in Hastings River Channel	Ebb

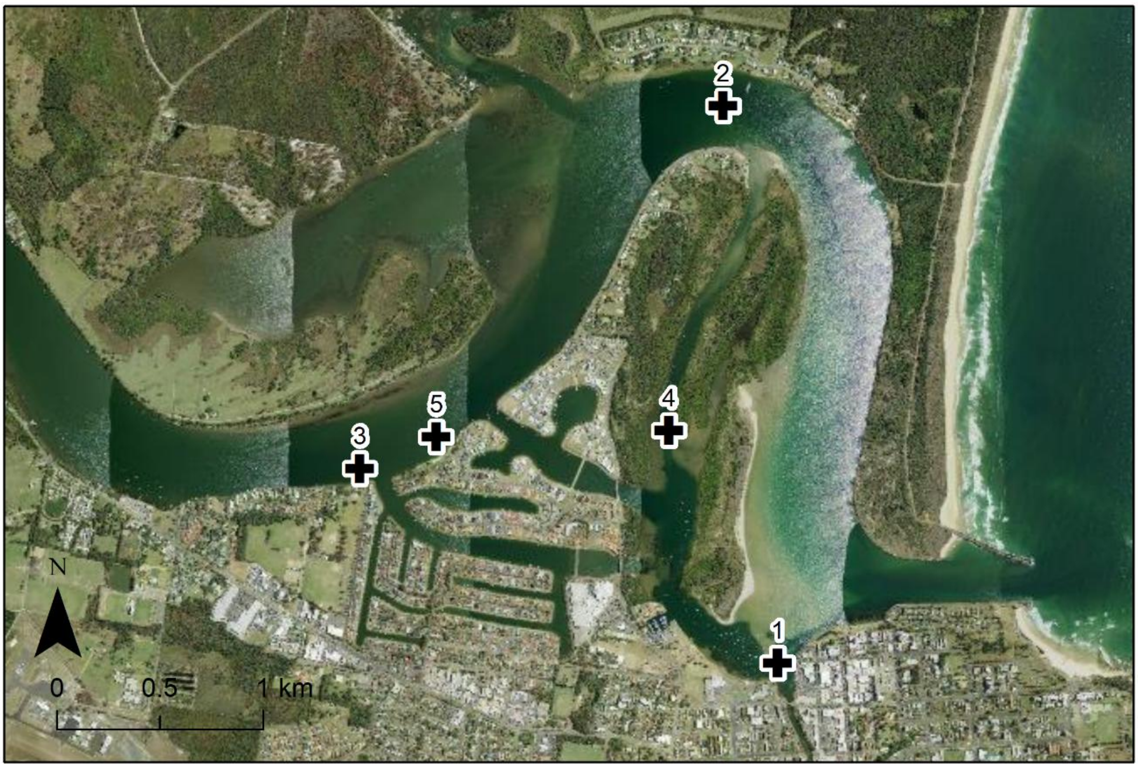

Figure 3-4 Rhodamine WT dye release locations

3.4.1 Release 1 – Confluence of Kooloonbung Creek and Hastings River

Dye release 1 was completed to understand the transport of pollutants that are discharged through Kooloonbung Creek (where the Port Macquarie WWTP overflows). The dye release occurred on an incoming tide to improve the understanding of potential transport towards the oyster harvest areas near Big Bay. The dye was released at 8.08am and dye concentrations were observed for 1 hour 20 minutes following release. Figure 3-5 shows the observed dye concentrations over the period of monitoring, with the maximum concentration observed every 10 minutes highlighted.

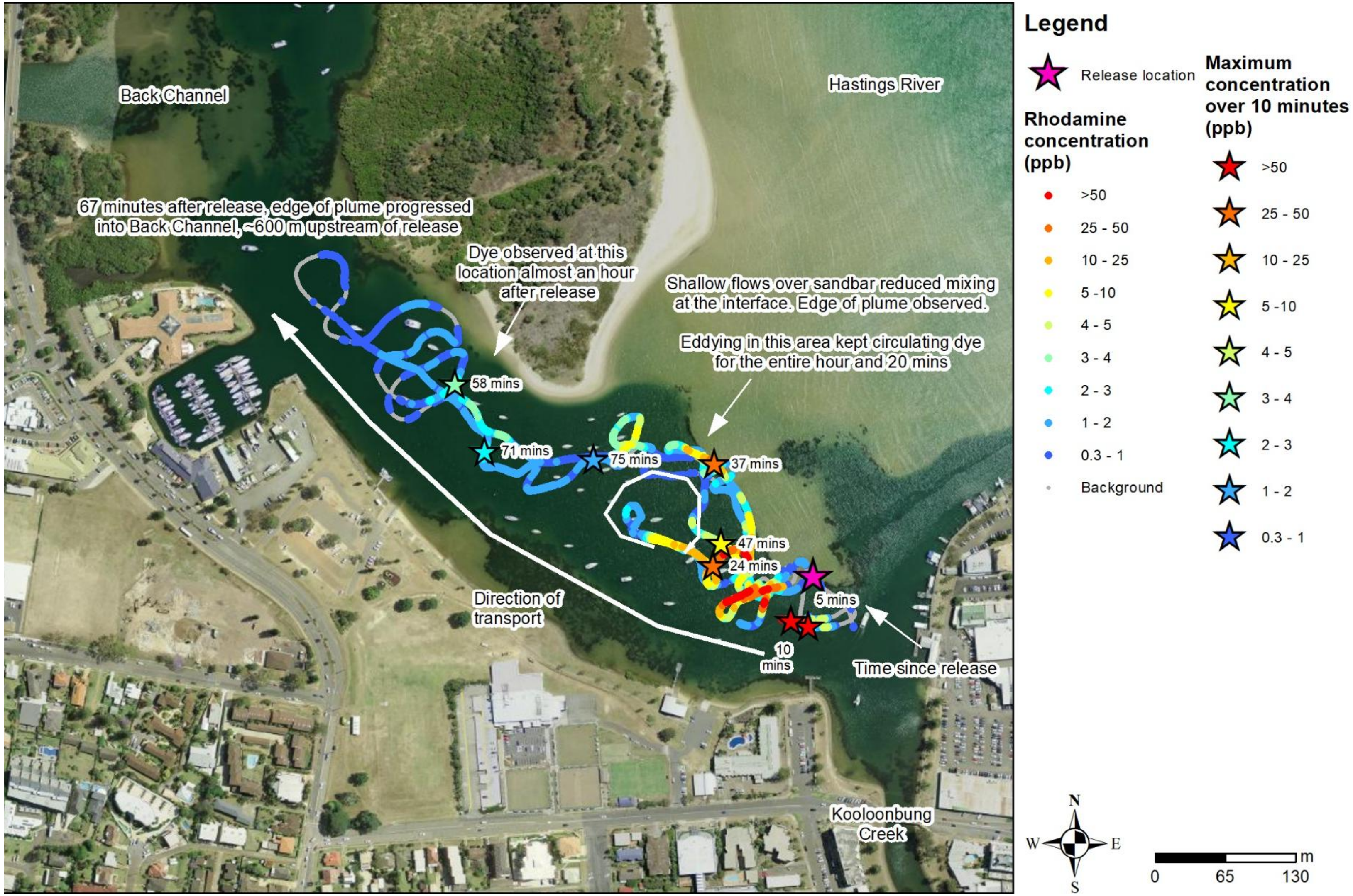

Figure 3-5 Dye release 1 at Kooloonbung Creek. All observed concentrations (circles) and maximum concentration observed every 10 minutes (stars, with time of observation highlighted)

To the northeast, at the confluence with the Hastings River, the plume had a distinct edge (see Figure 3-6), driven by sustained shallow flows over the adjacent sandbar. Almost 40 minutes after the dye release, dye concentrations of 30 ppb were observed at the plume edge at this location. For the period of monitoring, the dye continued to circulate and disperse between Kooloonbung Creek and the southern tip of Pelican Island, with concentrations above 1 ppb observed in that area 75 minutes following the release.

Figure 3-6 Stratified plume edge where saltier water from the Hastings River incoming tide mixed with fresher water

Dye released near the confluence of the Hastings River and Kooloonbung Creek on an incoming tide was observed to transport into Back Channel approximately 50 minutes after the release occurred. However, more than 1 hour after the release, concentrations 600 m upstream of the release point were at the limit of detection of the fluorimeter.

3.4.2 Release 2 – Settlement Point Ferry

Dye release 2 was conducted immediately upstream of the Settlement Point Ferry on an incoming tide at 9.58am on 11 October 2022. The purpose of this release was to improve the understanding of the fate of pollutants originating from the Back Channel. The dye concentrations were tracked for 58 minutes following the release. Figure 3-7 shows the observed dye concentrations over the period of monitoring, with the maximum concentration observed every 10 minutes highlighted.

The dye was observed to disperse more quickly in release 2 in the main channel than was observed in release 1. The plume travelled upstream with the incoming tide, and spread across most of the channel. Dye was observed within approximately 100 m of oyster leases in Big Bay and further transport of dilute rhodamine would have likely been observed further in the harvest areas (no observations were made as the concentrations were near the limit of detection and limited manoeuvrability within the lease areas).

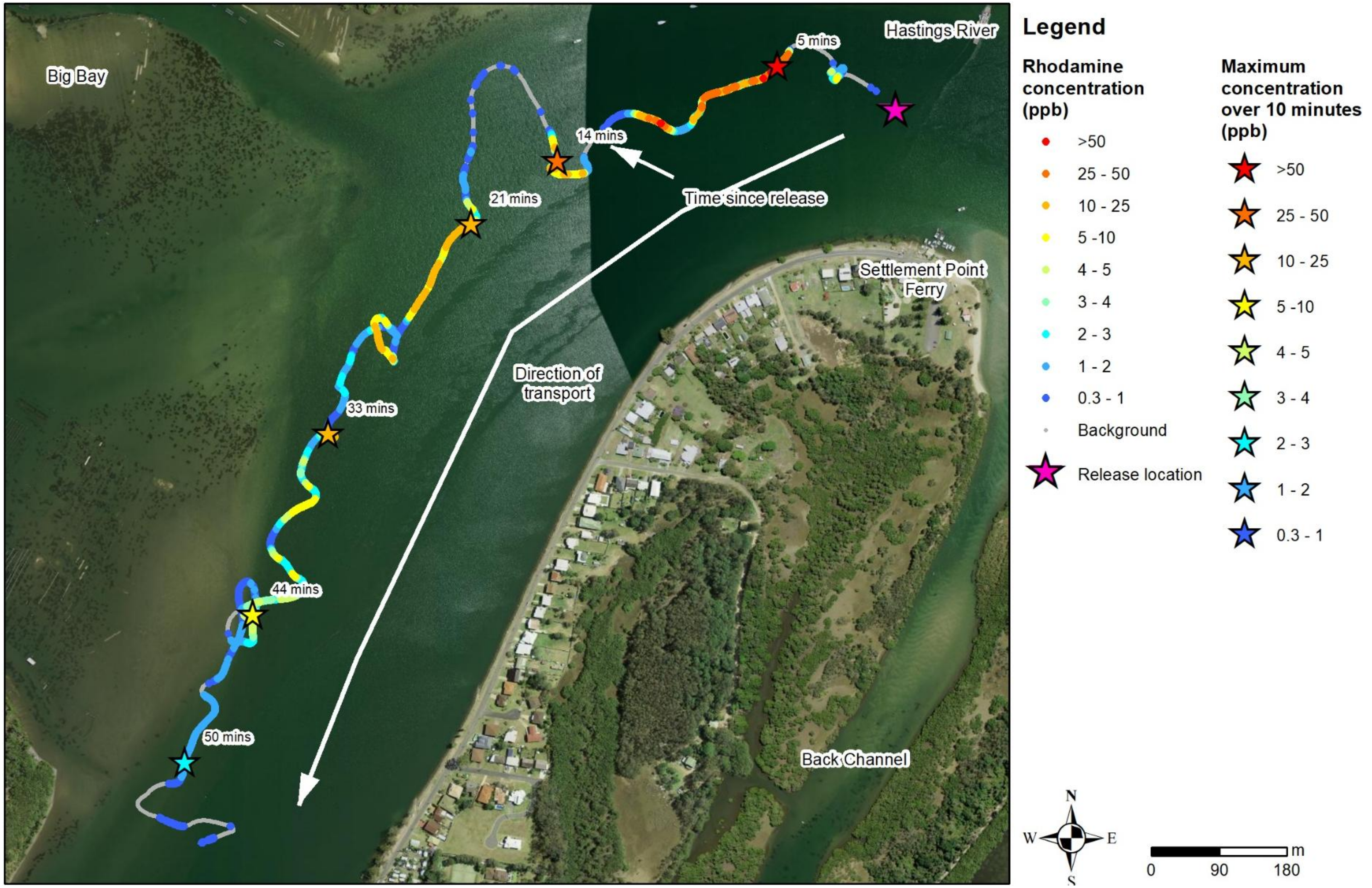

Figure 3-7 Dye release 2 at Settlement Point Ferry. All observed concentrations (circles) and maximum concentration observed every 10 minutes (stars, with time of observation highlighted)

3.4.3 Release 3 – Settlement Shores

Dye release 3 was completed from the canal estates upstream of Big Bay on the outgoing tide on 11 October 2022. However, the C3 fluorimeter malfunctioned and poor quality data was recorded. No results are presented for release 3. Release 5 was conducted as a repeat of this experiment to ensure quality data was collected.

3.4.4 Release 4 – Back Channel

Dye release 4 was completed near the upstream extent of monitoring of release 1 in the Back Channel, on an incoming tide at 8.30am on 12 October 2022. The purpose of this release was to continue to improve the understanding of transport of pollutants from potential overflows from Kooloonbung Creek towards the oyster harvest areas upstream. The dye concentrations were tracked for 88 minutes following the release. Figure 3-9 shows the observed dye concentrations over the period of monitoring, with the maximum concentration observed every 10 minutes highlighted.

As shown in Figure 3-9, the plume moved through the Back Channel over approximately 55 minutes before discharging to the main channel of the Hastings River near Settlement Point Ferry. Dispersion within the channel was slow compared to other releases, with the plume being advected at relatively high concentrations (concentrations above 100 ppb observed 17 minutes after the initial release). The plume was transported past oyster leases in the channel (see Figure 3-8). Once the plume reached the Hastings River (at concentrations of 2 ppb) it rapidly dispersed across two thirds of the channel in approximately 15 minutes, close to leases within Big Bay at Lower Limeburners Creek.

Figure 3-8 Dye release 4, shortly after the release

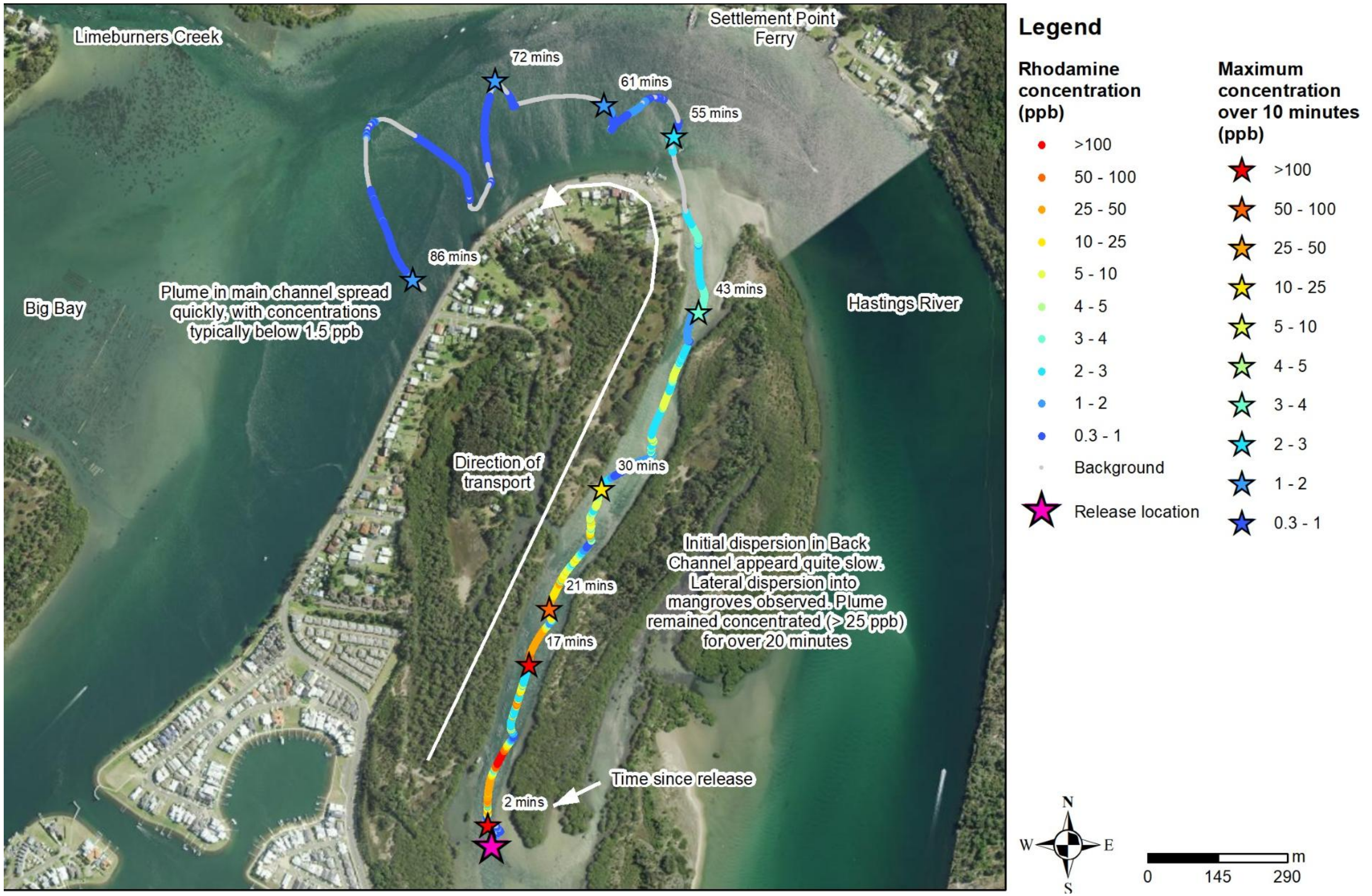

Figure 3-9 Dye release 4 in the Back Channel. All observed concentrations (circles) and maximum concentration observed every 10 minutes (stars, with time of observation highlighted)

3.4.5 Release 5 – Settlement Shores

Dye release 5 was a repeat of release 3 from near the Settlement Shores canal estate on an outgoing tide. The release occurred at 1.55pm on 12 October 2022. The purpose of this release was to improve the understanding of potential overflows originating from the canal estate waterways to nearby oyster harvest areas. The dye concentrations were tracked for 45 minutes following the release. Figure 3-11 shows the observed dye concentrations over the period of monitoring, with the maximum concentration observed every 10 minutes highlighted.

