Shoalhaven River Floodplain Prioritisation Study: Appendix A – J

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Appendix A Floodplain waterways

A1 Preamble

Up to date mapping of floodplain waterways within the study area was required to inform the prioritisation assessment and can also be used to inform the implementation of management options. The following section summarises the available existing data which maps present day waterways across the Shoalhaven River floodplain (below 5 m AHD) and also presents an updated spatial waterways data layer, created using existing data, which provides a consistent and uniform dataset across the floodplain. This updated spatial layer incorporates the results of a detailed multi criteria analysis for categorising a waterway as a natural waterbody watercourse, an artificial waterbody, or a watercourse or connector watercourse. Details on the development of the updated spatial layer and the multi criteria analysis can be found in Section 12 of the Methods report (Rayner et al., 2023). The updated waterways layer was used to calculate subcatchment drainage density during the subcatchment prioritisation assessment and will also be a valuable tool for informing management option implementation.

A2 Existing waterway data

Available information for the floodplain waterway network across the Shoalhaven River floodplain was from multiple data sources as summarised in Table A-1.

Table A-1: Summary of available waterway data

Dataset	Data format	Provides waterway naming information?	Distinguishes between artificial and natural waterways?	Local or state wide dataset?
Geoscience Australia surface hydrology lines	Geodatabase	Yes	Yes	State wide
NSW Spatial Services hydrology lines	Shapefile	Yes	No	State wide
NSW Spatial Services hydrology lines	WMS layer	Yes	Yes	State wide
NSW DPI Fisheries manmade drains	Shapefile	No	Yes	State wide
Shoalhaven City Council Flood Mit. Drains	Shapefile	Yes	No	Local
Shoalhaven City Council Drains Not Flood Mit.	Shapefile	Yes	Yes	Local

A3 Waterway classification

For this study, an updated waterways spatial dataset was developed for the Shoalhaven River floodplain to incorporate the most recent changes to the waterway network and ensure a consistent level of detail across the floodplain. The alignments and configurations of floodplain waterways are continuously changing due to varying management requirements of waterway owners across the floodplain. Inspection of the existing waterway data showed varying degrees of accuracy and detail for the different datasets in Table A-1, reflecting the different purposes for which the individual spatial layers had been created.

To ensure an up-to-date waterways dataset across all areas in the Coastal Floodplain Prioritisation Study, a multi criteria analysis was completed to categorise waterways into the following:

- Natural waterbody watercourses – a natural waterway that pre-dates European settlement. Natural waterbody watercourses are typically sinuous and follow geological features;
- Artificial waterbodies – a constructed waterway that was purpose built to enhance drainage of backswamps or redirect water. Artificial waterways are typically straight, and deep;
- Watercourses – typically a waterway that follows a natural drainage system, but has been heavily modified or disconnected from the upstream catchment; and
- Connector watercourses – a waterway with either natural or artificial sections that provides a connection between two (2) natural waterbody watercourses. Typically, connector watercourses flow through a drainage network which was once a backswamp connecting the upper catchment to the river.

Further details on the approach taken to update the waterways spatial layer and the multi criteria analysis can be found in Section 12 of the Methods report (Rayner et al., 2023). The updated spatial dataset and results of the multi criteria analysis are presented in Figure A-1. Note, update and classification of waterways was completed for elevations below 5 m Australian Height Datum (AHD) as is consistent with catchment delineation used for the subcatchment prioritisation.

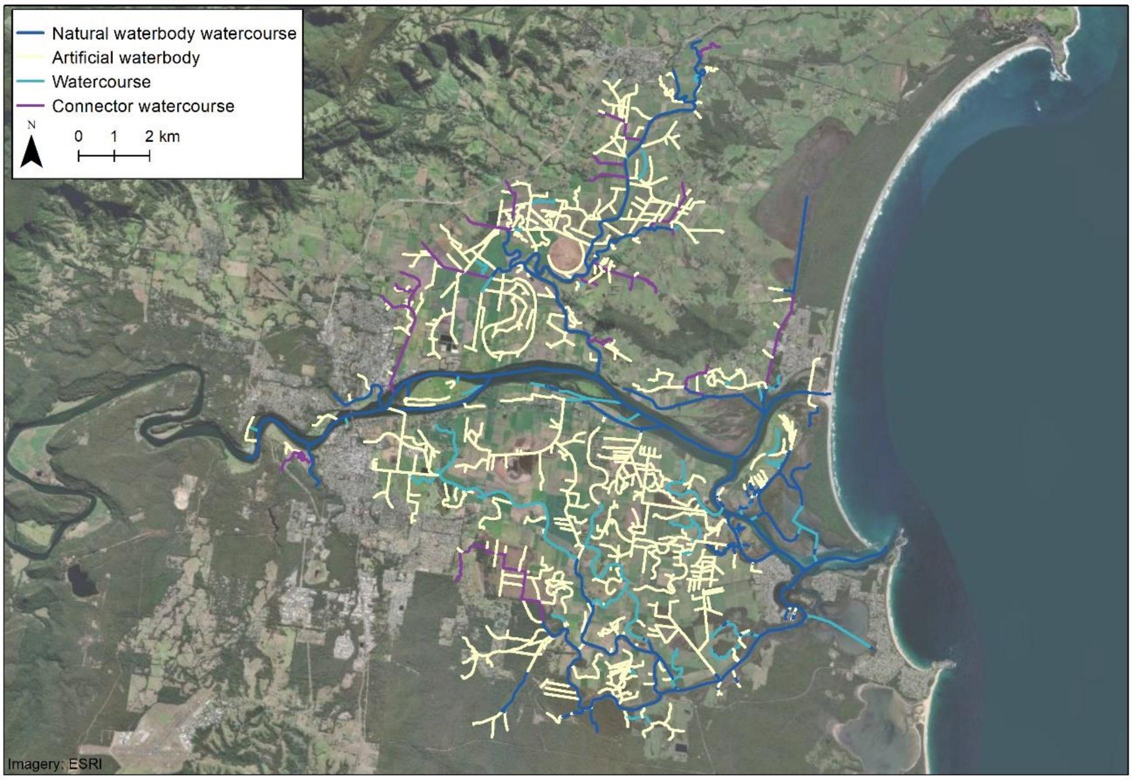


Figure A-1: Shoalhaven River floodplain waterways

A4 Drainage density

The drainage density of each flood mitigation drainage area is determined by the total waterway length across the subcatchment relative to the subcatchment area affected by acid sulfate soils (see Section 4.3.1 of the Methods report (Rayner et al., 2023)). When assessing the length of waterways that contribute to the drainage of an acid sulfate soil affected landscape, all waterways within the subcatchment boundaries were included in the priority assessment to provide a total waterway length for each subcatchment, as all waterways have the potential to impact acid sulfate soil oxidation and acid mobilisation. A summary of the floodplain drainage density analysis is provided in Table A-2 and the ranking of the drainage density factors for each subcatchment of the Shoalhaven River floodplain is presented in Figure A-2.

Table A-2: Floodplain drainage density

Subcatchment	Total waterway length (m)	Floodplain area* (km^2)	Drainage density (m/km^2)	Drainage density rank**
Jaspers Creek	1,410	0.47	3,009	23
P10D1	26,260	8.34	3,148	19
P12D1	47	0.08	578	40
P1D1	17,097	5.70	3,001	24
P2D1	10,548	7.12	1,481	35
P2D2	8,161	2.41	3,386	17
P2D3	3,607	1.62	2,223	32
P2G1	10,033	3.32	3,021	22
P3D1	15,913	5.23	3,045	21
P3D10	155	0.13	1,157	38
P3D2	8,131	2.38	3,416	16
P3D3	1,751	0.17	10,156	1
P3D4	3,353	0.53	6,333	3
P3D5	2,445	1.15	2,123	33
P3D6	10,384	1.78	5,823	4
P3D7	5,158	1.33	3,868	15
P3D8	2,339	0.92	2,550	31
P3D9	830	0.28	2,935	26
P4D1	17,188	5.48	3,136	20
P4D2	8,845	2.23	3,971	14
P4D3	2,413	1.93	1,252	37
P4D4	361	0.25	1,421	36
P5D1	25,864	6.10	4,238	10
P5D2	3,534	1.28	2,762	29
P5D3	32,320	7.75	4,168	11
P6D1	2,179	0.73	2,995	25
P6D2	2,608	0.64	4,098	12
P6D3	12,896	2.45	5,270	6
P6D4	4,275	1.28	3,329	18
P6D5	7,455	1.32	5,665	5
P6D6	955	0.21	4,454	8
P6D7	3,575	0.90	3,981	13
P6D8	9,052	1.83	4,956	7
P6D9	1,706	0.40	4,279	9
P7D1	32,654	11.64	2,805	28
P8D1	1,718	0.65	2,643	30
P8D2	10,229	3.54	2,892	27
P8D3	2,315	1.32	1,754	34
P9D1	8,175	10.05	813	39
P9D2	468	0.07	7,029	2

* Floodplain area is calculated as the area below 5 m AHD that is high or low risk in the acid sulfate soil risk mapping.