In the first 15 minutes, the dye plume was observed to spread over almost 50% of the channel, with maximum concentrations of 75 ppb 50 m away from the south-east bank. Here the plume has a distinct edge near where the channel deepened close to the bank (Figure 3-10). As highlighted in Figure 3-11, the plume spread away from the south-east bank about 1.5 km downstream of the release point, approximately half way across the entrance to Big Bay.

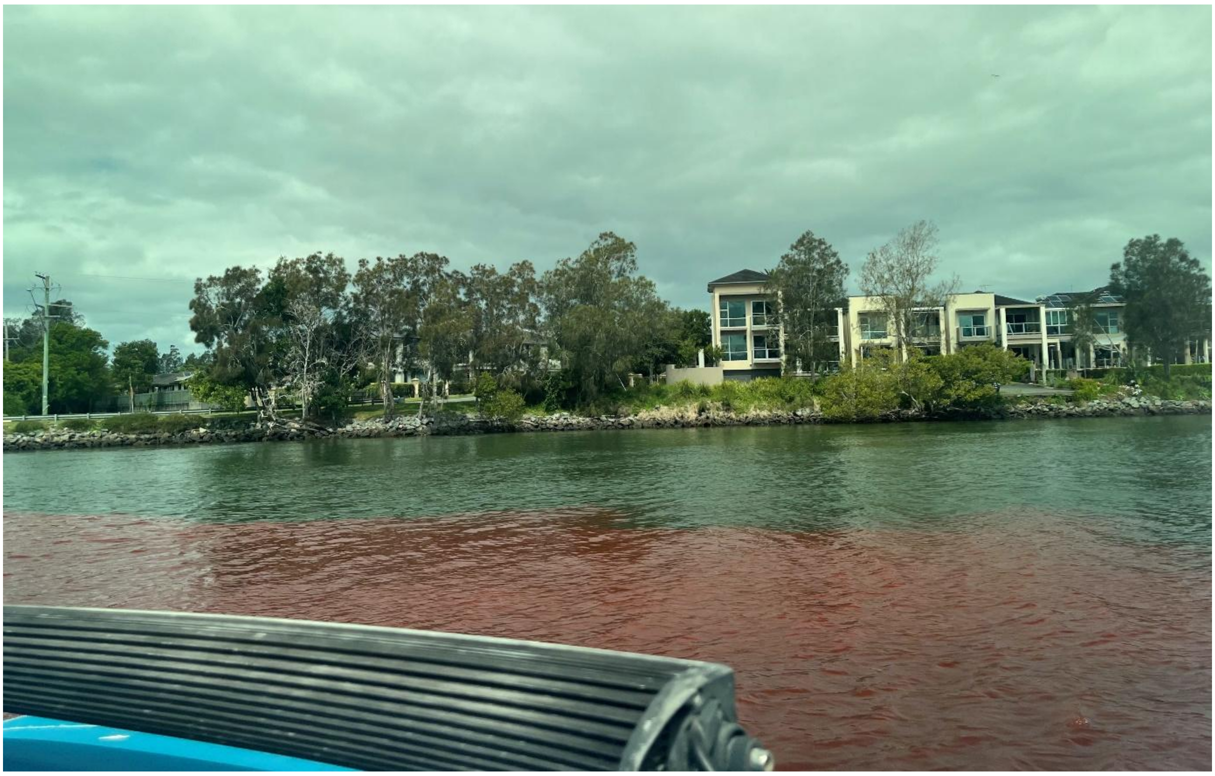

Figure 3-10 Approximately 15 minutes into the release a distinct plume edge was observed 50 m away from the south-east bank

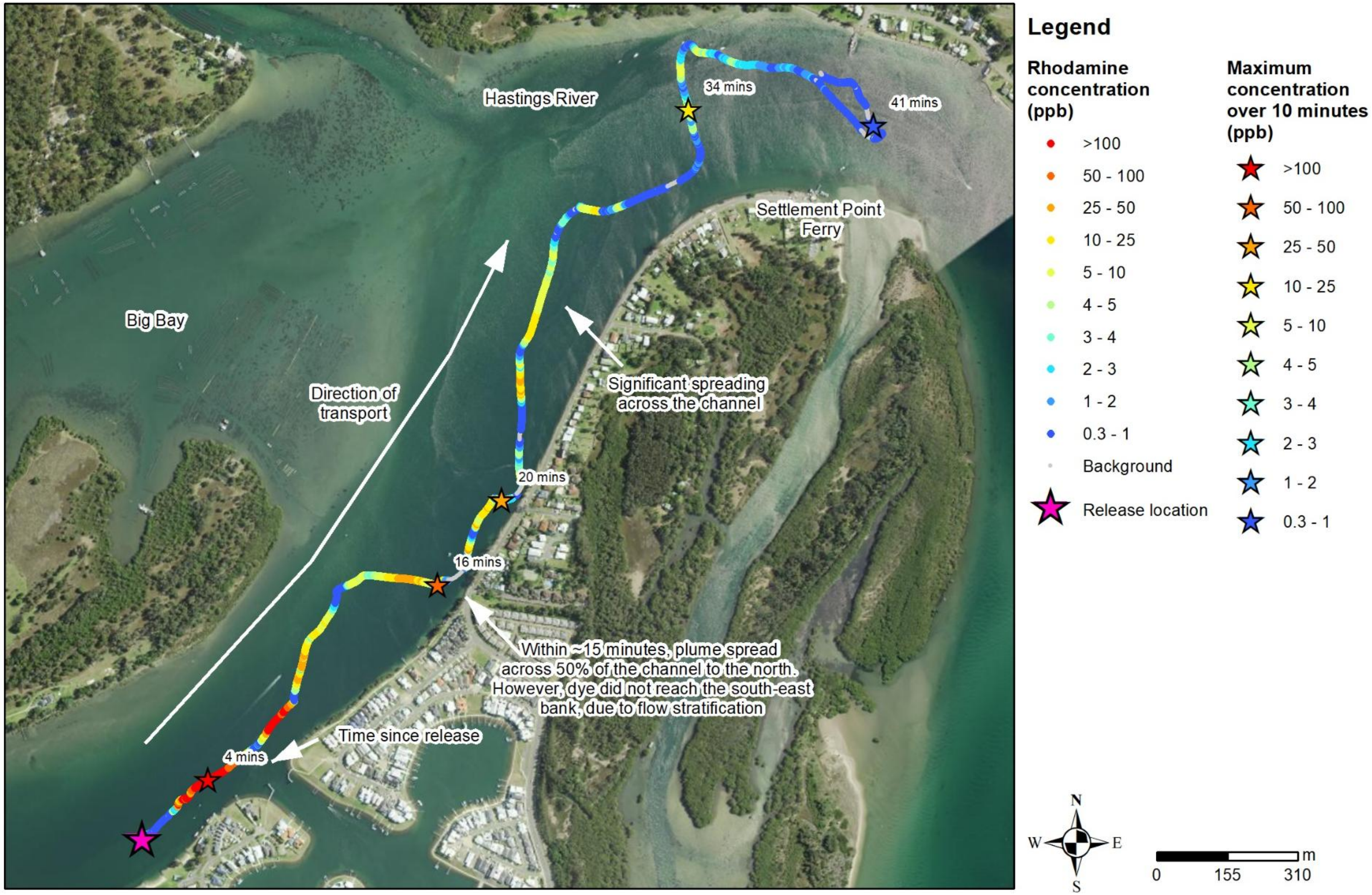

Figure 3-11 Dye release 5 at the Settlement Shores canal estate. All observed concentrations (circles) and maximum concentration observed every 10 minutes (stars, with time of observation highlighted)

3.4.6 Field derived dispersion values

Field dye experiments were used to obtain estimates of plume spreading dispersion rates in the Hastings River, using the methods described in WRL TR2023/32 Section 7.3. Unlike on other estuaries, transects were not completed during the Hastings River dye release experiments (instead the boat attempted to follow the peak of the plume). Therefore, instead of the transect maximum, the maximum concentration measured every 10 minutes was extracted and compared to theoretical estimates of maximum plume concentrations over time. This is shown in Figure 3-12.

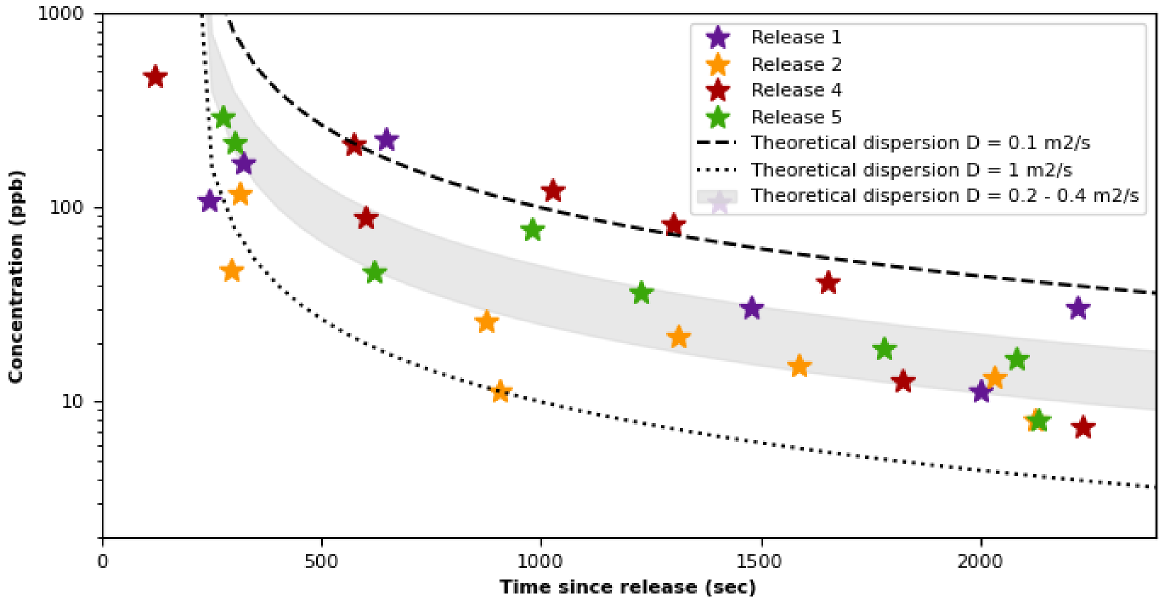

Figure 3-12 Observed dye concentrations compared to theoretical dispersion D=0.1 to 1.0 m^2/s

Measurements of field dispersion across the state for this project showed dispersion was spatially and temporally variable typically between D = 0.1 and 2 m^2/s, with the most common range 0.5 to 1.5 m^2/s, which was consistent in the Hastings River estuary. When comparing the observed peak observations to theoretical dispersion, most field dispersion values fall within D = 0.1 and 1 m^2/s.

3.5 GPS drifter drogue releases

To monitor surface current speeds and flow paths in the Hastings River estuary, GPS drifter drogues were deployed at strategic locations throughout the field campaign. Refer to WRL TR2023/32 Section 4.5 for further information on drifter drogues, however, note that the drogues used on the Hastings River were a different design than those used for other estuaries, shown in Figure 3-13. The design was changed as these were found to be cumbersome and too large for the depths required for this project, making the data difficult to process. However, the data provides the same information as the newer design once it has been carefully processed to remove periods where the drone became stuck. Drogue release timing can be seen in Figure 3-14, while the GPS tracks for the drogue releases are shown in Appendix A1.

Figure 3-13 Drifter drogues before deployment

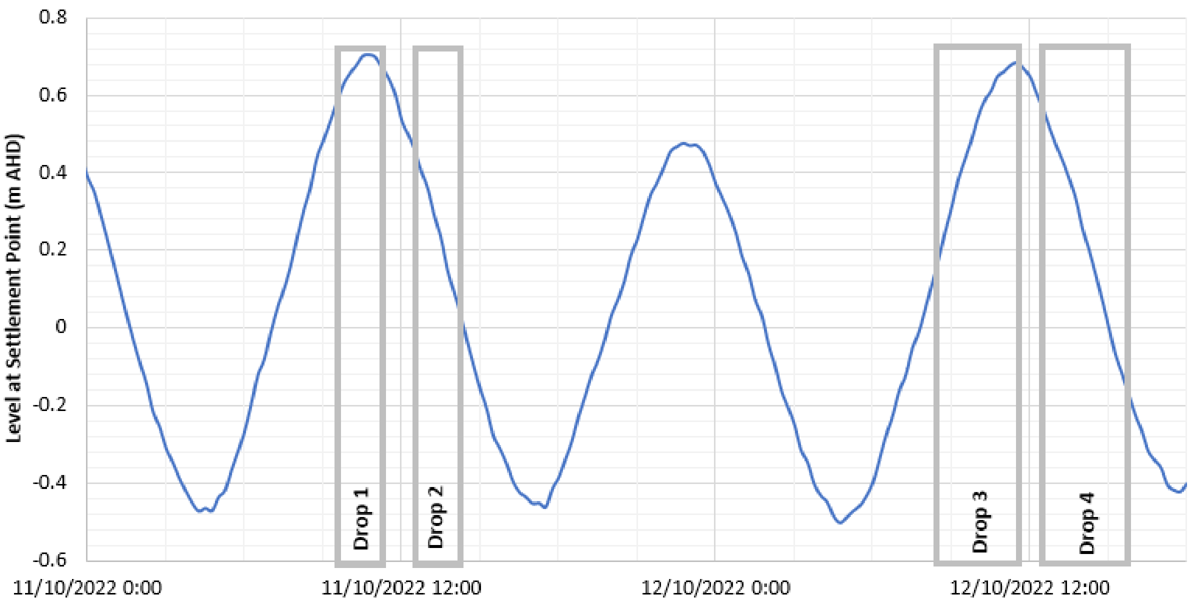

Figure 3-14 Timing of drogue releases

The drogue experiments and observations made included:

- Drogues released across the main channel of the Hastings River approximately 2 km downstream of Settlement Point Ferry on an incoming tide. Where the drogues did not get caught on the river banks, they were typically transported into Big Bay in the Lower Limeburners harvest area.
- Released across the main channel of the Hastings River, near the Hibbard Ferry released on an outgoing tide. Similar to dye release 5, this release showed that all drogues, regardless of release location, ended up along the northern shore of the Hastings River at the Settlement Point Ferry.
- Released in the Back Channel at the same time as dye release 4. Due to the shallow nature of the channel, the drogues were regularly snagged in shallow water depths and mangroves, and the data is unlikely to be representative of current speeds or pathways.
- Released in the main channel of the Hastings River, 750 m downstream of the confluence of Maria River on an outgoing tide. These drogues were observed moving at speeds greater than 1 m/s near Hibbards Ferry. Within 2.5 hours, drogues were observed to travel distances of around 7 km since release.

4 Model development

4.1 Preamble

The model used for this project consists of both a hydrodynamic and a water quality model. Initially, a hydrodynamic pilot model was developed by extending and significantly refining the existing model from Harrison et al. (2023). The pilot model identified data gaps to be targeted during field data collection. After incorporating new data from the field, the hydrodynamic model was iteratively refined through calibration based on the MHL data collection campaign in 1999, and verification based on field data collected for this project in 2022. The hydrodynamic model was then used as an input for the water quality model. This model was informed by dye release experiments and was then used to run sewage overflow scenarios. A schematic of this process can be seen in Figure 4-1. For a detailed overview of the model development used for the broader project, refer to WRL TR2023/32 Sections 6 and 7.

While the model development and calibration of the hydrodynamic model remains unchanged from the original study (WRL TR2022/26), changes to the water quality modelling were included based on the findings of the broader study. This is discussed in more detail in Section 4.7.

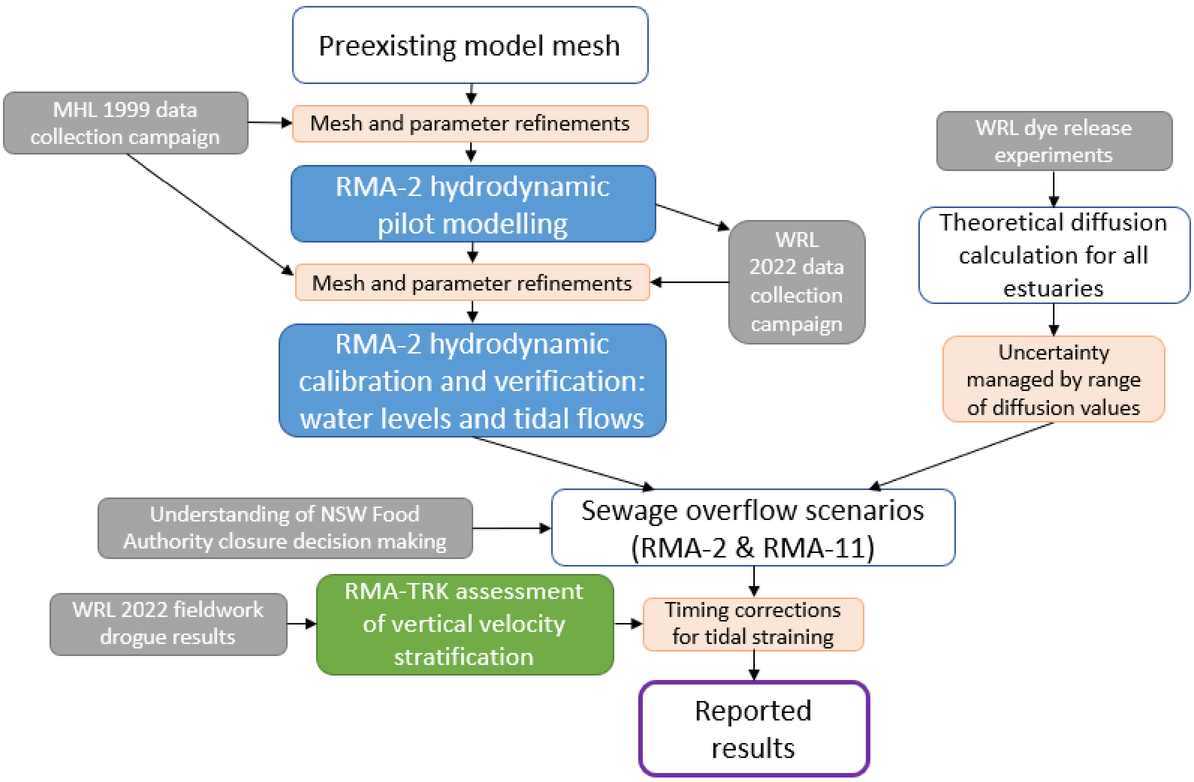

Figure 4-1 Overview of modelling approach

4.2 Model mesh development

The model domain extends from approximately 500 m offshore of the ocean entrance of the Hastings River, to the tidal limits of the estuary and its major tributaries. The model mesh was based on previous modelling, with grid resolution increased in areas downstream of the confluence of the Maria and Hastings River (Blackmans Point), shown in Figure 4-2. The model mesh consists of over 15,000 elements, varying in size from 15 m^2 to over 100,000 m^2. A two-dimensional, depth averaged model mesh was chosen for the Hastings River, where advective transport is largely driven by tidal and riverine flow (not wind). A discussion on the impact of model dimensionality is provided in WRL TR2023/32 Section 6.2.2. Mesh resolution is highest in the lower Hastings River, near both the overflow locations and oyster harvest areas, with lower resolution in upstream reaches. Refer to WRL TR2023/32 Section 6.2.3 for a discussion of model resolution.