** Ranking is from highest drainage density to lowest drainage density.

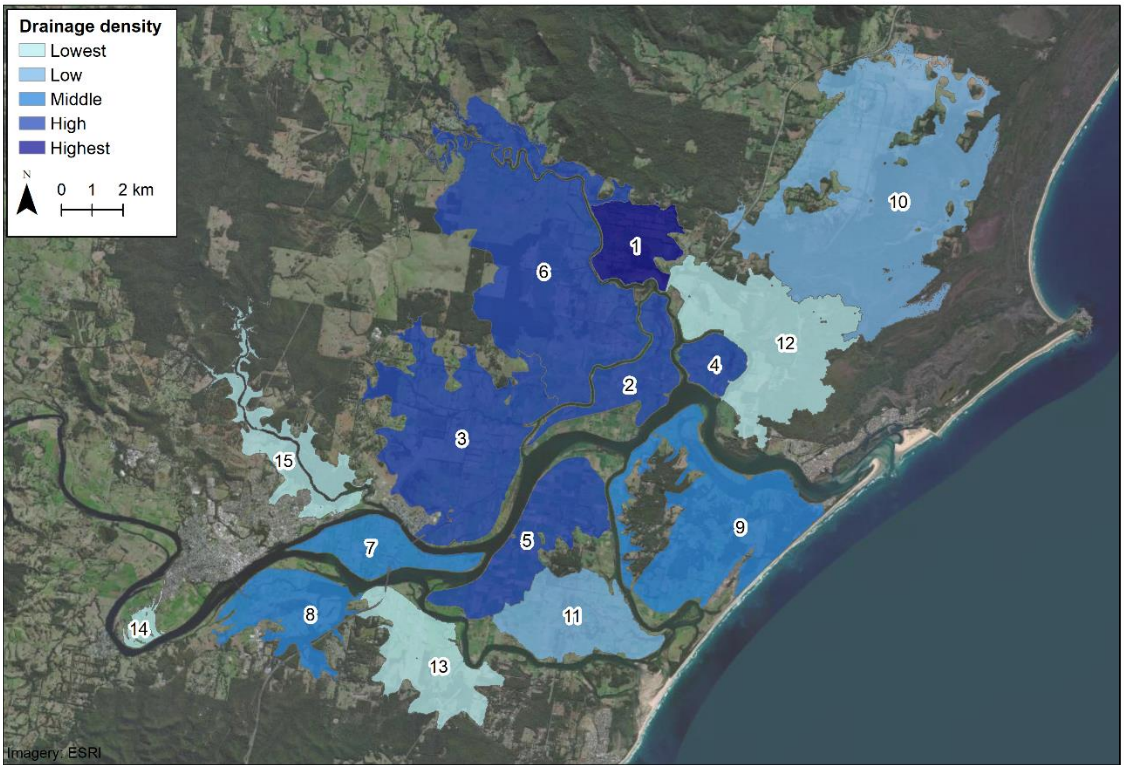


Figure A-2: Floodplain drainage density ranking

Appendix B Catchment hydrology

B1 Preamble

The following appendix details the catchment hydrology which is included in the normalised inflow factor in the acid sulfate soil prioritisation assessment, described in detail in Section 4.3.2 in the Methods report (Rayner et al., 2023). This includes the calculation of a runoff coefficient (Section B2) and a catchment size factor (Section B3), to determine an inflow factor (Section B4).

B2 Runoff coefficient

The catchment runoff assessment for the Shoalhaven River floodplain was undertaken by comparing the volume of runoff generated by precipitation from incident rainfall with the observed subsequent streamflow data. Details of the methods used to calculated the runoff coefficient can be found in Section 4.3.2 in the Methods report (Rayner et al., 2023). The WaterNSW network of river flow gauges and the available daily rainfall data from the Bureau of Meteorology (BOM) for the Shoalhaven River floodplain is shown in Figure B-1.

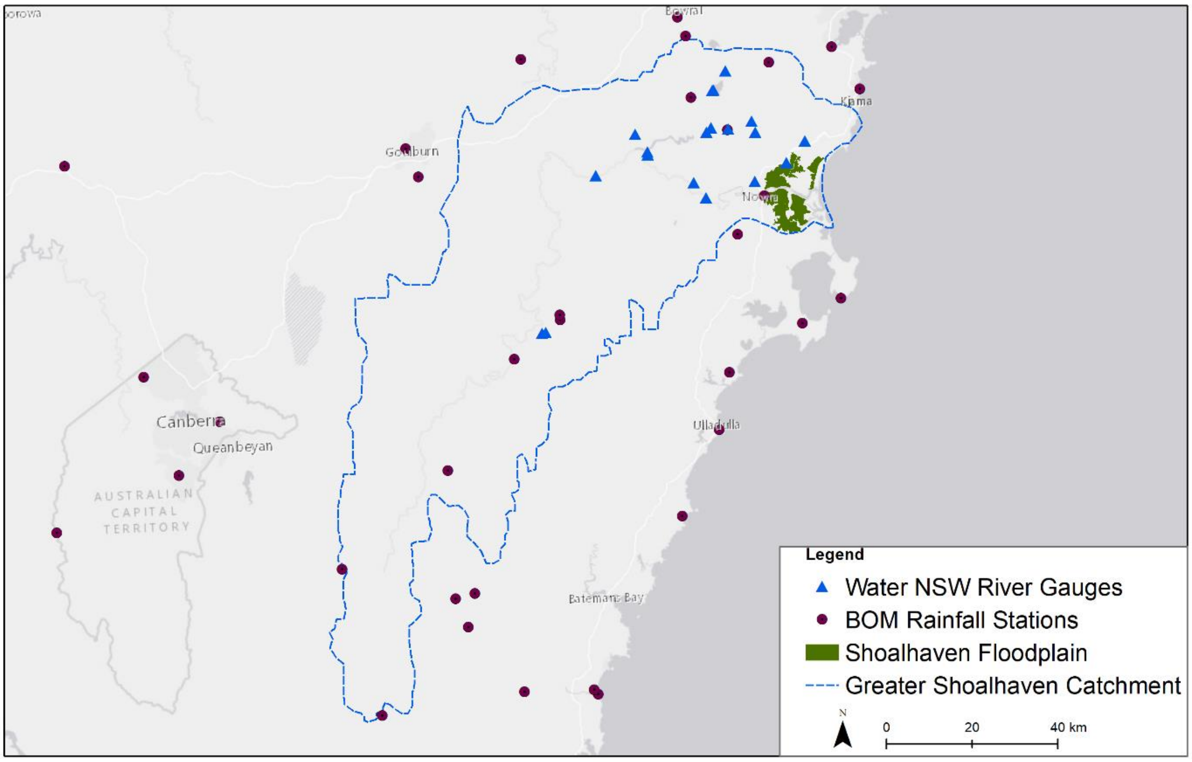


Figure B-1: Shoalhaven River Floodplain location of rainfall and runoff stations

Stream flow gauges upstream of the tidal confluence that are most representative of the lower catchment rainfall-runoff conditions were selected for the catchment hydrology analysis. WaterNSW gauging stations 215016 and 215019 were selected for the Shoalhaven River Floodplain assessment. The upstream contributing areas of these sites were delineated using standard GIS techniques based on a digital elevation model (DEM) of the catchment. Daily rainfall data relative to the river gauging station was sourced from the BOM database and a Thiessen polygon approach was applied. The location of the gauging sites, upstream catchment areas of the gauging sites, and the BOM rainfall contributions (shown in parenthesis) used in the analysis are summarised in Figure B-2.

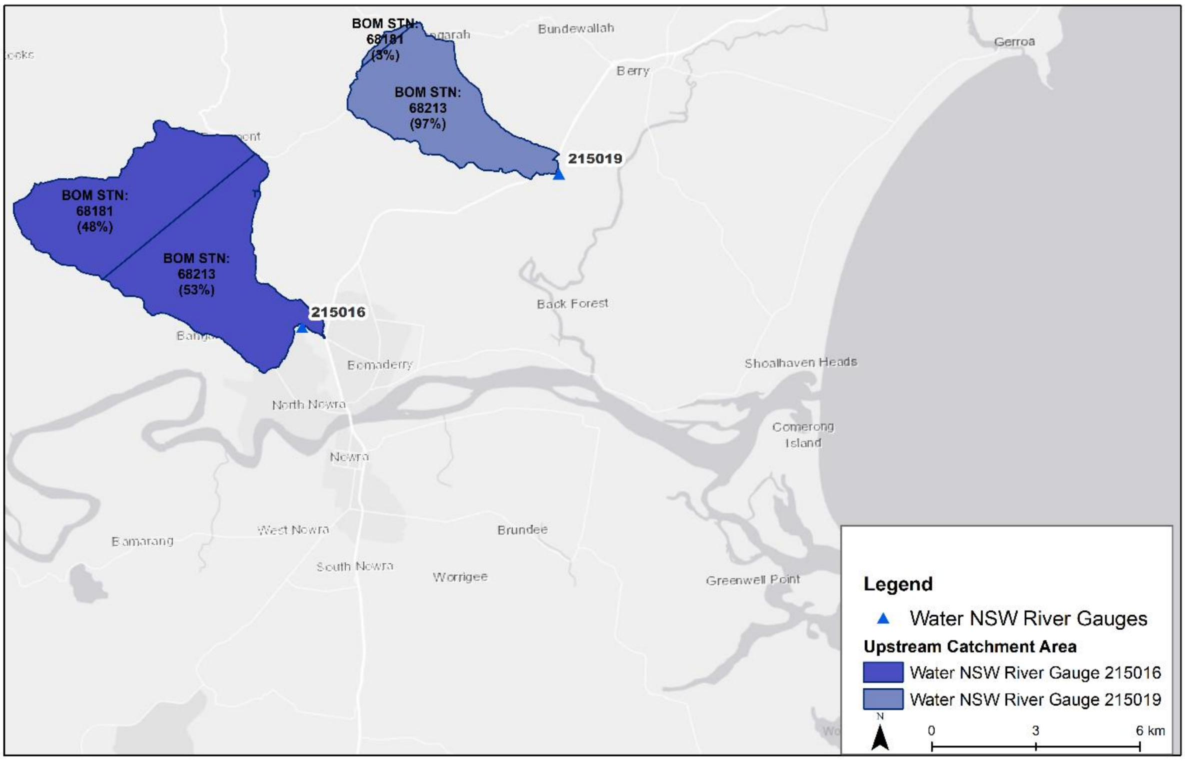
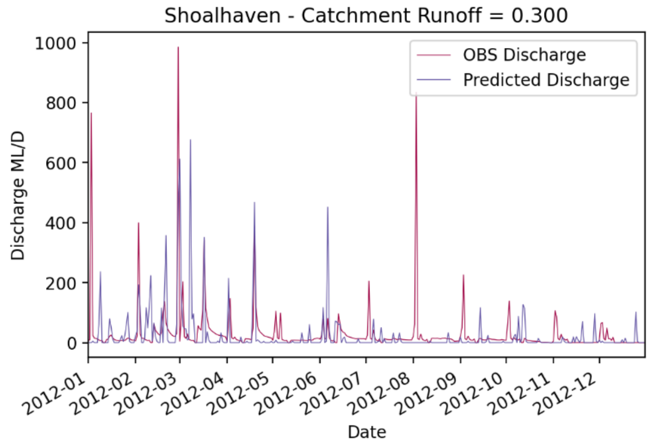


Figure B-2: Upstream catchment of selected flow sites

The runoff coefficient provides a relationship between rainfall-runoff volumes and allows for varying amounts of pervious and impervious surfaces across a catchment. It follows that if the predicted runoff volume from incident rainfall is known, and is compared to the available observed streamflow data, then the volume difference would be equivalent to the runoff coefficient (assuming the catchment was 100% impervious). For consistency, in this study, it was also assumed that land-use type, vegetation, and the proportion of pervious and impervious surfaces, was the same for each subcatchment in the floodplain (i.e. the runoff coefficient for this study represents an amalgamated factor, taking into account catchment variables such as soil type, land use etc. for each subcatchment).