4.3 Model bathymetry

Model bathymetry was based on the sources discussed in Section 2.5 and utilised point bed elevation data collected by NSW OEH (now NSW DCCEEW) in 2000, with marine LiDAR data collected by NSW DPIE (now NSW DCCEEW) in 2018 for areas downstream of Settlement Point. The model bathymetry, and nodal bed elevations are shown in Figure 4-3. The deepest sections of the model are in the lower estuary, reaching approximately -10 m AHD. The channel invert in Kooloonbung Creek beneath the Gordon Street bridge was set to 0.1 m AHD (Cardno Lawson Treloar, 2006) and represented as a broad crested weir.

Estuaries are dynamic systems and bathymetric changes through time will alter water levels, velocities, and tidal flows for the same set of boundary conditions. The Hastings River estuary has a trained river entrance, which prevents significant short-term changes in the entrance conditions. A single bathymetry was developed for this model, and used for all model runs. This was shown to result in reasonable model calibration and verification for water levels and flow across the main channel, discussed further in Section 4.6.

4.4 Model boundaries

The model includes four main upstream flow boundaries, shown in Figure 4-2 and discussed in Section 2.3. A tidal elevation boundary was included in the model offshore of the Hastings River (refer to Figure 4-2). This modelled water level boundary was based on observed tidal elevation data collected by MHL at Port Macquarie (station number 207420). This data was then smoothed to remove signal noise to increase model stability. For modelling water quality scenarios, all boundaries (upstream and ocean) were set to a constant constituent concentration of zero (e.g. no pollutant inflows from these boundaries).

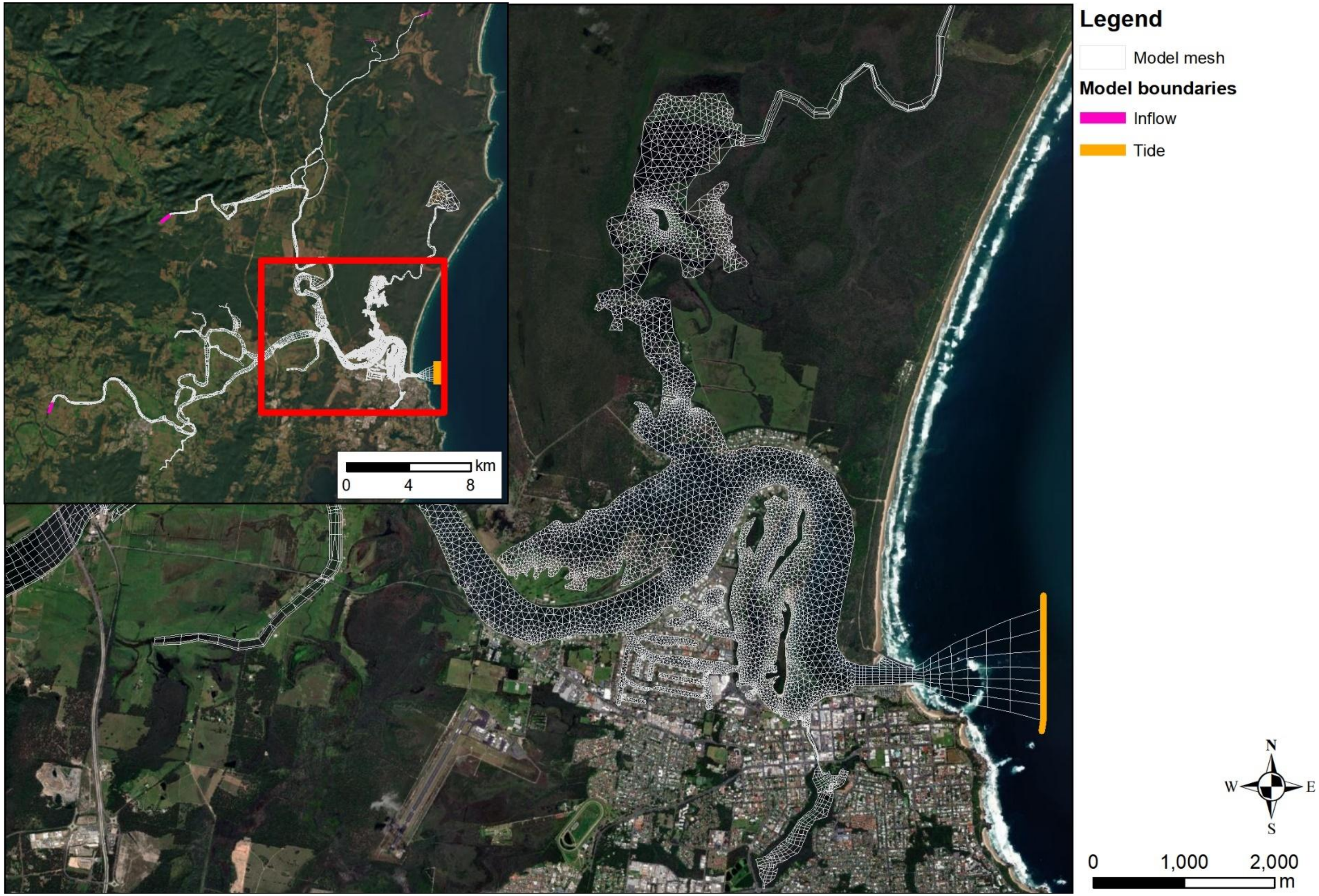

Figure 4-2 RMA model mesh showing boundary condition locations

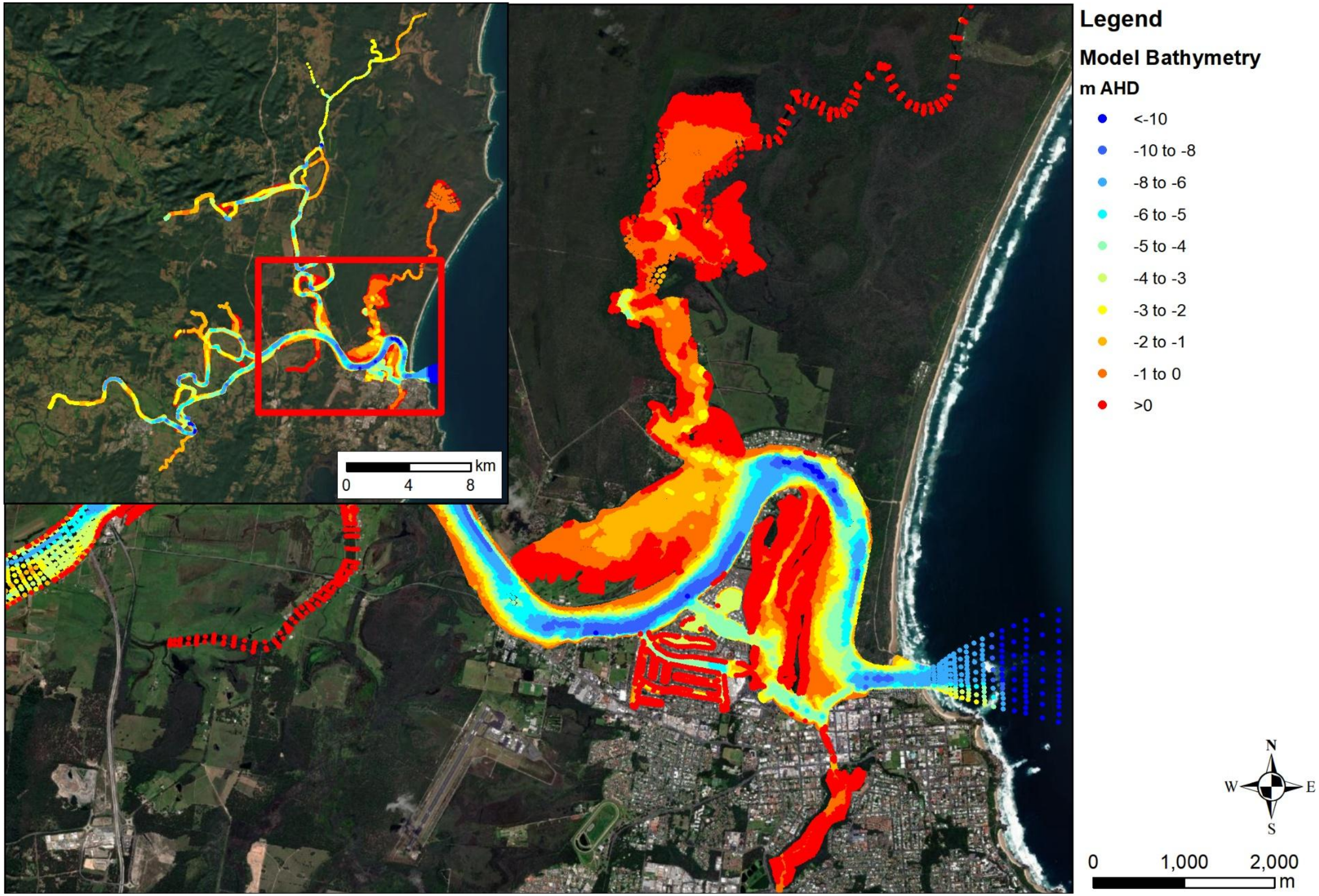

Figure 4-3 RMA model bathymetry

4.5 Pilot model

Initially, a hydrodynamic pilot model was developed using the existing data described in Section 2. For more details on pilot modelling and its purpose refer to WRL TR2023/32 Section 3. This initial modelling was used to identify data gaps to be targeted during fieldwork. The primary gaps identified were dispersion data, information on vertical velocity distributions and modern flow data.

4.6 Hydrodynamic calibration and verification

Hydrodynamic calibration should be based on flow, velocities and water levels at several locations throughout the estuary. For more details on calibration and how models were determined to be fit for purpose refer to WRL TR2023/32 Section 6.4.

Initially the model was calibrated using the hydrodynamic data from the 1999 MHL campaign, then the 2022 WRL data collection campaign period was used to verify the model. Both calibration and verification also considered MHL long term water level gauges available at seven locations in the Hastings River estuary (see Section 2).

4.6.1 1999 Hydrodynamic calibration

The hydrodynamic model was calibrated for flow and water levels across the model domain, primarily using data collected by Manly Hydraulics Laboratory in 1999 (MHL, 1999). The model was run for a 7 week period from 18 October 1999 to 10 December 1999. The model parameters were calibrated to this period. Measured tide levels were applied at the ocean boundary and scaled measured catchment inflows were applied at the four upstream model inflow boundaries. Plots of all observed water level and flow compared with model results are shown in Appendix B1.1 and B1.2.

Water levels were well calibrated to six observation locations across the estuary, with the model able to replicate water levels across the model domain within 3 cm on average. Similarly, the model was also calibrated to tidal flow at nine locations, with the model able to acceptably replicate tidal flow volume and timing. The Nash Sutcliffe Efficiency (NSE) coefficient was used to assess the model's predictive ability for tidal flows, where an NSE of 1 indicates the model perfectly replicates observations, and an NSE of less than 0 indicates poor predictive skill. NSE coefficients greater than 0.94 were observed across the model domain, except at two sites in the upper Maria River. As the tidal flows in this area of the river are small (<25 m^3/s, compared to nearly 1,400 m^3/s at the river entrance), this is not expected to impact the results of the model in the lower estuary.

4.6.2 2022 Hydrodynamic verification

The model was also verified against field data collected in October 2022. The model was run for a two week period (1 October 2022 to 14 October 2022) to replicate the field data collection period. Measured tide levels were applied at the ocean boundary and scaled measured catchment inflows were applied at the four upstream model inflow boundaries. Model results were then compared with the observed data, using the same model parameters used for the 1999 model run. Plots of all observed water level and flow compared with model results are shown in Appendix B1.3 and B1.4.

Water levels across the model domain were still able to well replicate observations, except at Green Valley in the upper Maria River. High tide water levels at this location are significantly over predicted by the model in 2022, indicating there may be some bathymetric (including off channel storage) changes that are not reproduced. However, this site is not located near the oyster leases or sewage overflows and is not anticipated to impact the areas of interest in the model.

4.6.3 Roughness coefficients

Table 4-1 lists the roughness coefficients (Manning's n) which control the frictional losses in the final calibrated model. Most areas have a coefficient between 0.02 and 0.03, which is typical for large sandy channels. The bridge and the Kooloonbung Creek weir have a higher roughness coefficient to account for additional losses due to interactions with the bridge pylons, etc. Additionally, the eddy viscosity coefficient is set to 0.1, rather than 0.5 over the weir.

The roughness coefficient through the entrance, 0.013, is also unusually low. This was necessary as the Port Macquarie tides were used as the driving tides, thus losses through the entrance were already captured.

Table 4-1 Mannings n roughness coefficients of the final model

Location	Manning's n roughness coefficient
Entrance	0.013
Hastings River to Rawdon Island and Limeburner's Creek	0.020
Pacific Highway Bridge	0.100
Hastings River upstream of Rawdon Island	0.023
Intertidal areas	0.060
Maria River and Wilsons River	0.022
Kooloonbung Creek weir	0.140

4.7 Water quality model development

4.7.1 Modelling of dispersion in RMA-11

Dye dispersion experiments, discussed in Section 3.4, provided valuable information on dispersion and its simulation in modelling. In particular, they provided evidence for a sensible range of dispersion coefficients to use in the modelling. However, it was concluded that they could not be used to produce estuary specific values for dispersion.

In this updated version of the study, a range of dispersion values, derived from the field experiments, was used across all the estuaries. This is a deviation to the approach used in WRL TR2022/26, where specific values for dispersion were adopted in the model.

Models were run with two dispersion coefficients, 0.5 and 1.5 m^2/s, and the scenario results presented are a combination of the two to manage the uncertainty in dispersion. This is one source of the small differences between the model results presented here and in WRL TR 2022/26. While the impact on the results vary, the results produced by this modelling typically predict a slightly larger area impacted due to the higher dispersion coefficient tested. For further details on how these dispersion values were determined, sensitivity testing, and how model results were combined refer to WRL TR2023/32 Section 7.3, 7.4 and 8.2.3.

The RMA-11 model utilised a 3 minute timestep, with results output every 12 minutes. High temporal resolution was required in this system due to the high velocities which result in rapid plume movement through the channels.

4.7.2 Tidal straining and vertical velocity distribution

As outlined in WRL TR2023/32 Section 7.5, tidal straining is a process leading to asymmetrical velocity distributions in some estuaries. In instances of tidal straining, much higher velocities are observed at the surface than at the bed on the ebb tide, with much less velocity difference observed on the flood tide. Using the methods described in WRL TR2023/32 Section 7.5, RMA-TRK (Lagrangian model) was used to compare the travel times from field observations with drifter drogues (see Section 3.5) with modelled transport.

The understanding of tidal straining and its implications for this project developed as fieldwork and modelling were conducted on multiple riverine estuaries. Therefore, the initial modelling for this estuary, reported in WRL TR 2022/26, did not correct for tidal straining.

Unlike other estuaries, velocity ratios were not computed for all drogue releases. However, similar modelling completed in WRL TR2022/26 showed that model velocity factors (e.g. the amount the velocity in the models had to be scaled) of around 1.7 were required to match the observed transport of drogues on the ebb tide (see Figure 4-4), which is similar to the ratios observed in other riverine estuaries (such as Nambucca River). Moreover, evidence of asymmetrical vertical velocity profiles was observed at both transect locations where measurements were taken on the ebb and flood tide (see Figure 4-5 and Figure 4-6).

Given this evidence, tidal straining was considered to be a process occurring on the Hastings River estuary. Therefore, the methods described in WRL TR2023/32 Section 7.5 were used to adjust travel times for the Wauchope WWTP overflow location. Other discharge locations were in the lower estuary, immediately adjacent to the oyster harvest areas, and no adjustments are required for these locations.

Because the modelling reported in WRL TR 2022/26 did not correct for tidal straining, the velocity corrections described here and in WRL TR2023/32 Section 7.5 are an update from the earlier modelling and not discussed in WRL TR 2022/26. This change in approach results in some overflows reaching harvest areas faster than originally estimated.

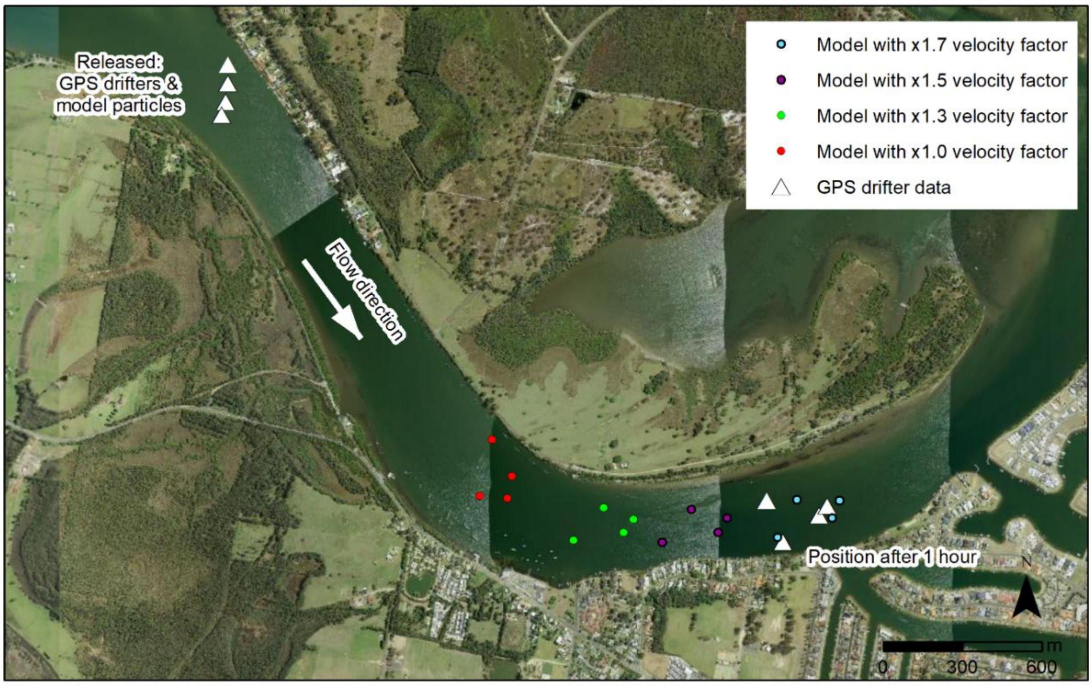

Figure 4-4 GPS drifter drogue data (Drop 4) compared to modelled particles

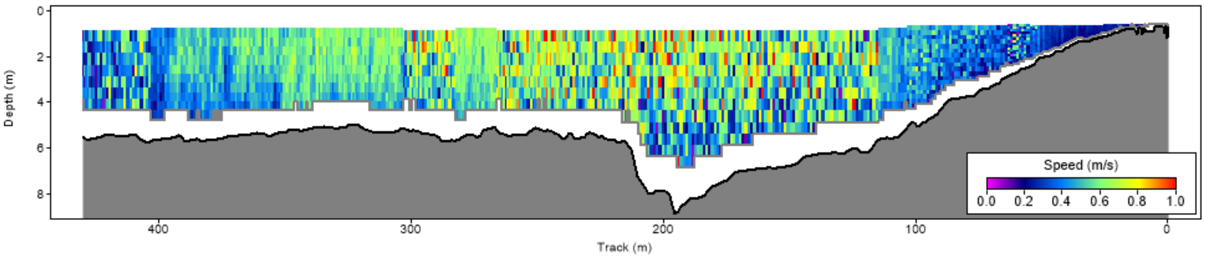

Figure 4-5 Vertical velocity distribution – Location 5 – incoming flow - (2022/10/12 10:49)

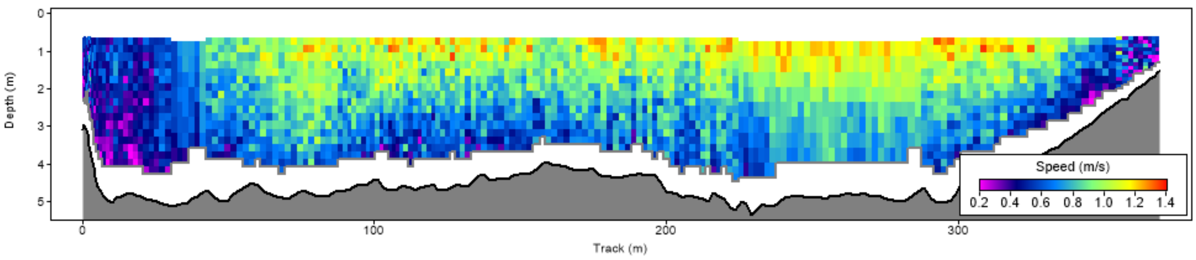

Figure 4-6 Vertical velocity distribution – Location 5 – outgoing flow - (2022/10/12 15:33)

4.8 Limitations for future model uses

This model has been constructed and calibrated to be fit for the purpose of modelling sewage overflow transport from the modelled locations to oyster harvest areas. The model may be adapted for other uses, however the limitations must be considered. A general discussion on the limitations of applying these models to other use cases can be found in WRL TR2023/32 Section 6.6.

Limitations specific to the Hastings River model include:

- Poor fit to the Green Valley site in the upstream Maria River in the 2022 period, indicating there have been changes to the bathymetry in this region since 1999 which are not reproduced in the model.
- Losses through the entrance are not well simulated, as the driving tides are sourced from inside the entrance. These driving tides, coupled with a small roughness coefficient for the entrance, were found to result in a satisfactory calibration and improved results compared to using offshore tides. However, this is a case of equifinality and means the entrance losses are not being accurately simulated in the model. This approach may not be appropriate for use cases where the entrance dynamics are of greater concern, such as informing dredging.
- As discussed in WRL TR2023/32 Section 6.6, the model used for this estuary does not simulate density driven currents or three dimensional processes. This is relevant in this location, where tidal straining is likely to be occurring. This was dealt with in this model by adjusting travel times from upstream overflow locations, however other model use cases require reconsideration of the impacts of tidal straining for the relevant situation.

5 Sewage overflow scenarios

5.1 Preamble

A detailed description for the methods of scenario modelling for this project can be found in WRL TR2023/32 Section 8. For the Hastings River, a total of 108 model scenario simulations were completed, including permutations of:

- Four overflow locations
- Four stages of the tide
- Three catchment inflow conditions
- Three overflow volumes and duration

Reporting focused on the minimum dilution observed in each harvest area (during the 21 day scenario) and the time taken for the plume to reach each harvest area at 5,000,000 times dilution. Refer to WRL TR2023/32 Section 8.3 for more information. In situations where multiple scenarios gave very similar results, these scenarios were grouped for ease of use, and the worst case results (minimum dilution and shortest travel time) were reported, as detailed in WRL TR2023/32 Section 8.3.6.

The results of all modelled scenarios have been compiled into a user-friendly HTML tool. A description of the tool and its use can be found in the User Guide (WRL TR2024/26).

5.2 Overflow locations

Four locations were used to simulate overflow locations into the Hastings River estuary. These locations were based on historical overflow events (Section 2.4) and input from NSW Food Authority and are unchanged from WRL TR2022/26. These locations typically correspond to creek lines or infrastructure where sewage may be directed to following an overflow. The model only considers overflows from the moment they enter the estuary surface water system. Containment prior to reaching the estuary may still be effective. A judgement of whether the overflow reached the estuary should be made in consultation with local authorities to determine if the modelled scenarios need to be considered. Moreover, in situations where there is a delay between the overflow occurrence and the time it reaches the estuary, this delay and related uncertainty needs to be considered when determining which stage of the tide scenario to use. If it is uncertain which scenario timing should be used, use the possible timing which results in the worst case scenario. Modelled overflow locations are shown in Figure 5-1.

At each overflow location, three different overflow conditions were considered:

1. 10 kL overflow over 1 hour (10 kL/hr)
2. 30 kL overflow over 3 hours (10 kL/hr)
3. 100 kL overflow over 10 hours (10 kL/hr)

The rate of discharge (10 kL/hr) was kept constant between each condition. This is equivalent to a rate of approximately 3 L/s. Note that these volumes differ from the original modelling to replicate the approach in the other 10 estuaries for ease of use. Intermediate results can be inferred for overflows of the same duration, but a different volume. See WRL TR2023/32 Section 8.3.3 for details on how to do this.

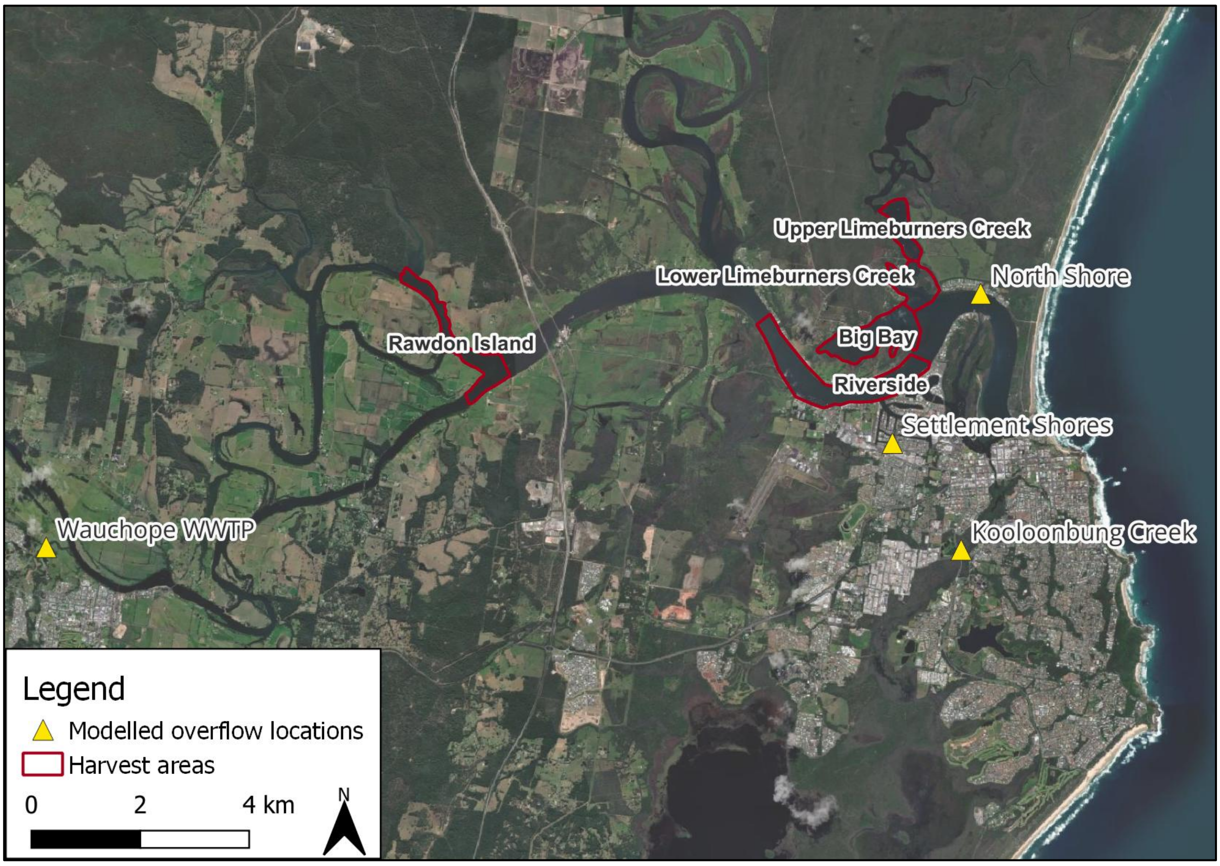

Figure 5-1 Modelled overflow locations in the Hastings River estuary

5.3 Environmental variables

Two environmental variables were tested for the Hastings River:

1. Stage of the tide (slack low tide, slack high tide, mid ebb tide and mid flood tide)
2. Magnitude of catchment inflows (median, 80th percentile and 95th percentile)

5.3.1 Stage of the tide

Stage of the tide for all locations is indexed to the MHL water level gauge, via the relationship described in Table 5-1. The timing of the stage of the tide has been updated slightly from WRL TR2022/26 to use the same method as the other 10 estuaries for ease of use.

Table 5-1 Model stage of tide timing relative to the MHL water level gauges

Overflow location	Results scenario	MHL water level gauge	Water level at start of spill
Kooloonbung Creek, North Shore and Settlement Shores	Slack high tide	Settlement Point (207418)	High tide
Kooloonbung Creek, North Shore and Settlement Shores	Mid ebb tide	Settlement Point (207418)	Half way between high and low
Kooloonbung Creek, North Shore and Settlement Shores	Slack low tide	Settlement Point (207418)	Low tide
Kooloonbung Creek, North Shore and Settlement Shores	Mid flood tide	Settlement Point (207418)	Half way between low and high
Wauchope WWTP	Slack high tide	Wauchope Railway Bridge (207401)	High tide
Wauchope WWTP	Mid ebb tide	Wauchope Railway Bridge (207401)	Half way between high and low
Wauchope WWTP	Slack low tide	Wauchope Railway Bridge (207401)	Low tide
Wauchope WWTP	Mid flood tide	Wauchope Railway Bridge (207401)	Half way between low and high

The stage of the tide is only important for overflows from North Shore, where overflows of 3 h or less occurring on a high tide are able to leave the estuary entirely before the turn of the tide. Overflows on a mid ebb tide partially leave the estuary, leading to better outcomes than overflows on incoming tides. Overflows from other locations are either into slow moving areas (Kooloonbung Creek and Settlement Shores) or far enough upstream (Wauchope WWTP) that tide does not have a substantial effect on results. Results for these locations, where overflows on different stages of the tide resulted in functionally identical results, were grouped by tide. See WRL TR2023/32 Section 8.3.4 for more details on scenario grouping.

5.3.2 Catchment inflows

The catchment inflows tested have been updated slightly from WRL TR2022/26 to use the same method as the other 10 estuaries (i.e. constant inflows at the upstream boundaries) for ease of use. Catchment inflow had an effect on results from all overflow locations. For the three downstream overflow locations (Kooloonbung Creek, Settlement Shores and North Shore) higher catchment inflows have the potential to reduce upstream plume intrusion, reducing impacts to Rawdon Island. However, higher catchment inflows in the small catchments for Yippen Creek, Kooloonbung Creek and Settlement Shores also mean the overflow is pushed into the main estuary faster, and at a higher concentration, leading to more severe impacts. Thus, for the downstream overflow locations, it is important to check multiple overflow scenarios, as the relationship between catchment inflows and severity of impacts is variable. If there is uncertainty about which scenario to use, refer to the worst case possible scenario. Figure 5-2, Figure 5-3 and Figure 5-4 show an example of the variation in results with different catchment conditions.

For overflows from Wauchope WWTP, increased inflows lead to faster transport out of Yippen Creek and faster transport of the plume downstream in the Hastings River estuary, increasing impacts for higher catchment inflows.

For ease of use, results for different catchment inflow have been combined for scenarios when the implications for harvest areas are not functionally different. See WRL TR2023/32 Section 8.3.4 for more details on scenario grouping.

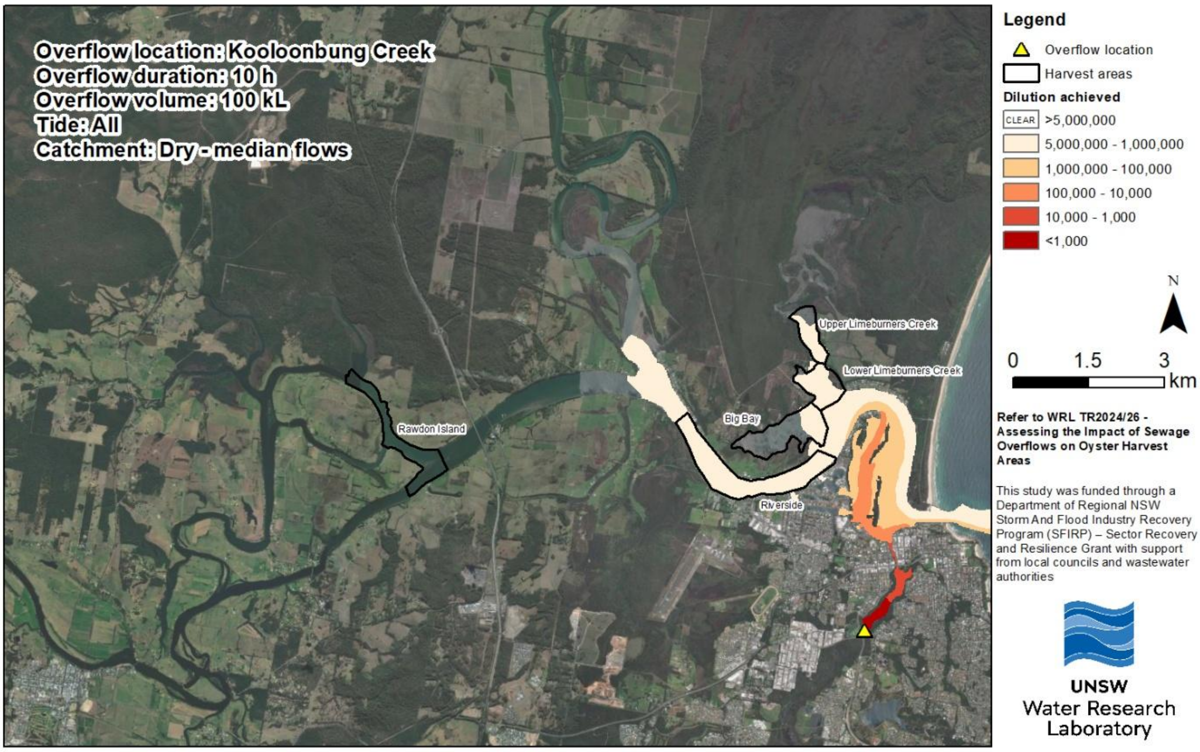

Figure 5-2 Example of a 10 hour overflow at Kooloonbung Creek during median inflow conditions*

*Result figures present the minimum dilution (i.e. maximum concentration) observed at each point during the entire scenario period (21 days).

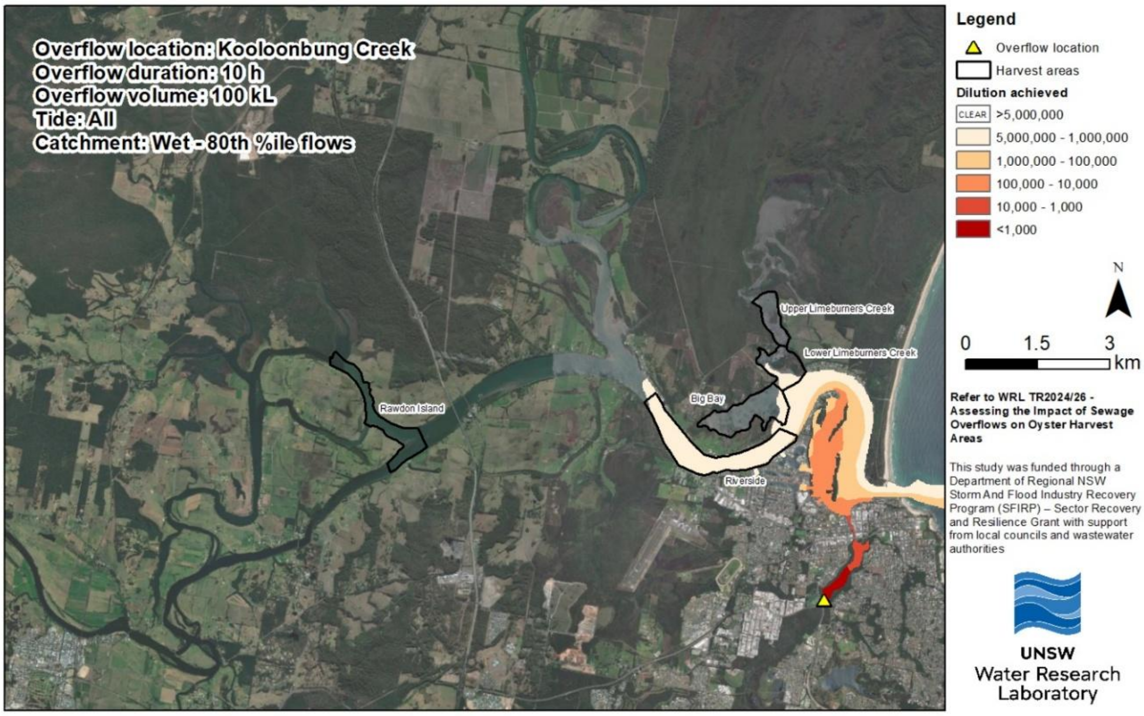

Figure 5-3 Example of a 10 hour overflow at Kooloonbung Creek during 80th percentile inflow conditions*

*Result figures present the minimum dilution (i.e. maximum concentration) observed at each point during the entire scenario period (21 days).