The runoff co-efficient was selected by comparing the annual time-series of streamflow data for the predicted runoff volume calculated for the selected gauging station. Figure B-3 shows an example time-series of predicted and observed runoff for 2012. This analysis yielded an estimated runoff coefficient of 0.30, which was applied to Shoalhaven Floodplain subcatchments for the acid prioritisation assessment.



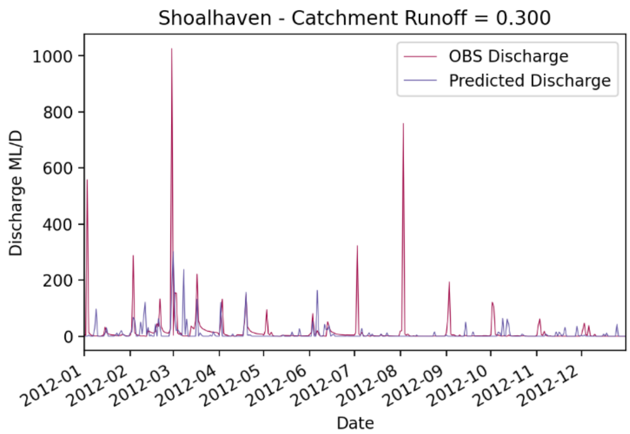


Figure B-3: Predicted and observed runoff for the catchment area upstream of river gauging station 215016 (Top) and station 215019 (Bottom)

B3 Catchment size factor

The size of the flood mitigation drainage area influences the hydrological response of the site during a rainfall event. When comparing drainage areas of similar acidity, a large catchment will have a greater potential to discharge more acid than a small catchment. That is, an ASS affected drainage unit with high-risk ASS and a large catchment area contributing to acid drainage has a greater potential to produce higher potential acid flux during a post-flood recession period. Subsequently, accurate estimates of subcatchment areas and the potential discharge from those areas is critical to assessing subcatchments that are of a high-risk for acid drainage.

For the purpose of this study, the floodplain subcatchments have been defined as areas that are below 5 m AHD and classified as at risk for ASS. The whole floodplain area is considered to contribute to acid drainage risk. Upland catchments (above 5 m AHD) were divided into areas that discharge to the estuary via an end-of-system floodgate structure or discharge uninhibited to the estuary. In this study, only upland catchments that are upstream of floodgates have been considered to contribute to acid drainage potential. These areas were identified using information on floodgate infrastructure and the NSW hydrography layer. Contributing catchments were then delineated using standard GIS techniques as shown in Figure B-4.

The total areas of each subcatchment were then normalised against the subcatchment with the largest total area (i.e. catchment size factor = 1.0) for comparison.

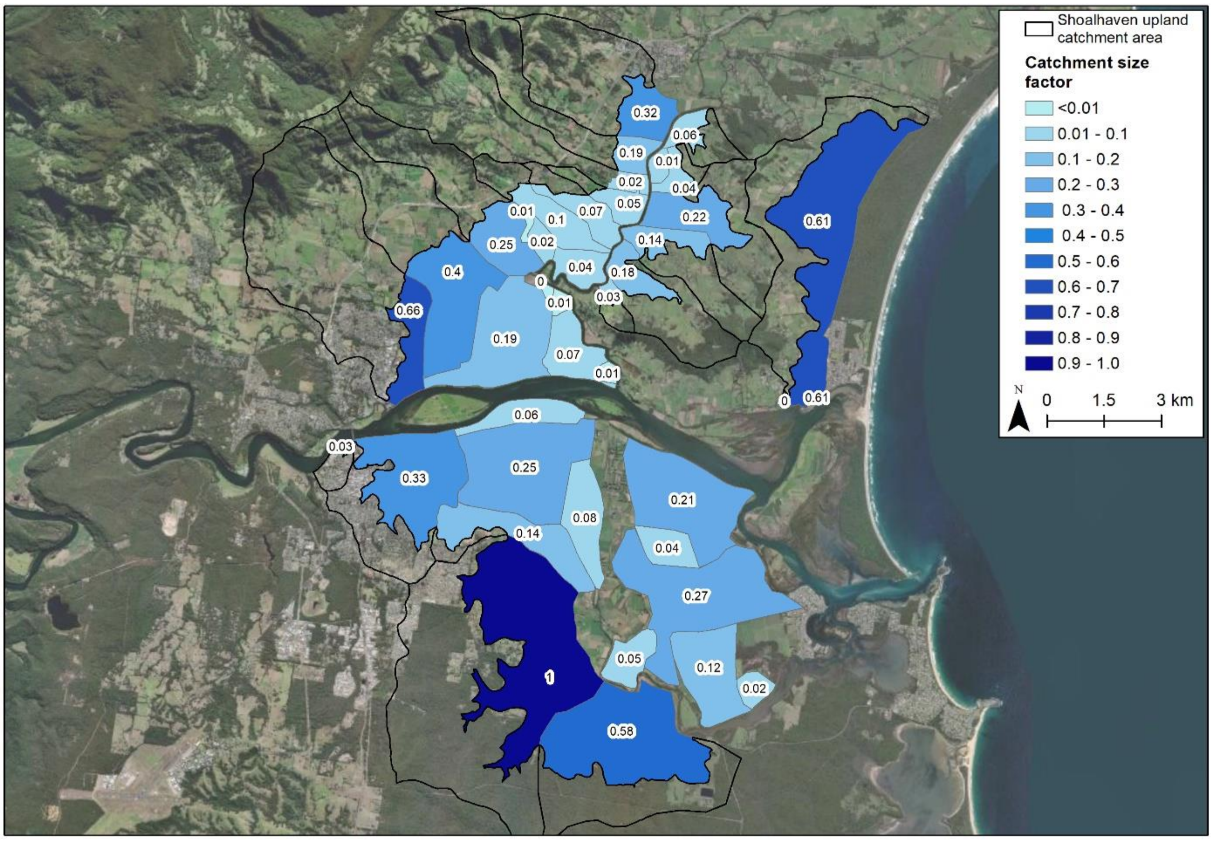


Figure B-4: Catchment size factor for each subcatchment in the Shoalhaven River Estuary

B4 Inflow Factor

The combination of a runoff coefficient and a normalised catchment size factor is used to provide an estimation of the relative water yield of each floodplain subcatchment. The inflow factor is calculated as per Equation B-1.

$$\begin{aligned}&\boldsymbol{Normalised\ inflow\ factor}\\&\quad= \boldsymbol{Runoff\ coefficient} \times \boldsymbol{Catchment\ Size\ Factor}\end{aligned} \qquad \textbf{Equation B-1}$$

The inflow factors for each Shoalhaven River floodplain subcatchment are detailed in Table B-1 and shown in Figure B-5.

Table B-1: Catchment hydrology analysis summary table

Subcatchment	Runoff Coefficient	Upland Catchment Area (m²)	Total Catchment Area (m²)	Catchment Size Factor	Inflow Factor
Jaspers Creek	0	0.30	0	468372	0.016
P10D1	8343066	0.30	8343066	16686132	0.576
P1D1	3929300	0.30	3929300	9625737	0.332
P2D1	0	0.30	0	7123233	0.246
P2D2	0	0.30	0	2410431	0.083
P2D3	0	0.30	0	1622791	0.056
P2G1	670152	0.30	670152	3990884	0.138
P3D1	6265756	0.30	6265756	11491339	0.396
P3D10	0	0.30	0	134296	0.005
P3D2	4915741	0.30	4915741	7295764	0.252
P3D3	0	0.30	0	172398	0.006
P3D4	0	0.30	0	529494	0.018
P3D5	0	0.30	0	1151751	0.040
P3D6	1033007	0.30	1033007	2816291	0.097
P3D7	653570	0.30	653570	1986971	0.069
P3D8	414054	0.30	414054	1331132	0.046
P3D9	0	0.30	0	282627	0.010
P4D1	0	0.30	0	5480209	0.189
P4D2	17034664	0.30	17034664	19261886	0.664
P4D3	0	0.30	0	1927630	0.066
P4D4	0	0.30	0	253814	0.009
P5D1	0	0.30	0	6103241	0.211
P5D2	0	0.30	0	1279669	0.044
P5D3	0	0.30	0	7754428	0.268
P6D1	1060744	0.30	1060744	1788399	0.062
P6D2	387635	0.30	387635	1023938	0.035
P6D3	4061894	0.30	4061894	6508907	0.225
P6D4	2871768	0.30	2871768	4156061	0.143
P6D5	3913578	0.30	3913578	5229472	0.180
P6D6	562698	0.30	562698	777094	0.027
P6D7	4637377	0.30	4637377	5535304	0.191
P6D8	7367426	0.30	7367426	9193839	0.317
P6D9	0	0.30	0	398660	0.014
P7D1	17345804	0.30	17345804	28988507	1.000
P8D1	0	0.30	0	650102	0.022
P8D2	0	0.30	0	3537039	0.122
P8D3	0	0.30	0	1319575	0.046
P9D1	7734211	0.30	7734211	17789038	0.614
P9D2	11589	0.30	11589	78205	0.003
P12D1	780303	0.30	780303	861083	0.030