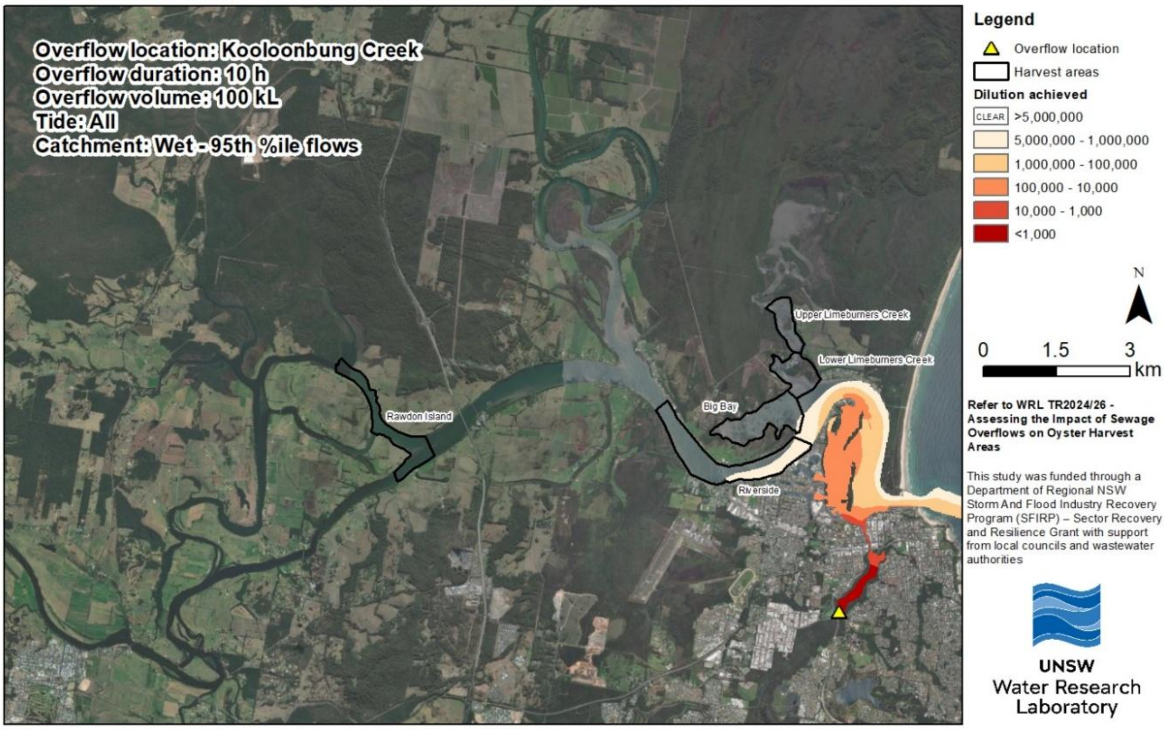

Figure 5-4 Example of a 10 hour overflow at Kooloonbung Creek during 95th percentile inflow conditions*

*Result figures present the minimum dilution (i.e. maximum concentration) observed at each point during the entire scenario period (21 days).

6 Conclusions

This report is focussed on the Hastings River estuary produced for the study “Assessing the impact of sewage overflows on oyster harvest areas in NSW”. The purpose of this report was to provide technical and estuary specific information on the process and data sources used to create the Hastings River estuary model. Key information included in the report relates to the integration of existing data sources, the October 2022 field data collection campaign, data processing, model development, and model verification. If wind is found to be significant for many management decisions on this estuary, further model refinement based on wind should be undertaken.

This report should be read in conjunction with WRL TR2023/32 which provides details on the technical methods used across each of the 11 study estuaries (including the Hastings) and discussions on modelling limitations including model parameter sensitivity and pollutant dispersion. Results of the scenario modelling is available in the accompanying tool, which is documented in the User Guide (WRL TR2024/26).

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7 References

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Appendix A Field data collection

A1 Drifter drogues experiments

The below figures summarise the behaviour of the four drifter drogue experiments. For more information on these deployments, refer to Section 3.5.

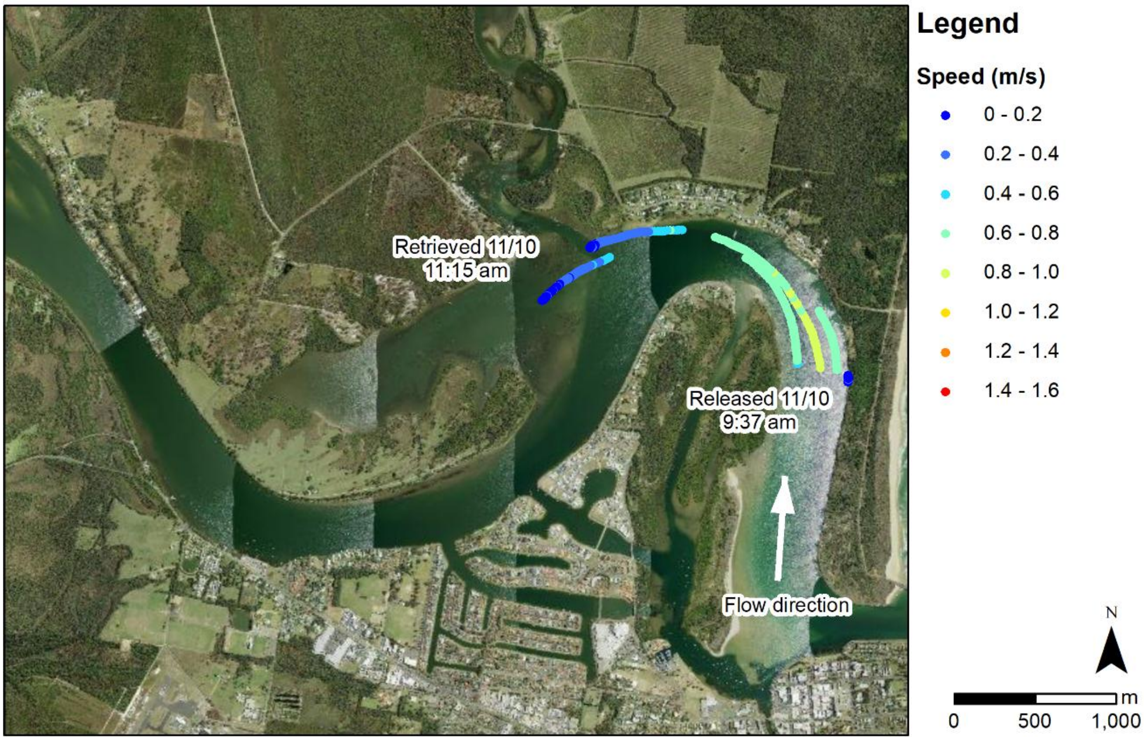

Figure A-1 Drogue drop 1 – incoming tide

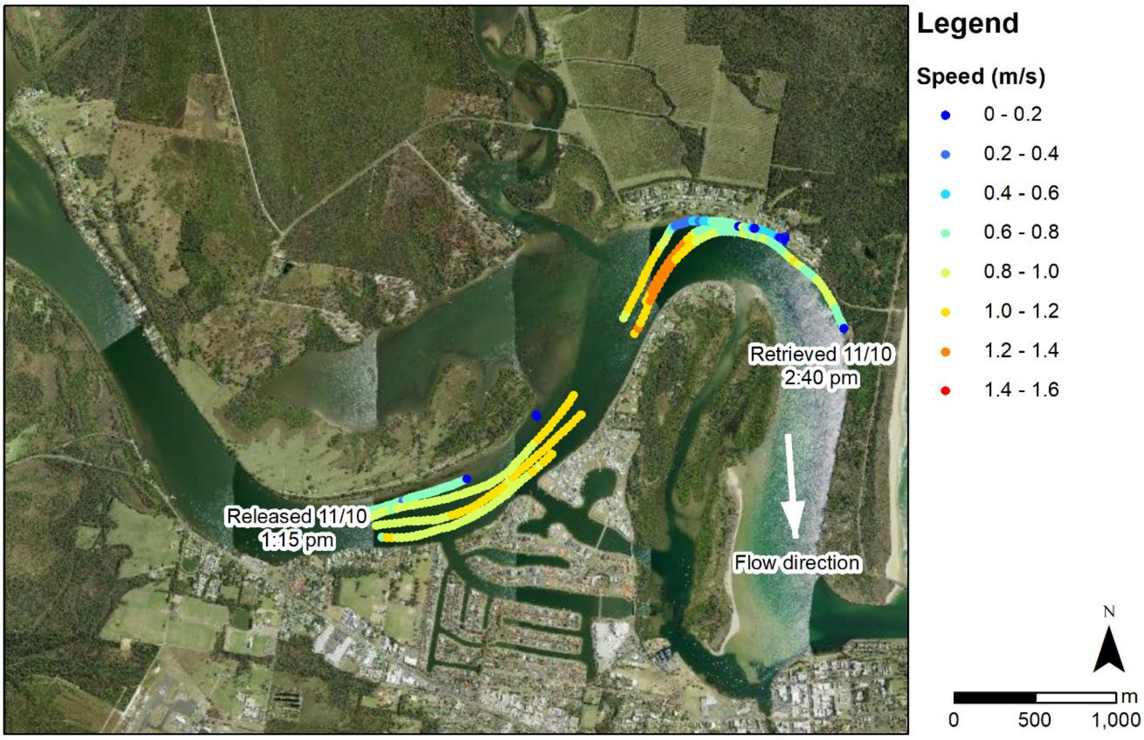

Figure A-2 Drogue drop 1 – outgoing tide

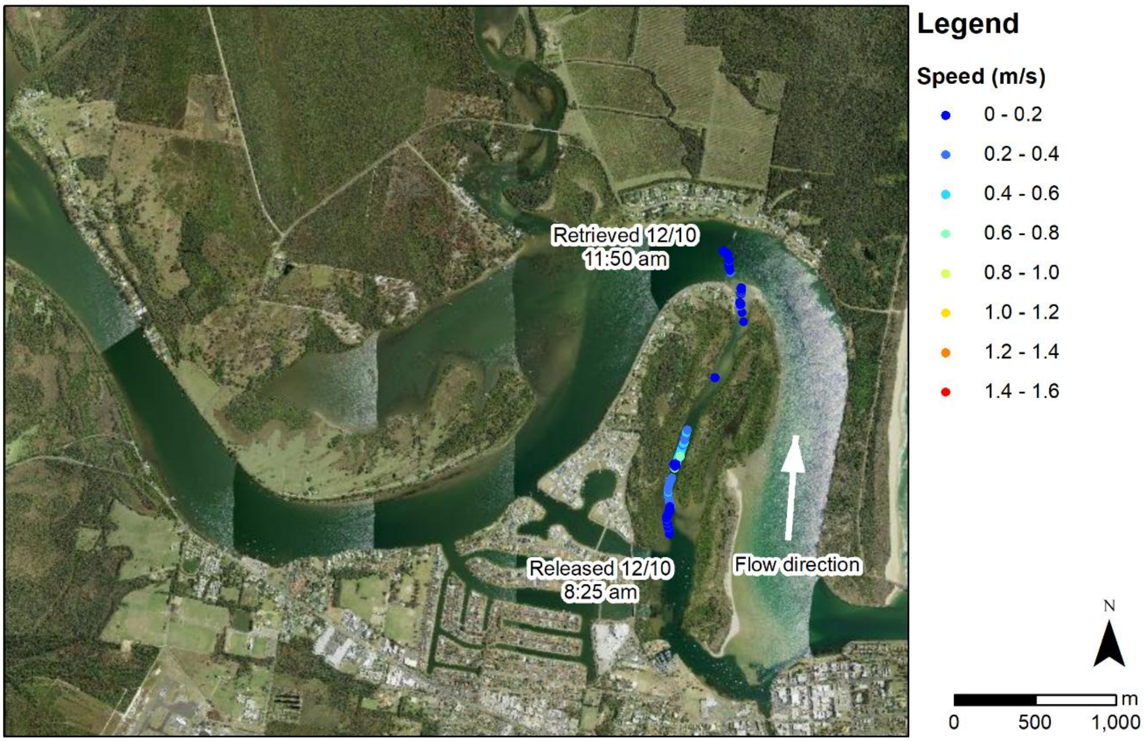

Figure A-3 Drogue drop 3 – incoming tide in the Back Channel

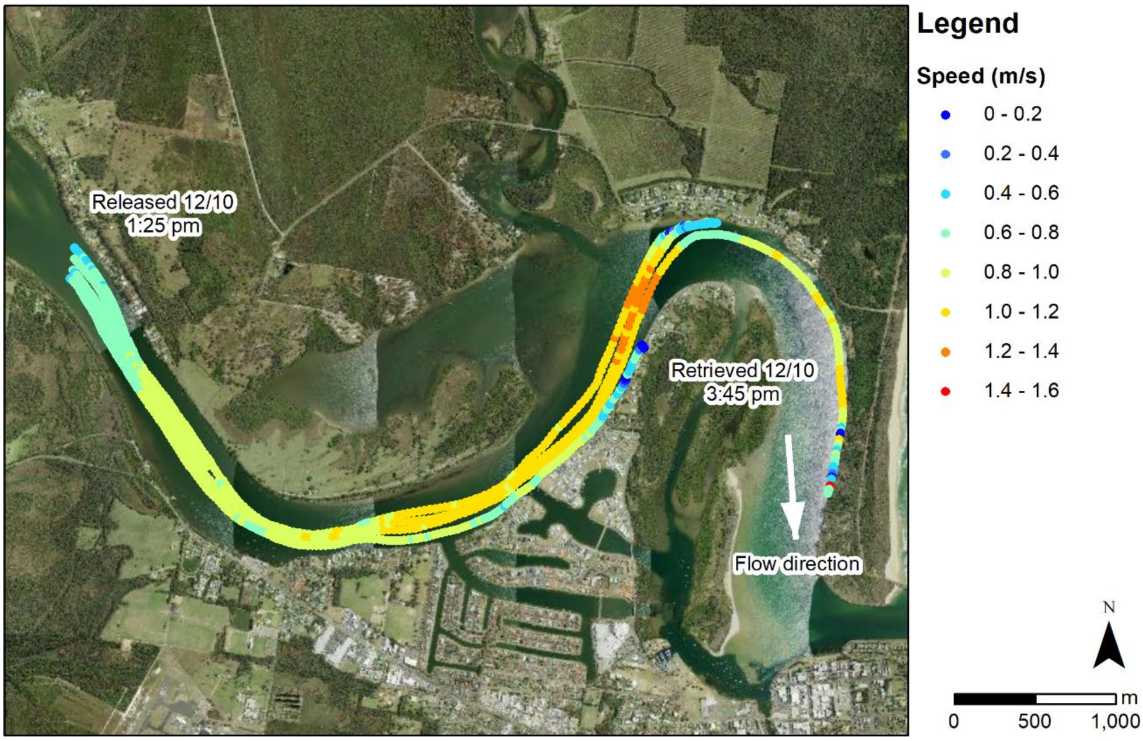

Figure A-4 Drogue drop 4 – outgoing tide

A2 Cross channel velocity distribution

The below figures summarise velocity distribution results from the 2022 field campaign. For more information, refer to Section 3.3. Note that all measurements are at a different stage of the tidal cycle so the magnitude of flow will vary. The primary purpose is to illustrate flow distribution across the channel.

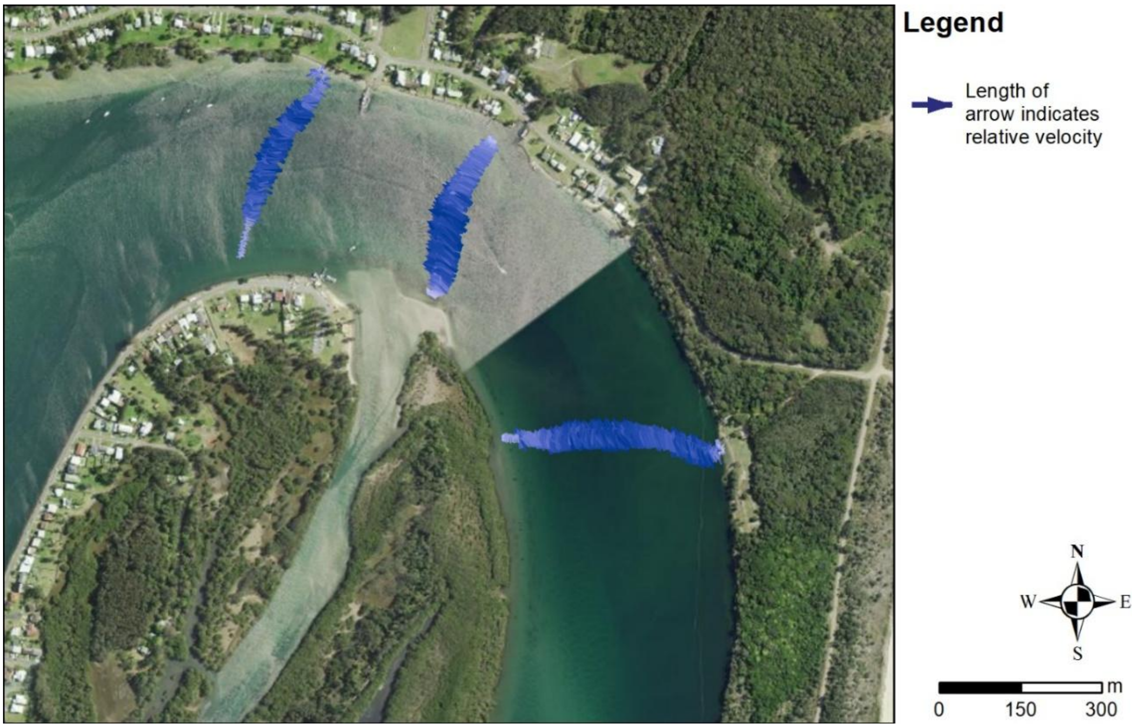

Figure A-5 Velocity distribution on an incoming flood tide

Figure A-6 Velocity distribution on an outgoing ebb tide

A3 Vertical velocity distributions

The following figures show the vertical distribution of horizontal speed for select transects measured during the 2022 field campaign. This was used to help assess whether vertical velocity distributions were significant. For more information, refer to Section 3.3 and 4.7.2. Bathymetry sometimes varies between ebb and flood transects because transects were not always taken at the exact same location due to boat manoeuvrability limitations. Transects were usually taken within a 50 m reach in which flow would be equivalent.