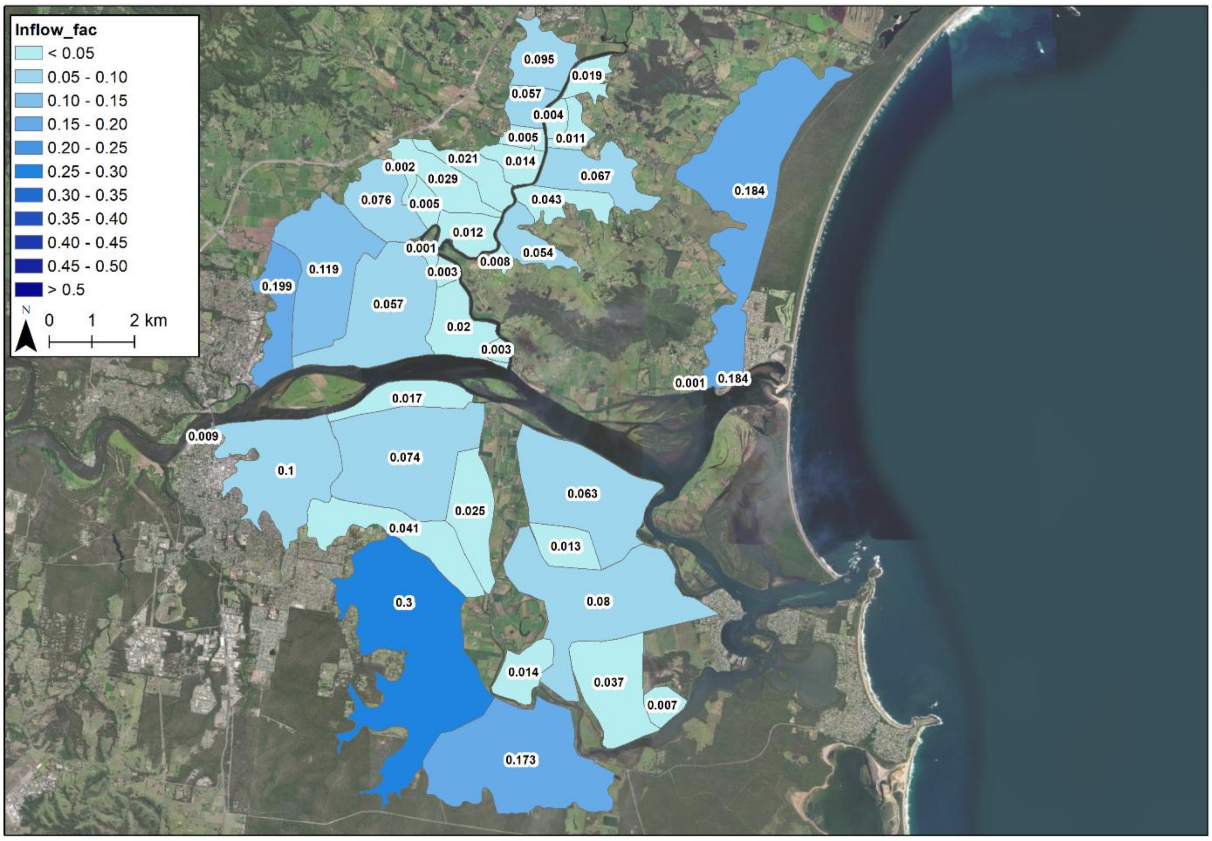


Figure B-5: Subcatchment inflow factors

Appendix C Groundwater saturated hydraulic conductivity data

C1 Preamble

The following section outlines the saturated hydraulic conductivity data (hereafter referred to as hydraulic conductivity) used in the prioritisation method (Section 4) for determining the groundwater factor for the Shoalhaven River floodplain. A detailed discussion of the principles relating to hydraulic conductivity and data collection can be found in Appendix A of the Methods report (Rayner et al., 2023). Details on the techniques and methods used to collect the field data presented in this section can be found in Appendix B of the Methods report (Rayner et al., 2023).

C2 Existing hydraulic conductivity data

Prior to Glamore and Rayner (2014), field measurements of in-situ saturated hydraulic conductivity across the subcatchments of the Shoalhaven River floodplain were limited. Hydraulic conductivity measurements across the Broughton Creek and Crookhaven River floodplains are sparse. Whilst widespread soil investigations have been undertaken, limited resources have been allocated to investigate hydraulic conductivity. Existing data shows a large range of K_{sat} between <0.0001 m/day to ~10 m/day. Data sources reviewed that presented hydraulic conductivity data were:

- Blunden and Indraratna (2000);
- Glamore (2003); and,
- Regional Effluent Management Scheme (REMS) (AWACS, 1995)

Published data from these sources is presented in Table C-1 to Table C-3. The location of hydraulic conductivity measurements is presented in Figure C-1. Measurements by Blunden and Indraratna (2000)showed variation in vertical and horizontal K values for the northern Broughton Creek floodplain. Whilst horizontal and vertical flow rates were similar in the shallow organic soil horizons, variability increased once the pyritic AASS and PASS layers were reached. Vertical hydraulic conductivity was observed to be 50% to 1,000% greater than horizontal hydraulic conductivity (Table C-1).

Table C-1: Soil physical properties published by Blunden and Indraratna (2000)

Soil Layer	Depth below surface (m)	Average dry bulk density (ρ_d) (t/m^3)	Porosity %	Saturated Hydraulic Conductivity (vertical) (m day^{-1})	Saturated Hydraulic Conductivity (horizontal) (m day^{-1})
Organic topsoil	0.3	0.80	0.70	3.95	3.72
Peat-Loam	0.6	1.11	0.58	3.84	3.76
Jarositic Layer	0.9	1.05	0.60	1.68	0.78
Actual ASS	1.2	0.95	0.64	2.08	0.88
Potential ASS	1.5	1.03	0.61	2.02	0.20
Pleistocene Clay	3.0	1.70	Not taken	0.20	0.20

Glamore (2003) observed similar soil properties in the drainage area adjacent to Blunden's study site (Table C-2).

Table C-2: Soil physical properties published by Glamore (2003)

Depth (m)	$K_{sat(H)}$ (mm s^{-1})	Porosity %	Saturated volumetric moisture content
0.5	3.62	48	0.37
1.0	1.11	41	0.42
1.5	1.82	37	0.41
2.0	0.53	23	0.54

Early work was undertaken by AWACS (1995) as part of preliminary investigations for the Regional Effluent Management Scheme (REMS) which included the construction of six (6) monitoring boreholes, two (2) located on the southern Broughton Creek floodplain, and four (4) across the northern to central Crookhaven River floodplain. Hydraulic conductivity measurements showed varying potential flow rates ranging from less than 0.0001 m/day to approximately 10 m/day (Table C-3).

Table C-3: Hydraulic conductivity measured by AWACS (1995)

	Bore 1	Bore 2	Bore 3	Bore 4	Bore 5	Bore 6
K (m/day)	1.9	1.6	9.2	<0.0001	0.37	0.37

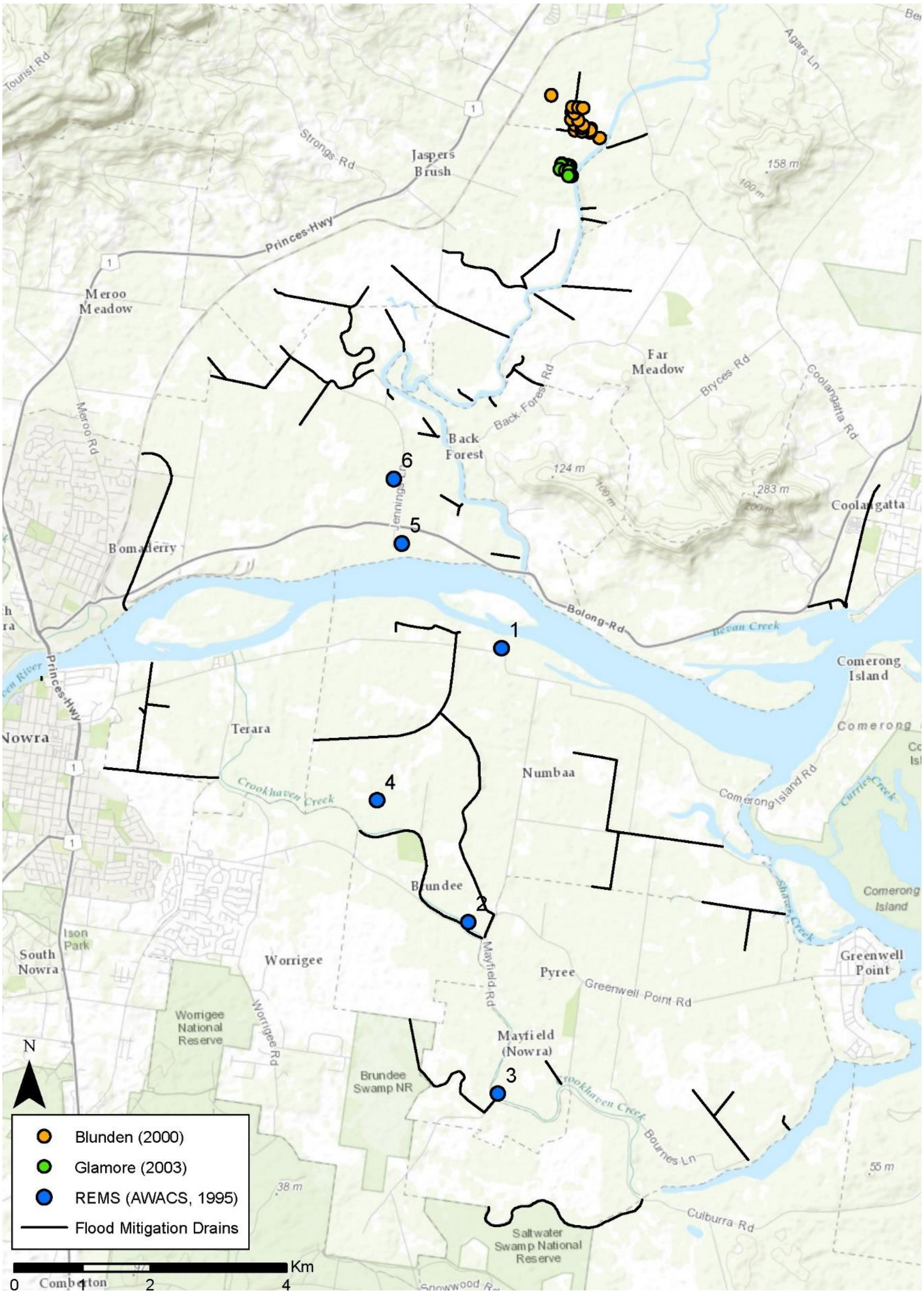


Figure C-1: Existing Ksat measurement locations

C3 Data collection from Glamore and Rayner (2014)

Due to the paucity of hydraulic conductivity data in the many flood mitigation drainage areas on the Shoalhaven River floodplain, Glamore and Rayner (2014) and Shoalhaven City Council completed field investigations to collect in-situ hydraulic conductivity data to undertake the priority assessment, particularly in the Broughton Creek floodplain. The Johnston and Slavich (2003) open pit methodology was applied to measure hydraulic conductivity in the field. Where data was available it has been reprocessed using the Boast and Langebartel (1984) technique to determine a discrete hydraulic conductivity value, otherwise values adopted by Glamore and Rayner (2014) have been used. Location and results of the field measurements are provided in Figure C-2 and Table C-4.