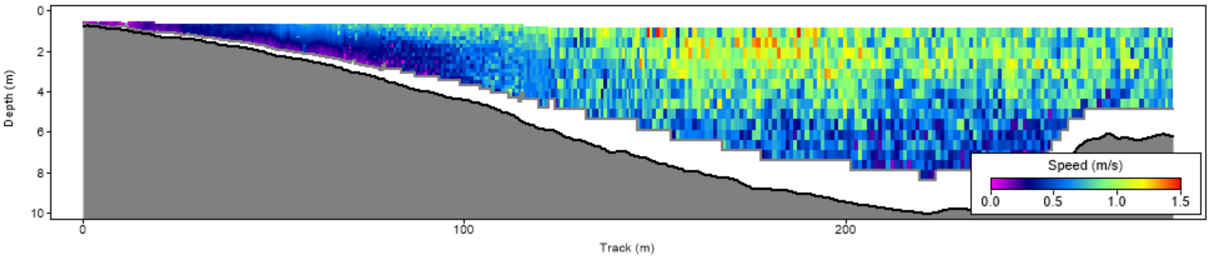

Figure A-7 Vertical velocity distribution – Location 1 – outgoing flow – (2022/10/11 15:25)

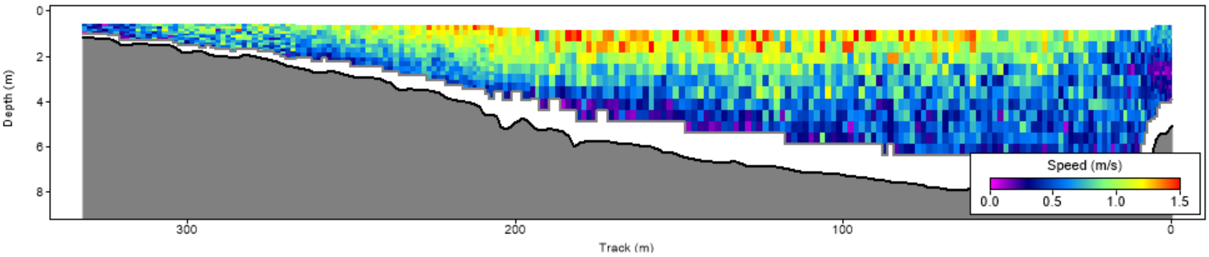

Figure A-8 Vertical velocity distribution – Location 2 – outgoing flow – (2022/10/11 15:36)

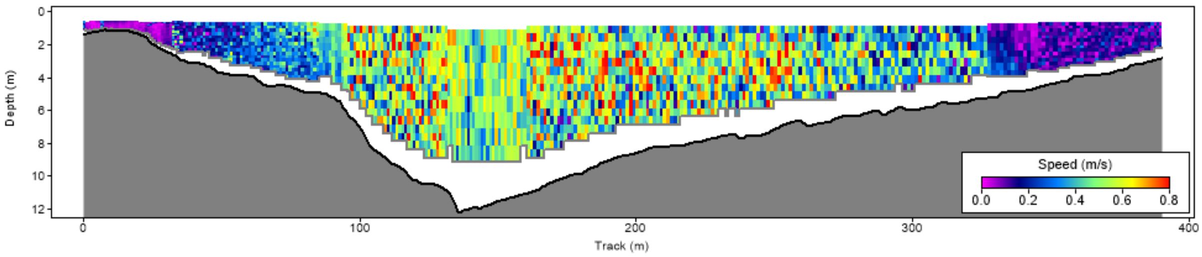

Figure A-9 Vertical velocity distribution – Location 3 – incoming flow – (2022/10/12 11:06)

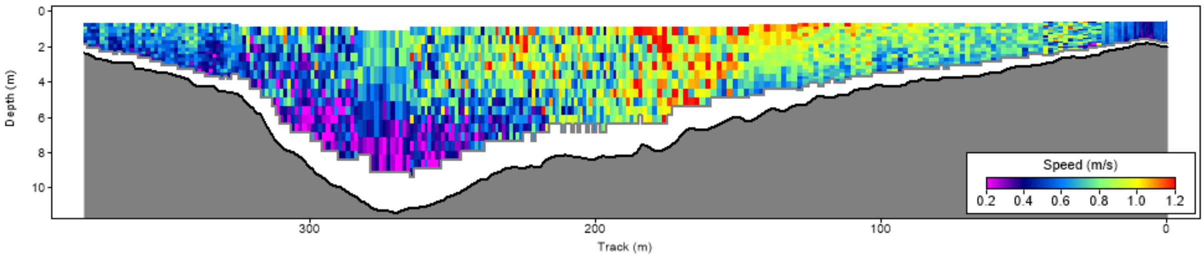

Figure A-10 Vertical velocity distribution – Location 3 – outgoing flow – (2022/10/12 15:06)

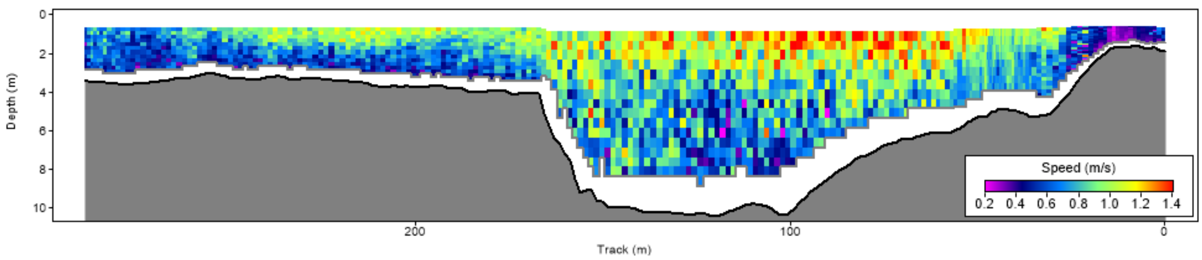

Figure A-11 Vertical velocity distribution – Location 4 – outgoing flow – (2022/10/12 15:17)

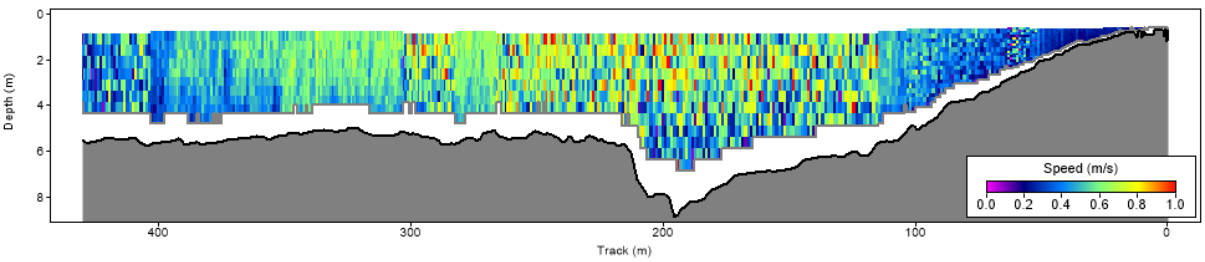

Figure A-12 Vertical velocity distribution – Location 5 – incoming flow – (2022/10/12 10:49)

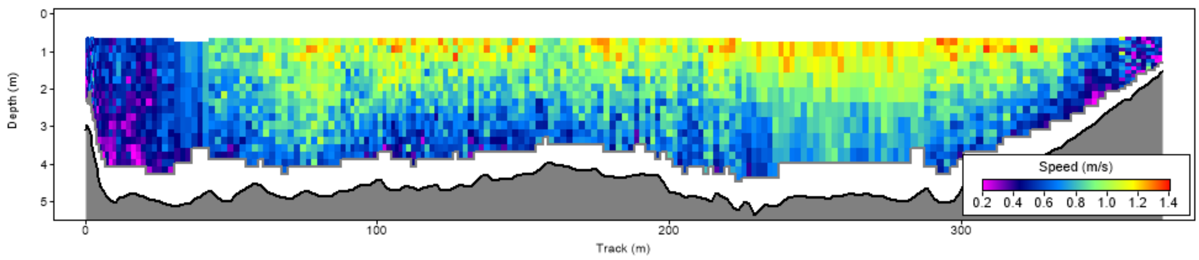

Figure A-13 Vertical velocity distribution – Location 5 – outgoing flow – (2022/10/12 15:33)

Appendix B Model calibration and verification

B1 Model calibration and verification results

The below figures summarise results from the Hastings hydrodynamic calibration and verification process. For more information, refer to Section 4.6.

Figure B-1 Hydrodynamic calibration locations

B1.1 Water level calibration – 1999

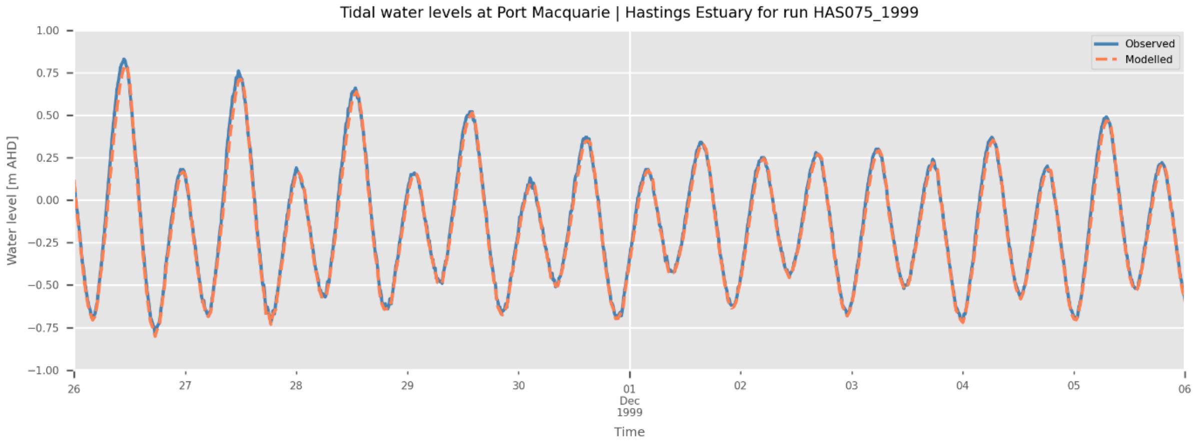

Figure B-2 1999 water level calibration – Port Macquarie

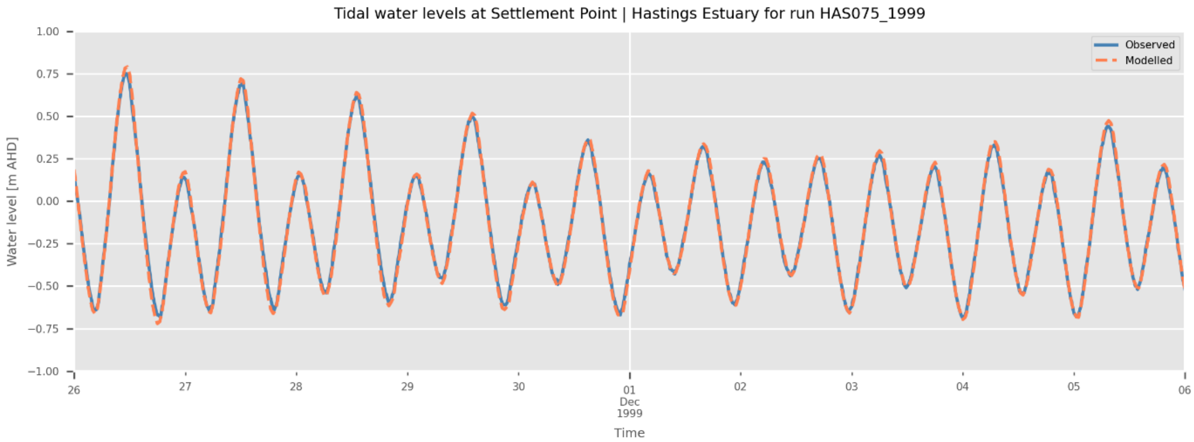

Figure B-3 1999 water level calibration – Settlement Point

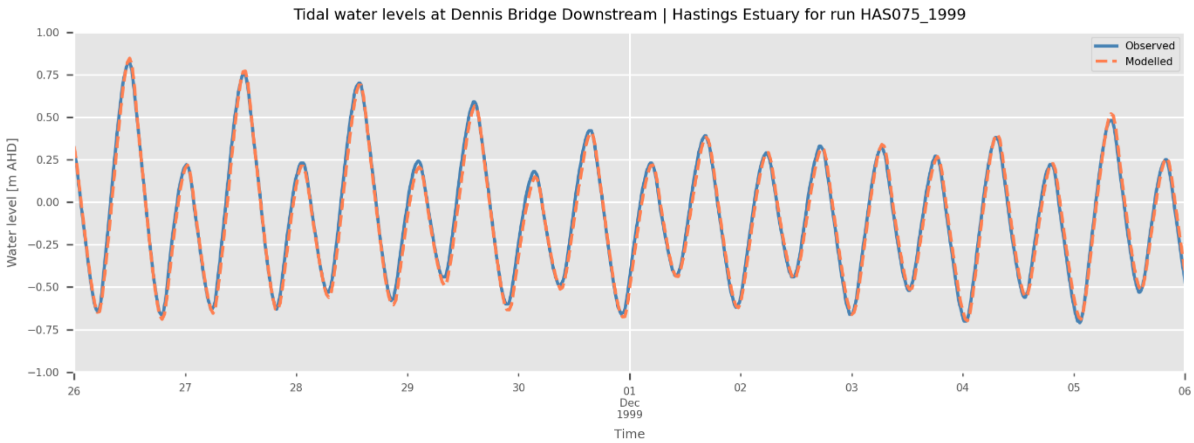

Figure B-4 1999 water level calibration – Dennis Bridge

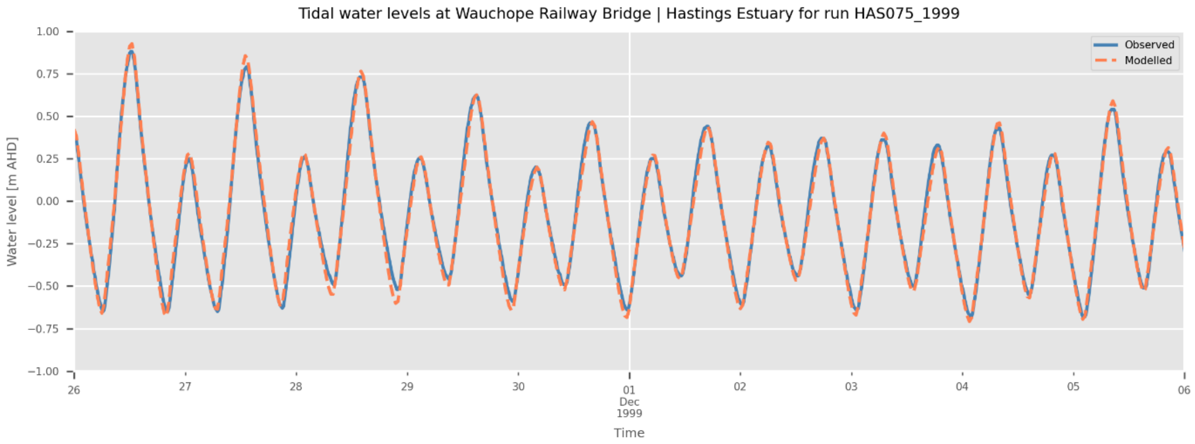

Figure B-5 1999 water level calibration – Wauchope

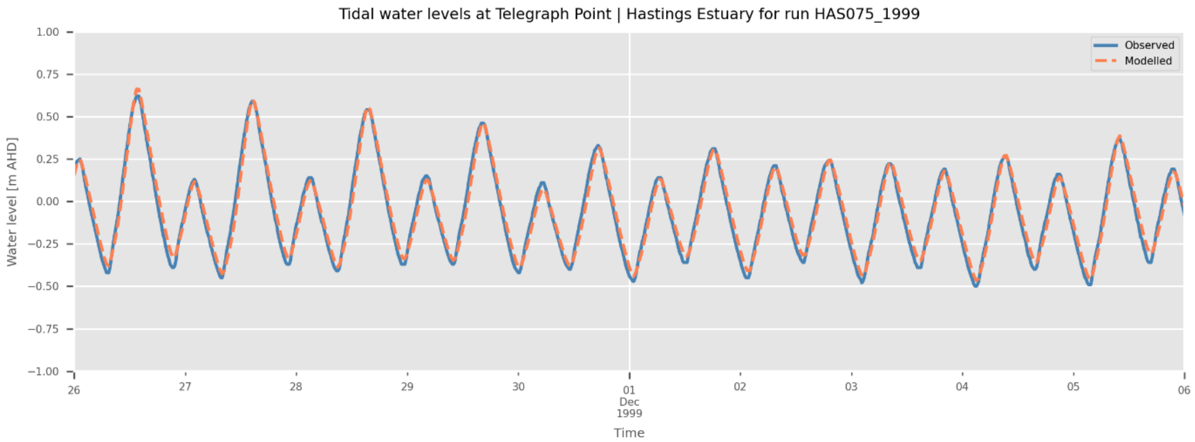

Figure B-6 1999 water level calibration – Telegraph Point

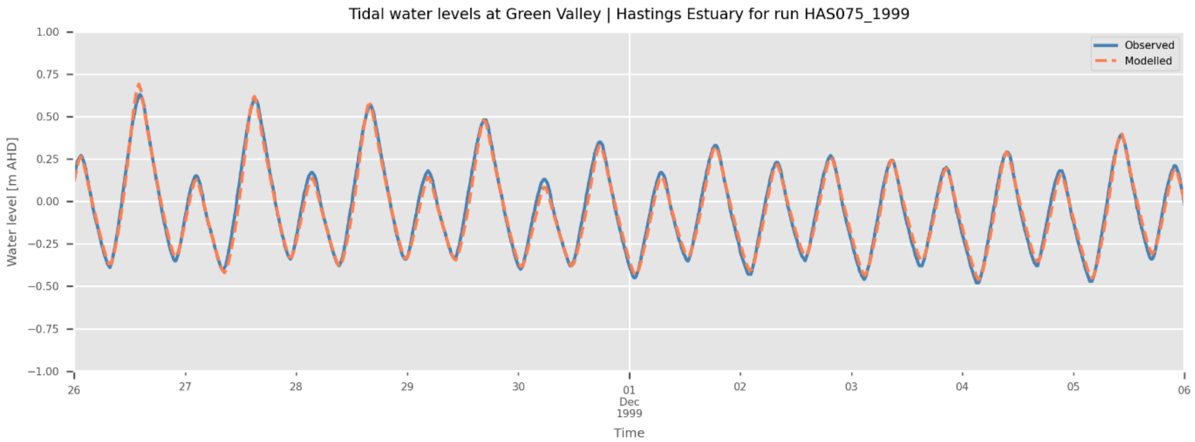

Figure B-7 1999 water level calibration – Green Valley

B1.2 Tidal flow calibration – 1999

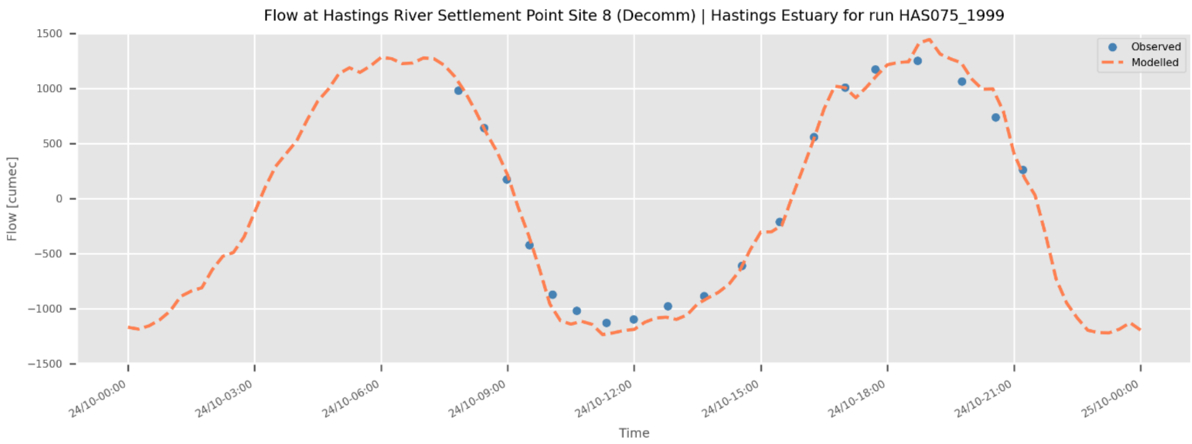

Figure B-8 1999 flow calibration – Settlement Point (MHL (1999) site 8)

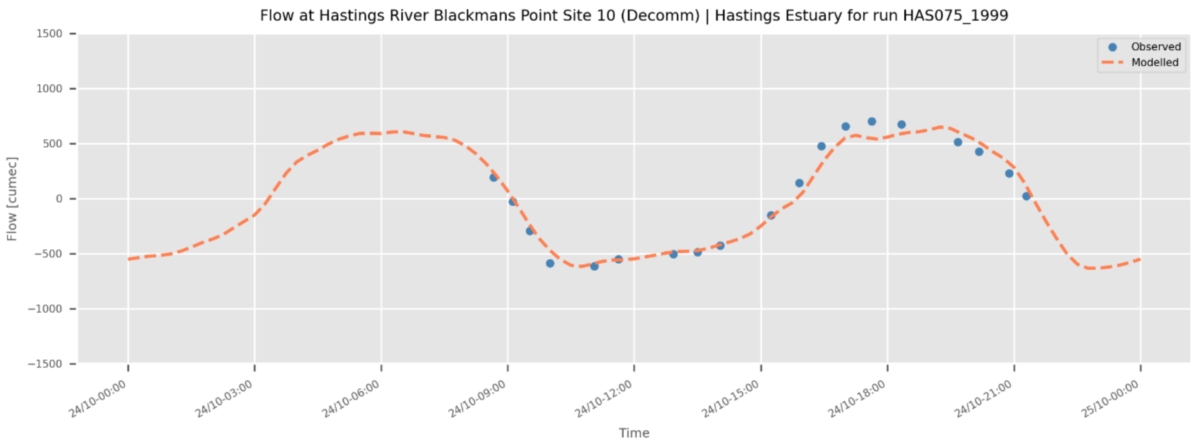

Figure B-9 1999 flow calibration – Blackmans Point (MHL (1999) site 10)

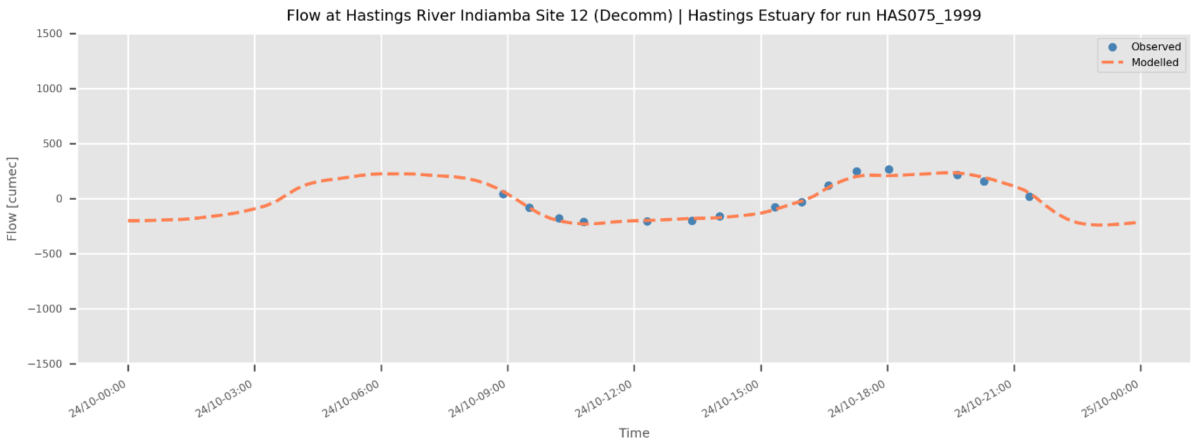

Figure B-10 1999 flow calibration – Indiamba (MHL (1999) location 12)

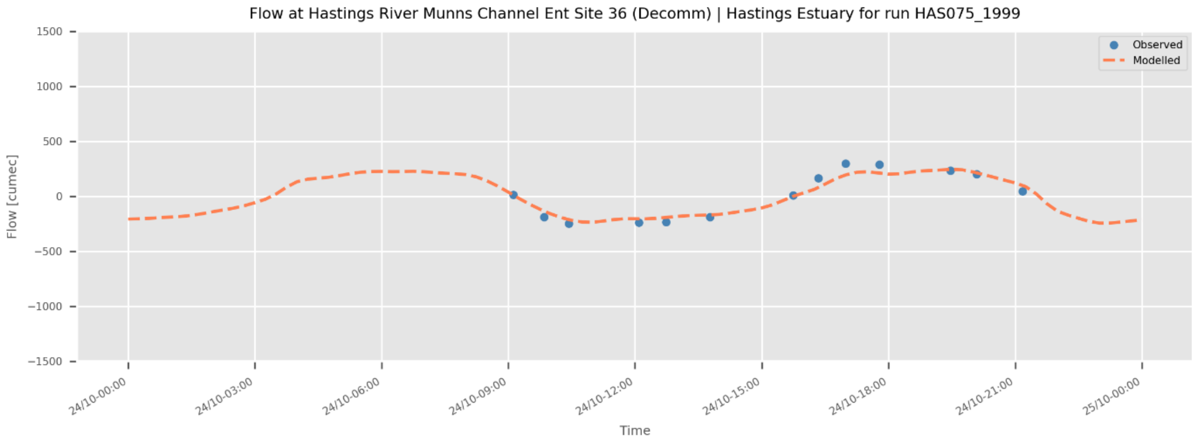

Figure B-11 1999 flow calibration – Munns Channel (MHL (1999) site 36)

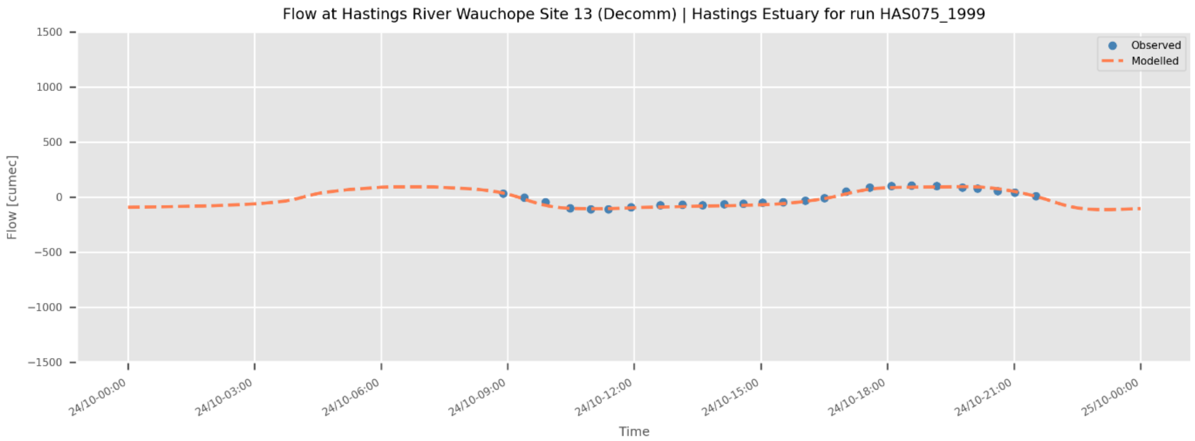

Figure B-12 1999 flow calibration – Wauchope (MHL (1999) site 13)

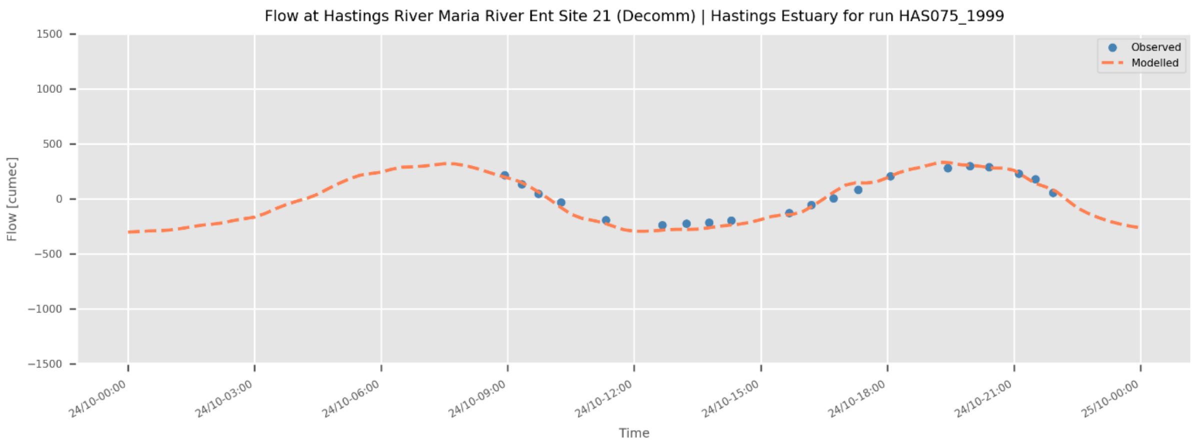

Figure B-13 1999 flow calibration – Maria River Entrance (MHL (1999) site 21)

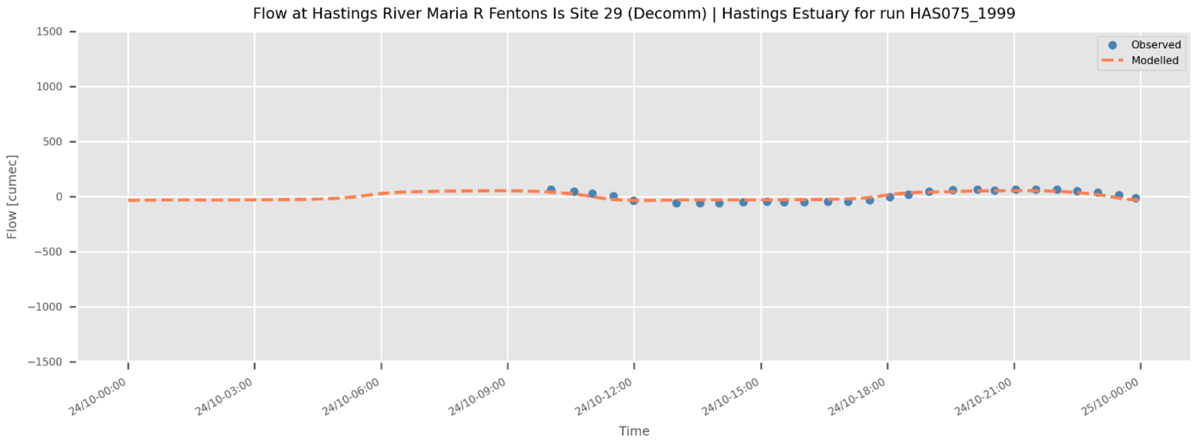

Figure B-14 1999 flow calibration – Maria River Fenton Island (MHL (1999) site 29)

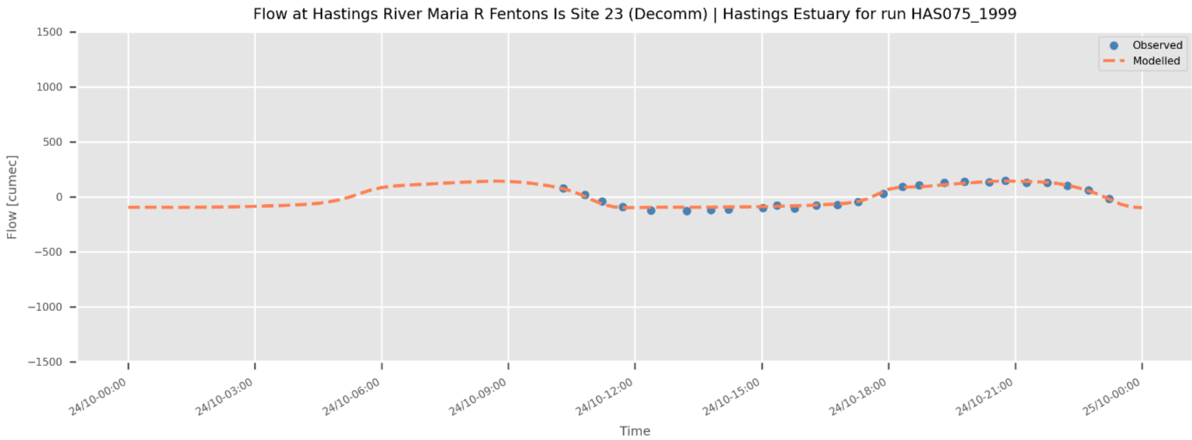

Figure B-15 1999 flow calibration – Maria River Fenton Island (MHL (1999) site 23)

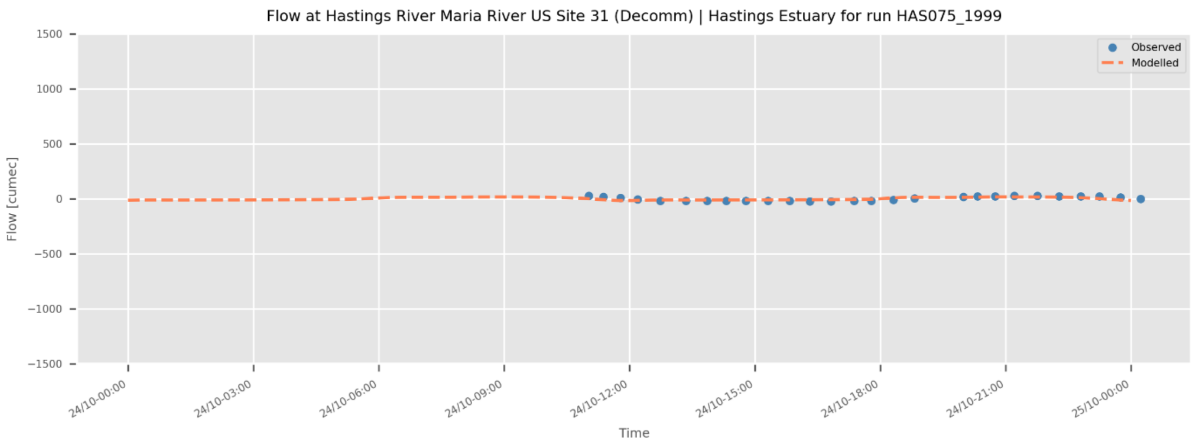

Figure B-16 1999 flow calibration – Maria River upstream (MHL (1999) location 31)