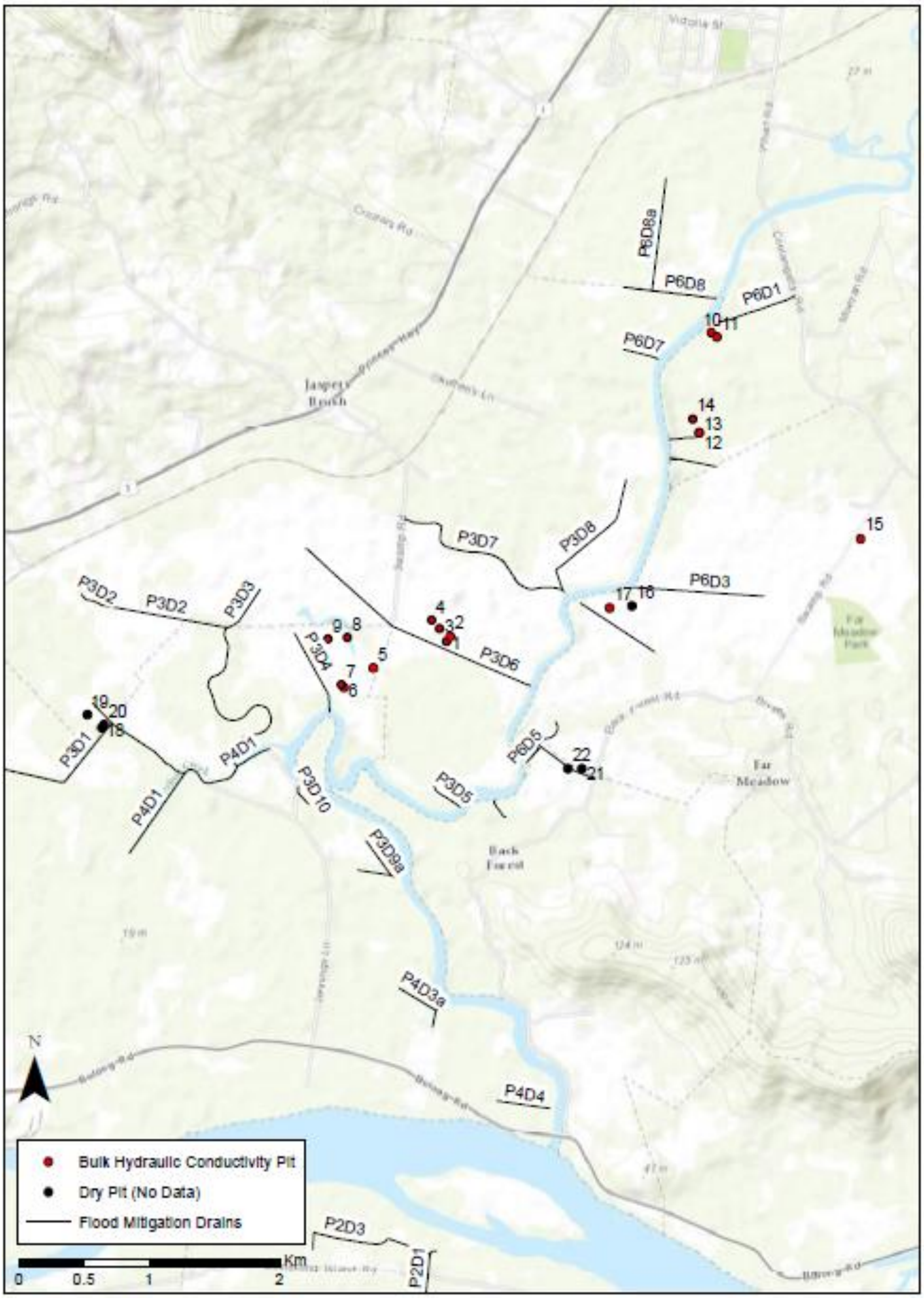


Figure C-2: 2012 field assessment locations of hydraulic conductivity

Table C-4: Summary of 2012 in-situ hydraulic conductivity data

Pit ID	Drain	Easting (MGA56)	Northing (MGA56)	Indicative Ksat	Approximate K_{sat} (m/day)
1	P3D6	286847	6144536	Moderate	6
2	P3D6	286872	6144575	Moderate	9
3	P3D6	286795	6144636	Moderate	13
4	P3D6	286731	6144701	Moderate	8
5	P3D6	286285	6144334	Moderate	11
6	P3D4	286057	6144180	High	27
7	P3D4	286040	6144206	Moderate	8
8	P3D6	286087	6144565	Moderate	14
9	P3D4	285936	6144554	Moderate	3
10	P6D1	288878	6146907	Extremely high	198
11	P6D1	288920	6146876	High	22
12	P6D9	288786	6146140	High	46
13	P6D9	288787	6146139	High	50
14	P6D9	288734	6146244	High	19
15	P6D3	290024	6145326	Moderate	8
16	P6D4	288267	6144812	Dry	Dry
17	P6D4	288096	6144795	Moderate	2
18	P3D1	284199	6143872	Dry	Dry
19	P3D1	284089	6143975	Dry	Dry
20	P3D1	284221	6143899	Dry	Dry
21	P6D5	287882	6143561	Dry	Dry
21	P6D5	287777	6143561	Dry	Dry

C4 Summary of saturated hydraulic conductivity risk ratings

Hydraulic conductivity measurements have been used to determine a risk rating which forms part of the groundwater factor during the subcatchment prioritisation (see Section 4 of the Methods report (Rayner et al., 2023)). The risk rating applies on a scale of one (1) to five (5) corresponding to the risk classifications, with extremely low equating to a risk rating of one (1), and extremely high equating to a risk rating or five (5). This results in subcatchments with larger hydraulic conductivities having an increased risk as they are able to transport larger volumes of acidic groundwater to the estuary. Since hydraulic conductivity measurements across ASS affected floodplains can be highly variable, further hydraulic conductivity investigations may be required to add further detail to the management options. An overall summary of the risk associated with hydraulic conductivity for each subcatchment is provided in Table C-5.

Table C-5: Summary of saturated hydraulic conductivity for each flood mitigation drainage area in the Shoalhaven River floodplain

Subcatchment	K_{sat} Category	Risk Rating
Jaspers Creek	3	Moderate
P10D1	3	Moderate
P1D1	3	Moderate
P2D1	3	Moderate
P2D2	3	Moderate
P2D3	3	Moderate
P2G1	3	Moderate
P3D1	3	Moderate
P3D10	3	Moderate
P3D2	3	Moderate
P3D3	3	Moderate
P3D4	3	Moderate
P3D5	3	Moderate
P3D6	3	Moderate
P3D7	3	Moderate
P3D8	3	Moderate
P3D9	3	Moderate
P4D1	4	High
P4D2	3	Moderate
P4D3	3	Moderate
P4D4	3	Moderate
P5D1	3	Moderate
P5D2	3	Moderate
P5D3	3	Moderate
P6D1	5	Extremely High
P6D2	4	High
P6D3	3	Moderate
P6D4	3	Moderate
P6D5	3	Moderate
P6D6	3	Moderate
P6D7	3	Moderate
P6D8	3	Moderate
P6D9	4	High
P7D1	3	Moderate
P8D1	3	Moderate
P8D2	3	Moderate
P8D3	3	Moderate
P9D1	3	Moderate
P9D2	4	High
P12D1	3	Moderate

Appendix D Acid sulfate soil distribution

D1 Preamble

This section provides an overview of the soil profile data, such as surface elevation, profile depths and minimum pH available within the Shoalhaven River floodplain. This includes existing data available on the NSW Government eSPADE database and data in published literature where applicable (Section D2). In areas with limited existing soil profile information, a targeted field campaign was undertaken to address data gaps. Information on the data collected (including soil profiles) is summarised in Section D3.

D2 Existing soil profile data

Soil profile data on the Shoalhaven River floodplain that was available prior to the commencement of this study was sourced from:

- eSPADE Database (DPIE, 2020);
- Glamore (2003);
- Pease (1994); and
- Lawrie and Eldridge (2002)

D2.1 eSPADE database

eSPADE provides a database of information collected by earth scientists and other technical experts. eSPADE contains descriptions of soils, landscapes and other geographic features, and is used by the NSW Government, other organisations, and individuals, to improve planning and decision-making for land management. eSPADE contains extensive soil profile data for the Shoalhaven area.

eSPADE data has been filtered to remove any profiles that do not contain acidity (pH) data for each of the layers. Elevation data has been extracted from a 1 m DEM of the Shoalhaven floodplain. Where data is available on the floodplain, it has been included in estimating acid export in the region. Note that a low pH often indicates oxidised acidic soils, particularly in conjunction with the presence of yellow/orange mottling (jarosite). A layer of near neutral pH (pH 7 to 8) below an acidic layer indicates potential acidic soils, often in conjunction with a soil description of dark grey estuarine muds and clays. The presence of potential acid sulfate soils can be confirmed via a field oxidation test, with high stored acidity confirmed by a violent oxidation reaction, although this is not typically provided in the eSPADE database. The location of all relevant eSPADE soil profiles within the study area is presented in Figure D-1 and a summary of the soil profile data, including approximate surface elevation and minimum profile pH (within the tidal range), is provided in Table D-1.

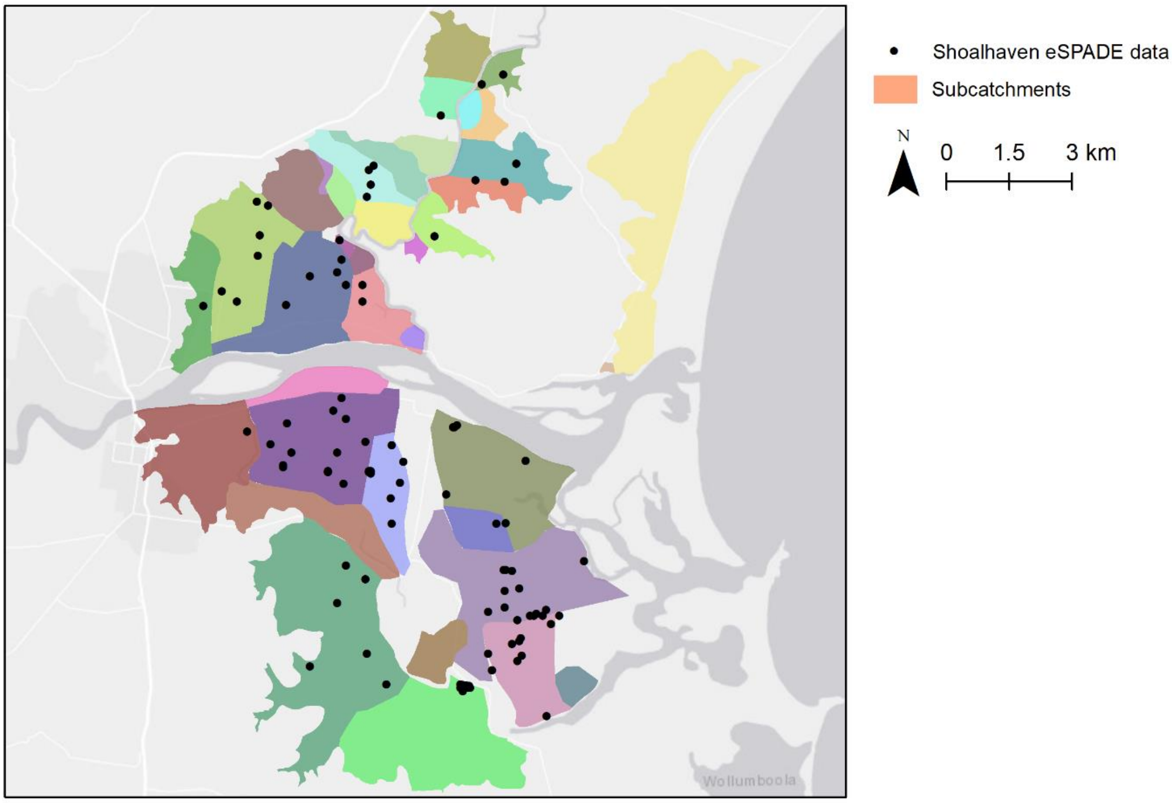


Figure D-1: Location of applicable eSPADE soil profiles in the study region

Table D-1: Summary of relevant eSPADE profiles (DPIE, 2020)

*Surface elevation extract from 1 m LiDAR.

** Minimum pH in this table is within the range of MLWS to 1 m AHD. Lower pH may have been observed elsewhere in the profile.

eSPADE Profile ID	Management area	Easting	Northing	Surface Elevation (m AHD)*	Total Profile Depth (m)	Minimum pH**
20076	P10D1	288774	6132670	1.24	1.15	6.5
20077	P10D1	288544	6132670	0.63	1.2	5.5
20078	P10D1	288544	6132750	0.53	1.2	5.5
20080	P10D1	288754	6132720	1.56	1	5
20081	P10D1	288734	6132670	1.22	1	5.5
20082	P10D1	288734	6132670	1.22	1	5.5
20084	P10D1	288724	6132680	1.16	1.1	5.5
20085	P10D1	288724	6132700	1.28	1.1	6
20086	P10D1	288714	6132720	1.37	0.8	5.5
20088	P10D1	288684	6132730	1.4	1.15	5.5
20089	P10D1	288614	6132700	0.75	1.2	5.5
20090	P10D1	288584	6132740	1.03	1.15	5.5
20091	P10D1	288574	6132740	0.87	1.1	5
20092	P10D1	288554	6132690	0.51	1.1	5
12849	P10D1	288604	6132590	0.75	0.9	4.5
12769	P1D1	283454	6138790	2.26	1.5	5.5

eSPADE Profile ID	Management area	Easting	Northing	Surface Elevation (m AHD)*	Total Profile Depth (m)	Minimum pH**
19058	P2D1	285704	6139590	1.73	1.1	5
19062	P2D1	285504	6139290	0.83	1.1	5.5
19059	P2D1	285804	6139090	0.3	1.1	4.5
19036	P2D1	284404	6138990	1.88	1.2	5
10951	P2D1	286279	6138540	-0.13	0.4	8
19033	P2D1	284004	6138490	1.76	1.1	7
19038	P2D1	284504	6138290	0.17	1.1	5
10954	P2D1	285604	6138290	-0.3	0.7	8
19034	P2D1	284304	6137990	-0.03	1.1	6
10955	P2D1	284304	6137940	0.22	0.86	7.5
13545	P2D1	285379	6137820	-0.22	1	5.5
13546	P2D1	285379	6137820	-0.22	1	6
13547	P2D1	285379	6137850	-0.29	1	6
10953	P2D1	285754	6137540	0.07	0.93	6.5
21973	P2D2	286904	6138465	0.36	1.72	6.5
21972	P2D2	287179	6138065	1.12	2.25	6.5
13543	P2D2	286354	6137820	1.65	1	8.5
13544	P2D2	286354	6137850	1.53	1	7.5
13548	P2D2	286404	6137790	1.43	1	8
13549	P2D2	286404	6137820	1.42	1	6
13550	P2D2	286404	6137850	1.3	1	6
21975	P2D2	287104	6137565	0.86	3	7
21970	P2D2	286879	6137190	0.76	1.6	7
21969	P2D2	286904	6136590	0.47	2.6	6.5
73328	P3D1	283679	6144278	1.26	0.9	4.5
73329	P3D1	283954	6144190	1.6	0.9	4.5
18026	P3D1	283754	6143478	0.92	2.3	4.5
12869	P3D1	283704	6142990	1.48	1.5	3
18028	P3D1	282842	6142140	2.52	3.11	5
19041	P3D1	283204	6141890	1.59	1.2	5.5
18027	P3D10	285654	6143365	1	2.1	5.7
18029	P3D6	286473	6145140	0.39	2.35	4
22567	P3D6	286354	6145040	0.16	0.85	4
12838	P3D6	286404	6144690	0.69	0.8	2.5
12870	P3D6	286304	6144390	1.21	0.9	3
12865	P4D1	285704	6142890	0.49	0.6	3.5
73332	P4D1	284954	6142500	0.55	0.7	4
19044	P4D1	285604	6142590	1.45	1.1	5
19045	P4D1	285804	6142290	1.43	1.1	5
20893	P4D1	284379	6141815	1.54	0.9	6.5
19039	P4D2	282404	6141790	0.78	1.1	5
19049	P4D3	286204	6142290	1.49	1.1	4.5
19046	P4D3	286204	6141890	0.9	1.1	5
65186	P5D1	288464	6138940	1.15	0.9	6

eSPADE Profile ID	Management area	Easting	Northing	Surface Elevation (m AHD)*	Total Profile Depth (m)	Minimum pH**
65187	P5D1	288374	6138890	0.8	0.9	6
65190	P5D1	288404	6138890	0.53	0.65	6.5
18019	P5D1	290104	6138090	0.56	1	3.7
73308	P5D1	288204	6137290	0.92	0.9	5
18021	P5D1	289629	6136603	0.81	1.1	4
12847	P5D2	289404	6136590	0.79	1.4	3.5
18024	P5D3	291492	6135690	0.77	0.8	6.5
71019	P5D3	289779	6135465	1.38	0.9	5
71020	P5D3	289629	6135490	1.29	0.95	5
21961	P5D3	289584	6135490	1.37	3	6.5
21962	P5D3	289954	6135040	1.53	1.8	6.5
73289	P5D3	289604	6134990	0.84	0.93	4.5
21963	P5D3	289604	6134590	1	2.7	7
18040	P5D3	290591	6134528	1.22	1.3	7
19071	P5D3	289204	6134490	1.03	1	4.5
65177	P5D3	290354	6134440	1.09	0.9	4.5
65188	P5D3	290204	6134390	1.03	0.9	7
65175	P5D3	290504	6134390	1.08	0.9	4.5
65176	P5D3	290304	6134390	0.97	0.9	4.5
21967	P5D3	289904	6134290	0.99	1.6	7
73627	P6D1	289565	6147317	1.14	0.8	4
18031	P6D1	289054	6147078	1.01	1.7	4
18032	P6D3	289879	6145190	1.26	3	4.5
18042	P6D4	289604	6144753	0.98	2.3	3.7
12837	P6D4	288904	6144790	0.53	0.7	3
18043	P6D5	287929	6143458	0.45	1.5	4
31773	P6D7	288079	6146340	1.4	0.97	4.5
12840	P7D1	285804	6135590	0.19	1	4
18039	P7D1	286279	6135265	0.93	1.6	6.5
12850	P7D1	285604	6134690	0.35	0.5	3
12848	P7D1	286304	6133490	0.12	0.9	4
19085	P7D1	284954	6133185	0.87	1	5.5
18041	P7D1	286779	6132753	0.34	2.3	5.5
70877	P8D2	290904	6134390	1	0.9	6
70876	P8D2	290704	6134190	1.07	0.9	5
73636	P8D2	289990	6133862	1.28	1.2	4.5
21966	P8D2	289779	6133715	0.51	1	7
21974	P8D2	289954	6133790	1.29	2	7
19072	P8D2	289204	6133490	1.25	1	5.5
21965	P8D2	290004	6133440	0.79	0.9	7
21964	P8D2	289904	6133315	0.53	0.9	6
19073	P8D2	289304	6133090	1.36	1.1	5
19076	P8D2	289304	6133090	1.36	1	6
19075	P8D2	290604	6131990	1.2	1.2	8

D2.2 Other literature

Published and grey literature was investigated for other soil profiles within the Shoalhaven River floodplain, which included data from Lawrie and Eldridge (2002), Glamore (2003) and Pease (1994). Only literature that provided information on pH at depth and suitable location information was included. Where no surface elevation data was provided, it was extracted from a 1 m DEM of the Shoalhaven floodplain. A summary of the soil profile data, including approximate surface elevation and minimum profile pH (within the tidal range), is provided in Table D-2 and shown in Figure D-2.