B1.3 Water level calibration – 2022

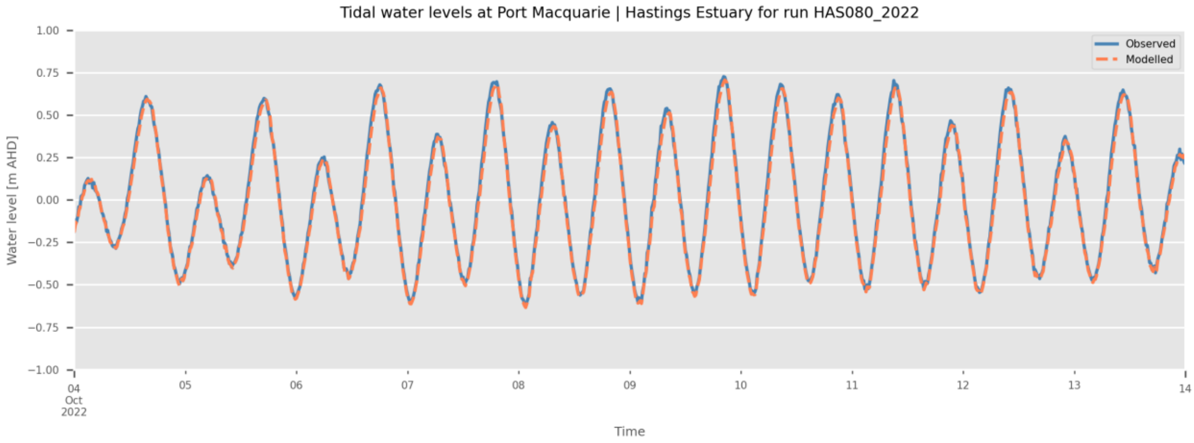

Figure B-17 2022 water levels – Port Macquarie

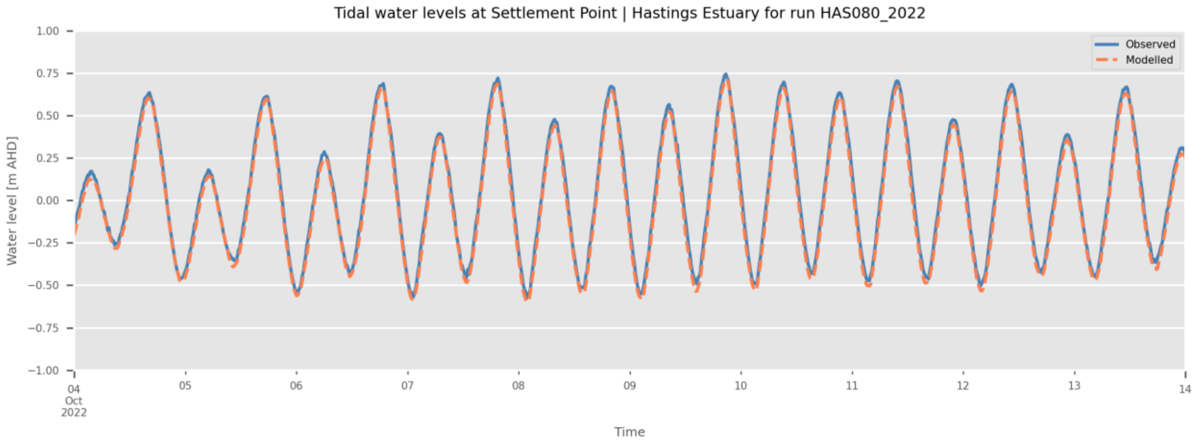

Figure B-18 2022 water levels – Settlement Point

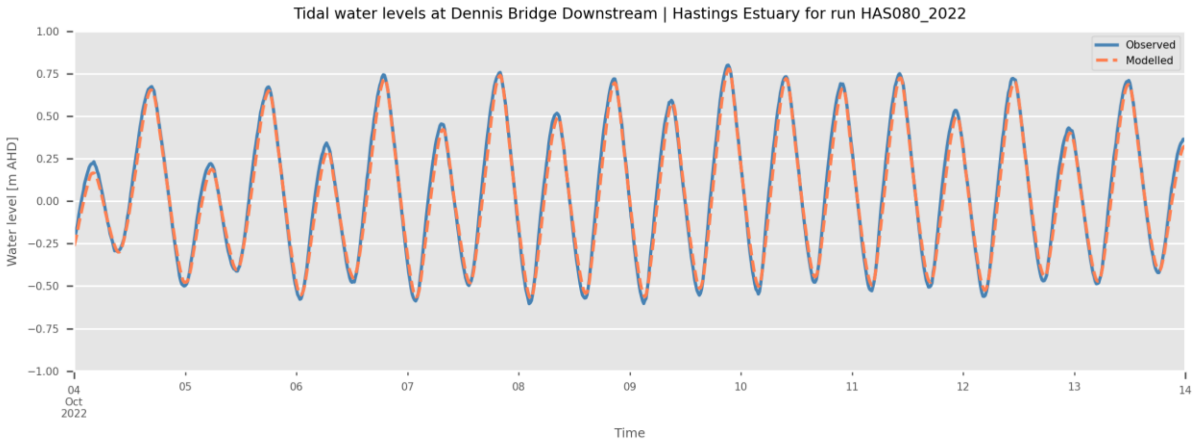

Figure B-19 2022 water levels – Dennis Bridge

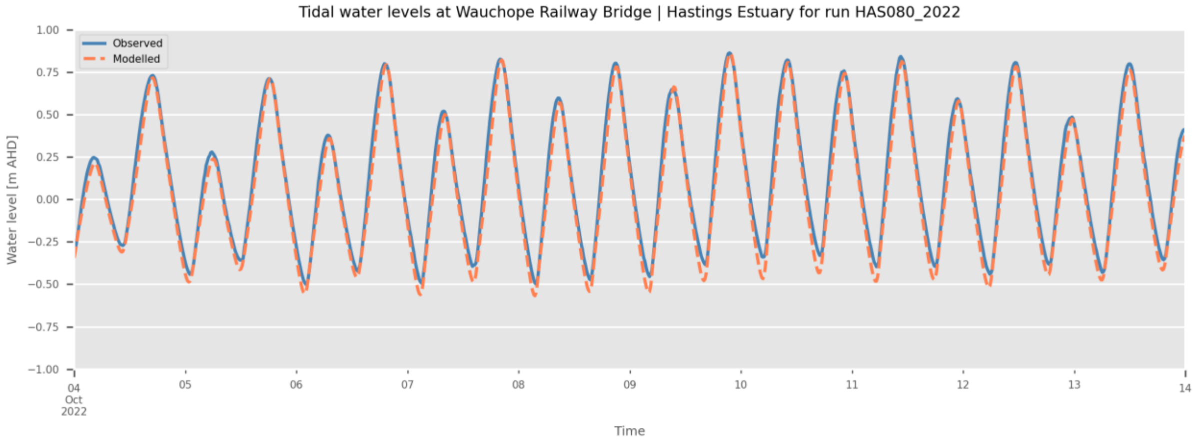

Figure B-20 2022 water levels – Wauchope

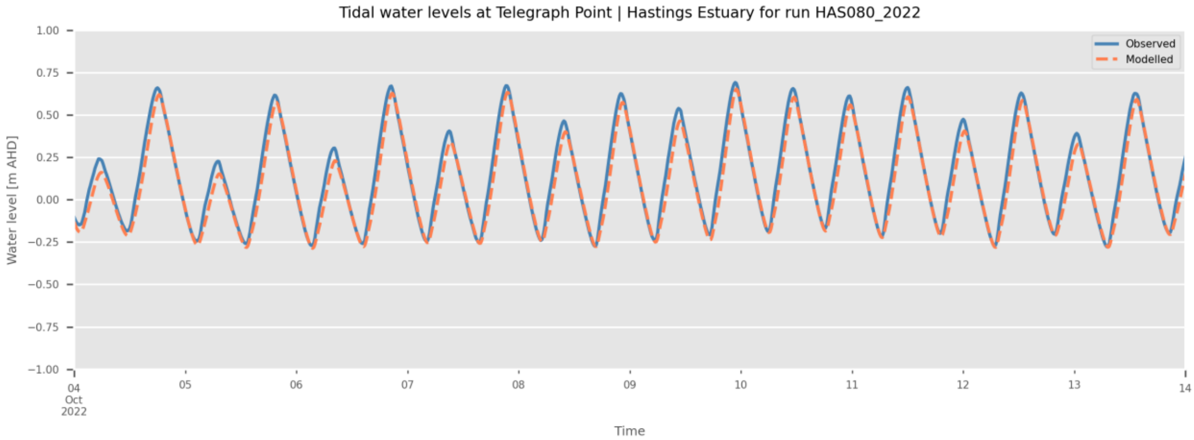

Figure B-21 2022 water levels – Telegraph Point

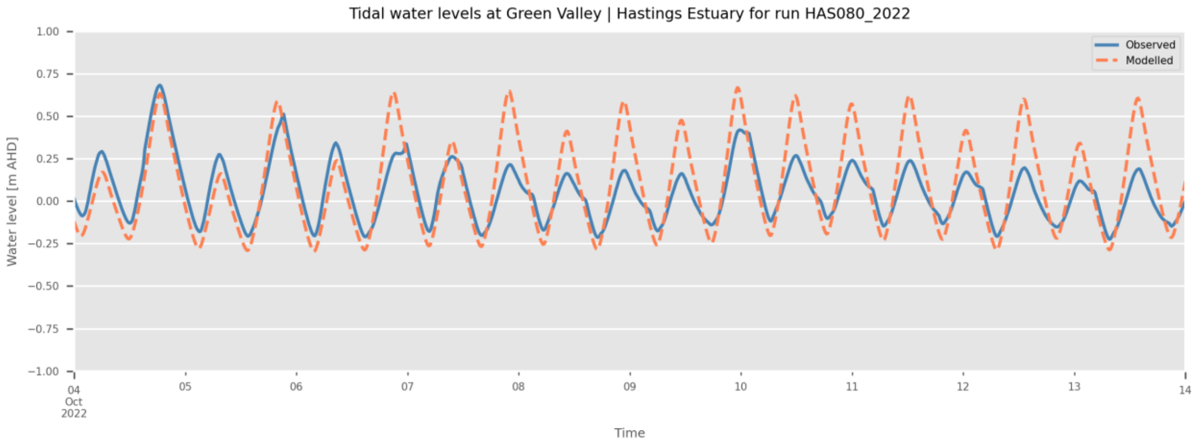

Figure B-22 2022 water levels – Green Valley

B1.4 Tidal flow verification – 2022

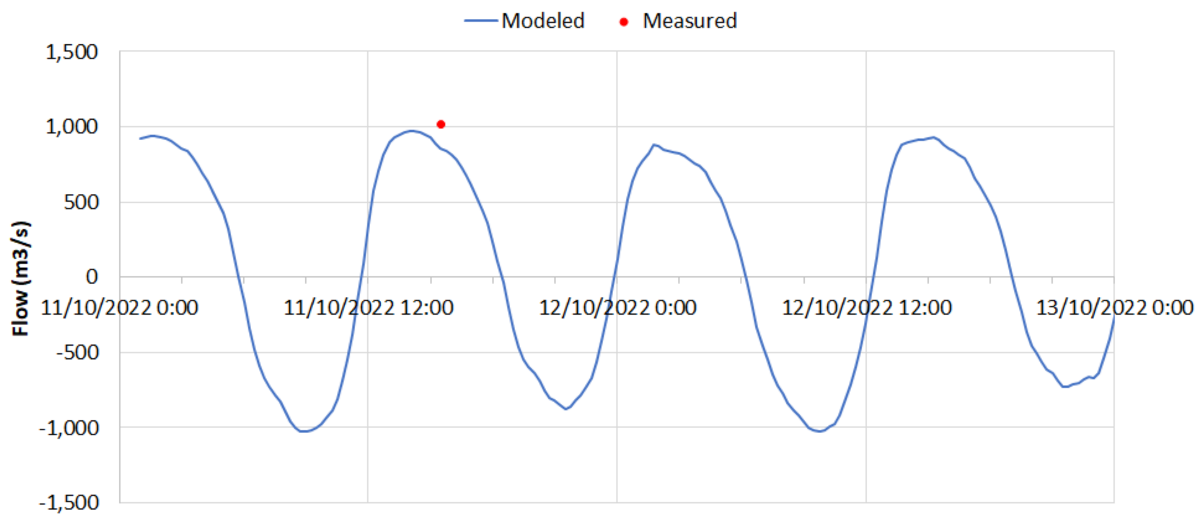

Figure B-23 2022 tidal flows – Transect 1

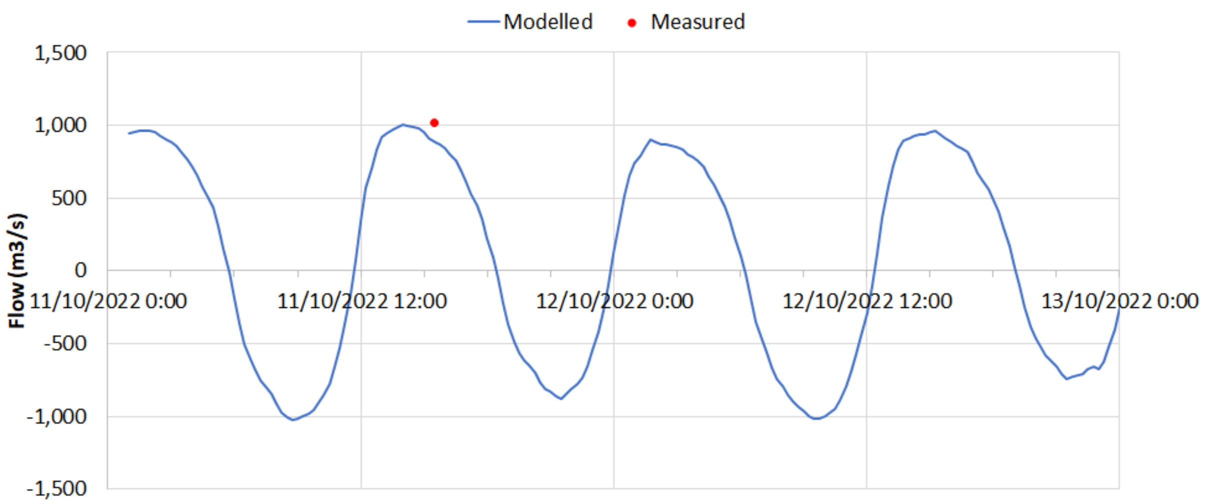

Figure B-24 2022 tidal flows – Transect 2

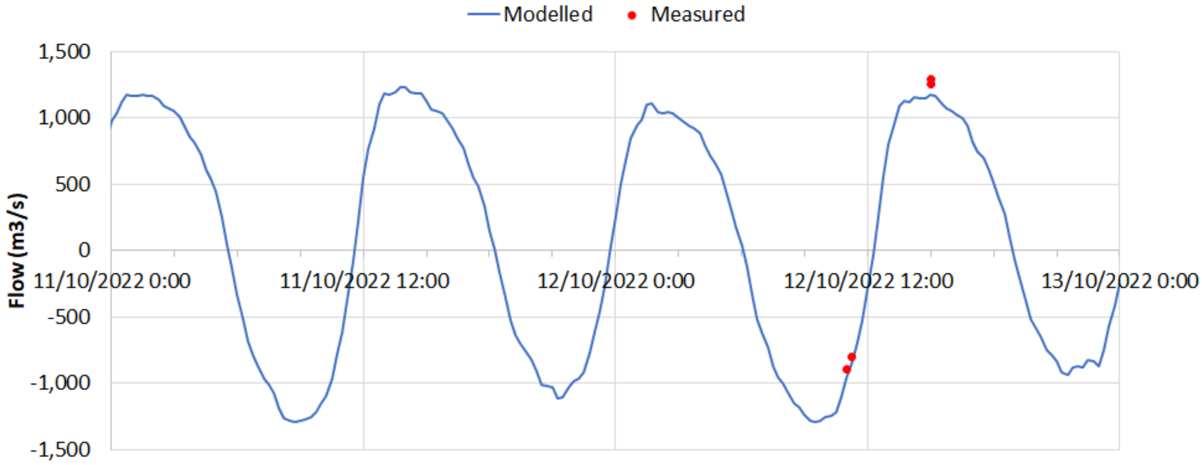

Figure B-25 2022 tidal flows – Transect 3

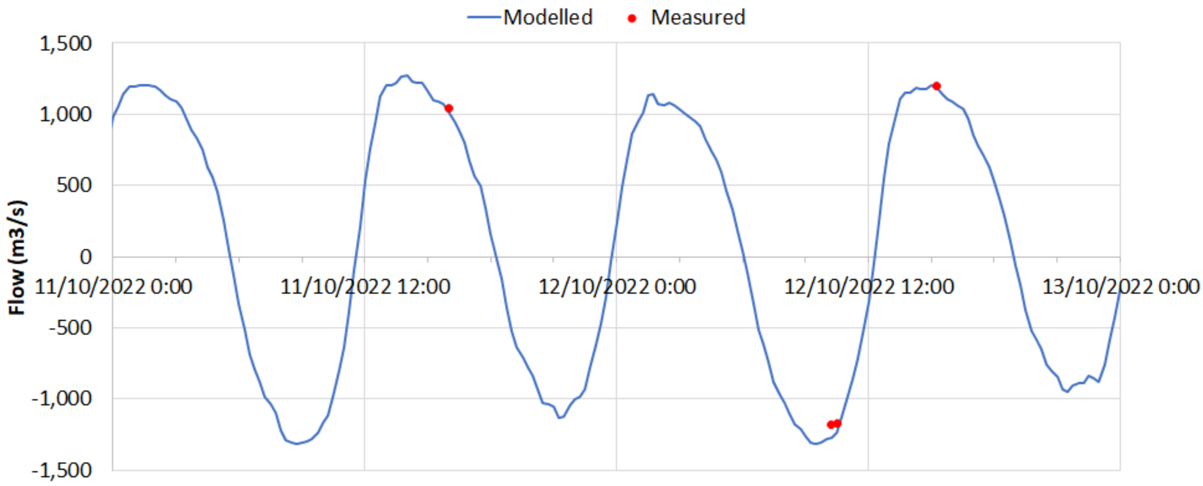

Figure B-26 2022 tidal flows – Transect 4

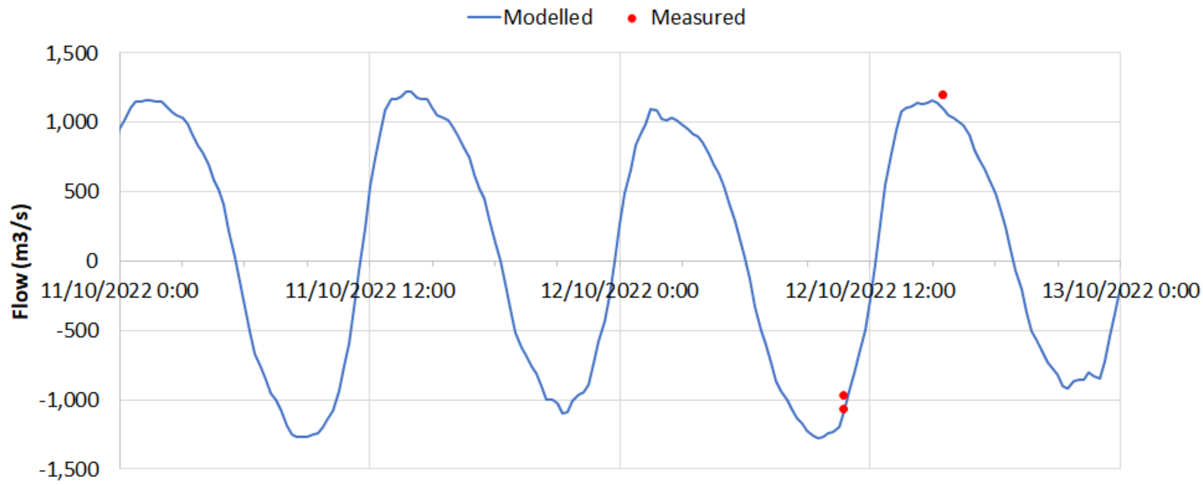

Figure B-27 2022 tidal flows – Transect 5