Table D-2: Summary of relevant soil profiles from literature

Profile	Management area	Easting	Northing	Surface Elevation (m AHD)	Total Profile Depth (m)	Minimum pH
Glamore_E1	P6D7	288399	6146715	1.19	3	3.4
Glamore_E32	P6D7	288352	6146728	0.9	2.4	4.1
Glamore_E8	P6D7	288270	6146748	1.16	2.8	4.0
Glamore_ E3	P6D7	288374	6146638	1.17	2.8	3.8
Lawrie & Edridge (2002)_19	P6D2	288838	6145923	0.3	1.25	3.5
Lawrie & Edridge (2002)_21	P3D8	288153	6145743	0.7	1.35	3.3
Lawrie & Edridge (2002)_27	P3D8	287820	6145162	0.5	3.95	3.3
Lawrie & Edridge (2002)_33	P3D7	287107	6145035	0.7	1.55	3.2
Lawrie & Edridge (2002)_34	P3D7	287326	6144752	0.5	1.95	3.5
Lawrie & Edridge (2002)_40	P4D3	286974	6141219	0.7	2.35	4.3
Lawrie & Edridge (2002)_41	P4D3	286641	6141563	0.5	2.75	4.2
Lawrie & Edridge (2002)_44	P4D3	286420	6141940	0.3	2.55	4.2
Lawrie & Edridge (2002)_47	P3D7	287003	6145485	0.85	2.55	3.9
Pease_BS1	P6D4	289260	6144757	0.55	2.5	3.0
Pease_BS5	P3D2	284608	6143798	0.85	2.5	3.6
Pease_BS10	P3D4	285752	6144777	0.2	2.5	3.6
Pease_BS12	P3D4	285783	6144777	0.6	2.5	2.9
Pease_BS22	P6D8	288521	6148067	1.3	2.5	3.4

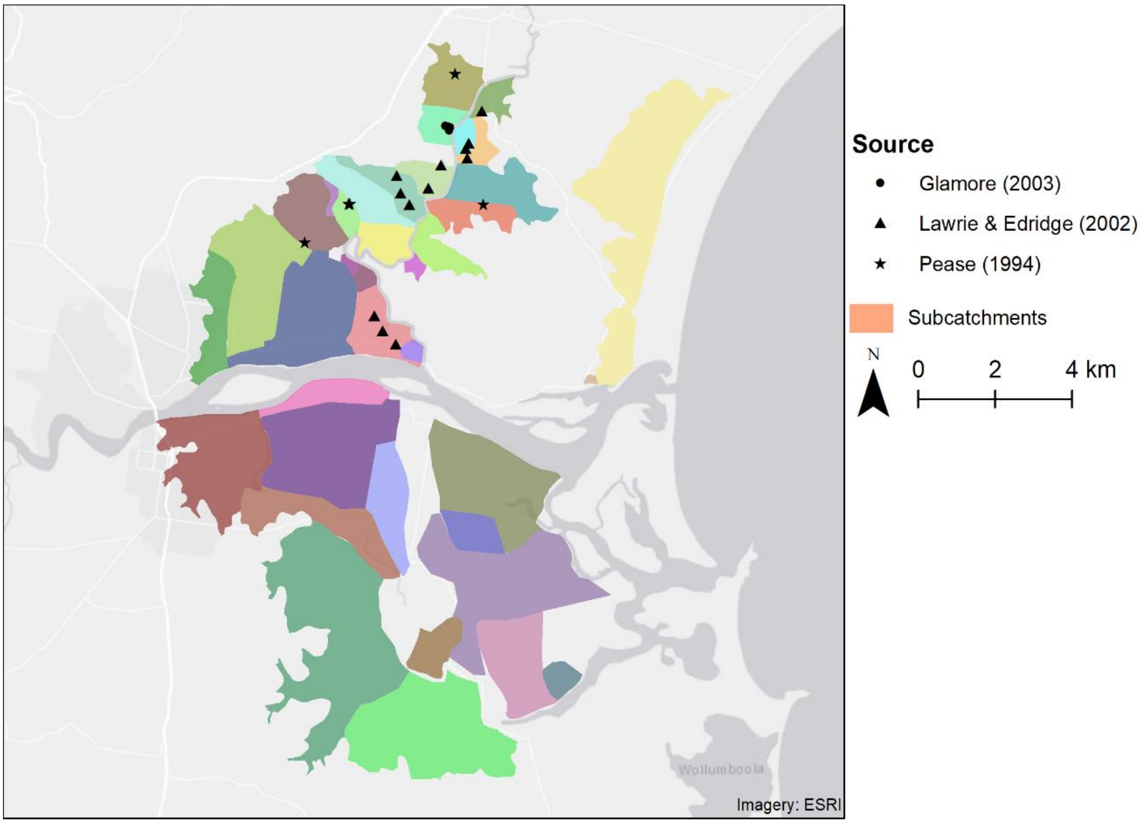


Figure D-2: Soil profiles from existing literature

D3 Field campaign

Glamore and Rayner (2014) completed a targeted field campaign which was undertaken to collect data in areas with limited information. The location of soil profiles collected for this study is shown in Figure D-3, and a summary of the soil profile data, including approximate surface elevation and minimum profile pH (within the tidal range), is provided in Table D-3. Detailed profile datasheets can be found in Glamore and Rayner (2014).

Figure D-3: Location of soil profiles from Glamore and Rayner (2014) field investigations

Table D-3: Summary of relevant soil profiles from Glamore and Rayner (2014) field investigations

Profile	Subcatchment	Easting	Northing	Surface Elevation (m AHD)	Total Profile Depth (m)	Minimum pH
BH001	P3D2	285258	6143979	1.25	2.7	3.88
BH002	P3D1	284605	6143413	0.38	2.4	5.99
BH003	P3D2	284389	6143912	0.56	2.4	3.84
BH004	P3D1	283203	6143864	1.13	2.8	4.7
BH005	P4D4	287622	6140940	1.84	2	4.33
BH006	P3D10	285845	6143293	0.49	3	3.96
BH007	P3D9	286357	6142778	1.10	2.8	5.36
BH008	P3D2	284395	6144730	0.97	2.8	4.13
BH009	P3D3	285190	6144575	0.51	2.5	3.89
BH010	P6D5	287463	6143690	0.30	2.5	5.08
BH011	P6D6	287278	6143232	0.64	2.5	4.27
BH012	P6D3	288384	6144892	0.76	2.7	4
BH013	P6D3	288593	6145052	0.49	2.7	3.9
BH014	P6D3	289752	6144986	0.40	2.6	3.99

D4 Summary of soil acidity for prioritisation

Section 4 of the Methods report (Rayner et al., 2023) summarises the method for prioritising subcatchments for acid generation. There are two (2) key pieces of information that are used to determine the pH factor used in the priority assessment that can be derived from the ASS data:

- Depth averaged hydrogen ion concentration (related to soil pH); and
- The contributing depth.

All else being equal, a higher hydrogen concentration (i.e. more acidic) and larger contributing depth is an indicator of a greater potential for acid generation and export. More information on how these are calculated can be found in Section 4 of the Methods report (Rayner et al., 2023). These are multiplied together to get the pH factor which forms part of the final prioritisation. Table D-4 summarises the information per subcatchment in the Shoalhaven River floodplain.

Across the Shoalhaven River floodplain, 10 flood mitigation drainage areas had no complete soil profile data to compute the pH factor. To provide a more complete prioritisation, other acidity data has been used for six (6) of these drainage areas, where it was available. Preference was given to soil profile data, but water quality data had been used as required. In these cases, the pH factor was calculated as the hydrogen ion concentration (in µmol/L) of the available acid data. The flood mitigation drainage units where this analysis was completed include:

- P2G1 – a groundwater pH of 6.6 was measured in this drainage area by AWACS (1995). A pH factor of 0.3 was adopted;
- P3D5 – a surface soil pH of 4.4 was measured by Pease (1994) in this drainage area. A pH factor of 40 was adopted;
- P6D9 – soil pH of 4.6 and 4.3 was measured by Lawrie and Eldridge (2006) and 4.7 was recorded by Pease (1994). A pH factor of 32 was adopted;
- P8D1 – Lawrie and Eldridge (2006) measured the minimum pH in the top 1 m of a soil profile in this drainage area of 7.8. A pH factor of 0.02 was adopted;
- P8D3 - Lawrie and Eldridge (2006) measured the minimum pH in the top 1 m of a soil profile in this drainage area of 4. A pH factor of 100 was adopted; and
- P9D2 - Glamore and Rayner (2014) recorded a surface water pH in this drainage area of 4.6 during a period of dry weather. A pH factor of 25.1 was adopted.

Table D-4: Summary of information from soil acidity information

Subcatchment	Depth averaged H+ concentration (µmol/L)	Contributing depth (m)	pH factor	Number of soil profiles available
Jaspers Creek	No data	1	No data	0
P10D1	4.0	1.4	5.7	15
P12D1	No data	No data	No data	0
P1D1	3.2	1.2	3.8	1
P2D1	4.6	1.3	6.0	14
P2D2	0.2	1.3	0.3	10
P2D3	No data	No data	No data	0
P2G1	No data	No data	0.3	0
P3D1	91.4	1.3	118.8	8
P3D10	32.2	1.3	41.8	2
P3D2	74.7	1.3	97.1	4
P3D3	85.7	0.8	68.6	1
P3D4	435.0	0.8	348.0	2
P3D5	No data	No data	40.0*	0
P3D6	313.2	1.3	407.1	4
P3D7	186.2	1.1	204.8	3
P3D8	293.8	1	293.8	2
P3D9	1.2	1.3	1.5	1
P4D1	81.0	1.3	105.2	5
P4D2	4.4	1	4.4	1
P4D3	27.9	1.3	36.2	5
P4D4	34.6	1.3	44.9	1
P5D1	54.4	1.4	76.2	6
P5D2	148.4	1.1	163.2	1
P5D3	6.9	1.4	9.6	14
P6D1	48.8	1.3	63.4	3
P6D2	158.8	0.5	79.4	1
P6D3	48.3	1.3	62.8	4
P6D4	270.0	1.2	324.0	3
P6D5	36.9	0.7	25.8	2
P6D6	37.4	0.9	33.7	1
P6D7	76.3	1.3	99.2	5
P6D8	204.8	1.3	266.2	1
P6D9	No data	No data	32.0*	0
P7D1	32.8	1.3	42.7	6
P8D1	No data	No data	0.02*	0
P8D2	2.8	1.4	3.9	11
P8D3	No data	No data	100.0*	0
P9D1	No data	No data	No data	0
P9D2	No data	No data	25.1*	0

* No soil profile data available. Other data used.

Appendix E Blackwater elevation thresholds

E1 Preamble

This section provides an overview of the data used to develop the elevation thresholds for the prioritisation of blackwater generation potential for floodplain subcatchments in the Shoalhaven River. The water level analysis undertaken is described in detail in Section 6 of the Methods report (Rayner et al., 2023).

E2 Water level gauges

There are seven (7) water level gauges operated by NSW DPIE Manly Hydraulics Laboratory (MHL) in the Shoalhaven River estuary that have been used for the analysis of critical thresholds for blackwater generation. The location of the gauges is shown in Figure E-1 and detailed in Table E-1. Water level data has been provided on a 15 minute time step throughout each monitoring period, although intermittent data gaps do occur.

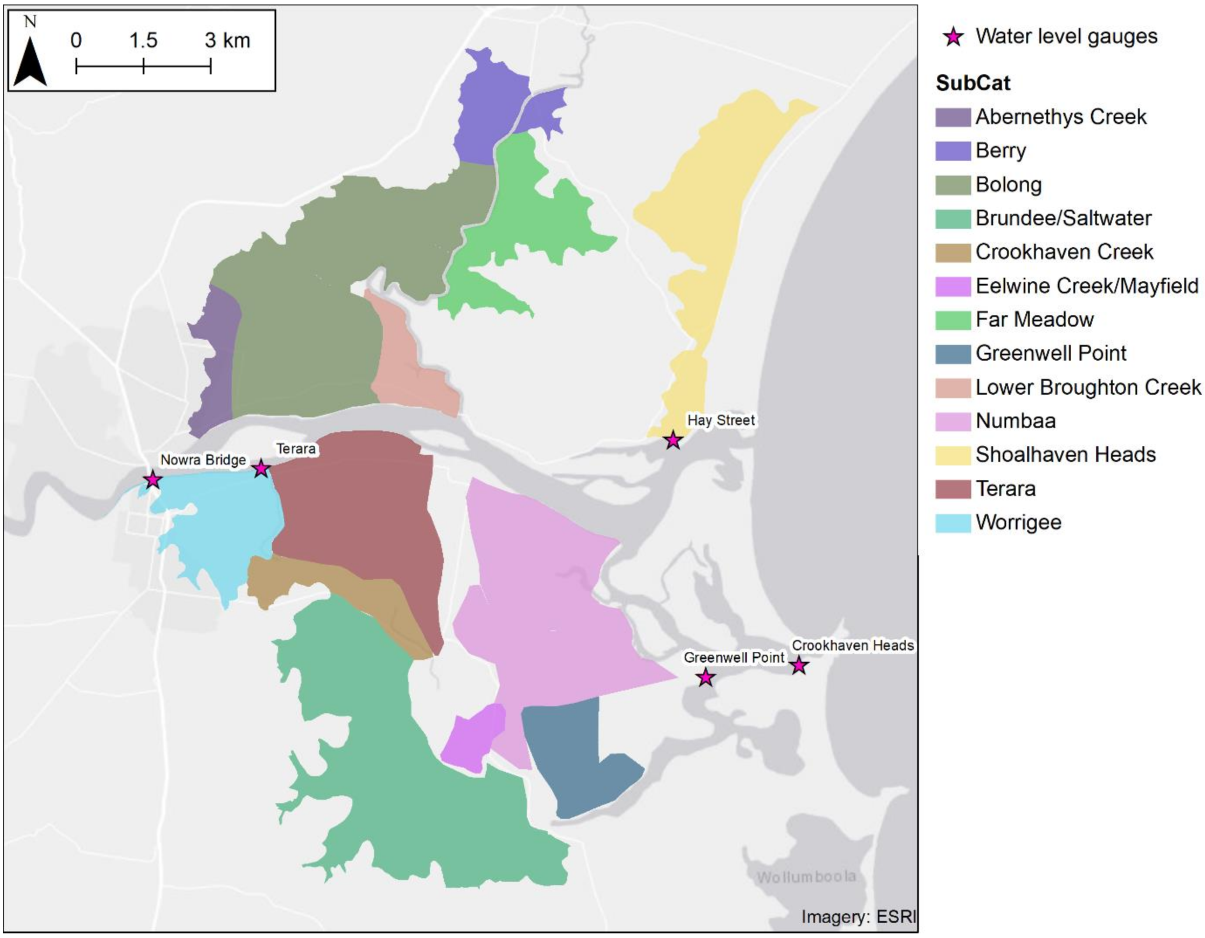


Figure E-1: Locations of water level gauges used for blackwater elevation thresholds

Table E-1: Details of water level gauges

Station	Chainage (km from entrance/ downstream confluence)	Length of Record (years)*	Mean High Water (MHW) (m AHD)
Crookhaven	0.2 (Crookhaven River)	27.4	0.4
Hay Street	0 (Shoalhaven River)	17.3	0.4
Greenwell Point	2.2 (Crookhaven River)	29.2	0.4
Terara	11.4 (Shoalhaven River)	17.4	0.4
Nowra Bridge	13.9 (Shoalhaven River)	28.8	0.4

* Excluding data gaps of greater than 6 hours.

Water level time series data at each gauge was analysed to establish a range of levels which can be applied to each floodplain subcatchment whereby the potential for prolonged inundation can be assessed. This is then related to floodplain topography and land use to prioritise blackwater generation across the floodplain. The analysis of the water level time series data is undertaken 25 times, to account for events that happen on average every 1, 2, 3, 4 and 5 years as well as events that result in inundation for 1, 2, 3, 4 and 5 days at a time. As a result, there can be up to 25 unique elevations at each gauge (noting that the minimum allowable level is mean high water (MHW)). The range of levels from this analysis, as well as the median and mean levels are shown in Table E-2.

Table E-2: Representative water level elevations at each water level gauge

Station	Minimum Level (m AHD)	Median Level (m AHD)	Mean Level (m AHD)	Maximum Level (m AHD)
Crookhaven	0.5	0.5	0.5	0.5
Hay Street	0.4	0.4	0.5	1.2
Greenwell Point	0.4	0.4	0.4	0.5
Terara	0.4	0.4	0.7	2.6
Nowra Bridge	0.4	0.4	0.8	2.9

E3 Subcatchment elevation thresholds

The subcatchments of the Shoalhaven River floodplain are shown in Figure E-1. For some of these catchments, the primary discharge point at the main river is sufficiently close to one of the water level gauges that the gauge well represents the downstream boundary condition. For other subcatchments, the main discharge points are located away from the available water level gauges. In these cases, the chainage along the river of the major discharge point has been measured, and the critical elevations have been interpolated between gauges. The water level stations used for each subcatchment is shown in Table E-3, as well as the interpolation used where required. Note, seven (7) of the subcatchments on the Shoalhaven River estuary are not well represented by water level gauges, and have been assumed to be the same as the most representative alternative subcatchment. This is because there are no water level gauges located within Broughton Creek and the Crookhaven River. This may result in an underestimation of the blackwater generation potential in subcatchments located upstream in either of these tributaries.

The range of levels, as well as the median and mean levels, at each subcatchment are shown in Table E-4. Figure E-2 shows spatially the area covered by the median elevation thresholds in each subcatchment.

Table E-3: Water level stations and subcatchments

Subcatchment	Water level station(s) used
Shoalhaven Heads	Hay Street
Coolangatta	Hay Street
Greenwell Point	Greenwell Point
Brundee-Saltwater*	Using Greenwell Point as a proxy
Eelwine Creek-Mayfield*	Using Greenwell Point as a proxy
Crookhaven Creek*	Using Greenwell Point as a proxy
Comerong Island*	Using Greenwell Point as a proxy
Numbaa	0.57 x Greenwell Point + 0.43 x Hay Street
Terara	0.43 x Hay Street + 0.57 x Terara
Lower Broughton Creek	0.40 x Hay Street + 0.60 x Terara
Bolong*	Using Lower Broughton Creek as a proxy
Far Meadow*	Using Lower Broughton Creek as a proxy
Berry*	Using Lower Broughton Creek as a proxy
Abernethys Creek	0.52 x Terara + 0.48 x Nowra Bridge
Worrigee	0.57 x Terara + 0.43 x Nowra Bridge

* Subcatchments are not well represented by an individual water level gauge. These subcatchments have been assumed to be the same as the closest subcatchment.

Table E-4: Representative elevations at each subcatchment in the Shoalhaven River floodplain

Subcatchment	Minimum Level (m AHD)	Median Level (m AHD)	Mean Level (m AHD)	Maximum Level (m AHD)
Shoalhaven Heads	0.4	0.4	0.5	1.2
Coolangatta	0.4	0.4	0.5	1.2
Greenwell Point	0.4	0.4	0.4	0.5
Brundee-Saltwater	0.4	0.4	0.4	0.5
Eelwine Creek-Mayfield	0.4	0.4	0.4	0.5
Crookhaven Creek	0.4	0.4	0.4	0.5
Comerong Island	0.4	0.4	0.4	0.5
Numbaa	0.4	0.4	0.5	0.9
Terara	0.4	0.4	0.6	2
Lower Broughton Creek	0.4	0.4	0.6	2
Bolong	0.4	0.4	0.6	2
Far Meadow	0.4	0.4	0.6	2
Berry	0.4	0.4	0.6	2
Abernethys Creek	0.4	0.4	0.7	2.7
Worrigee	0.4	0.4	0.7	2.7

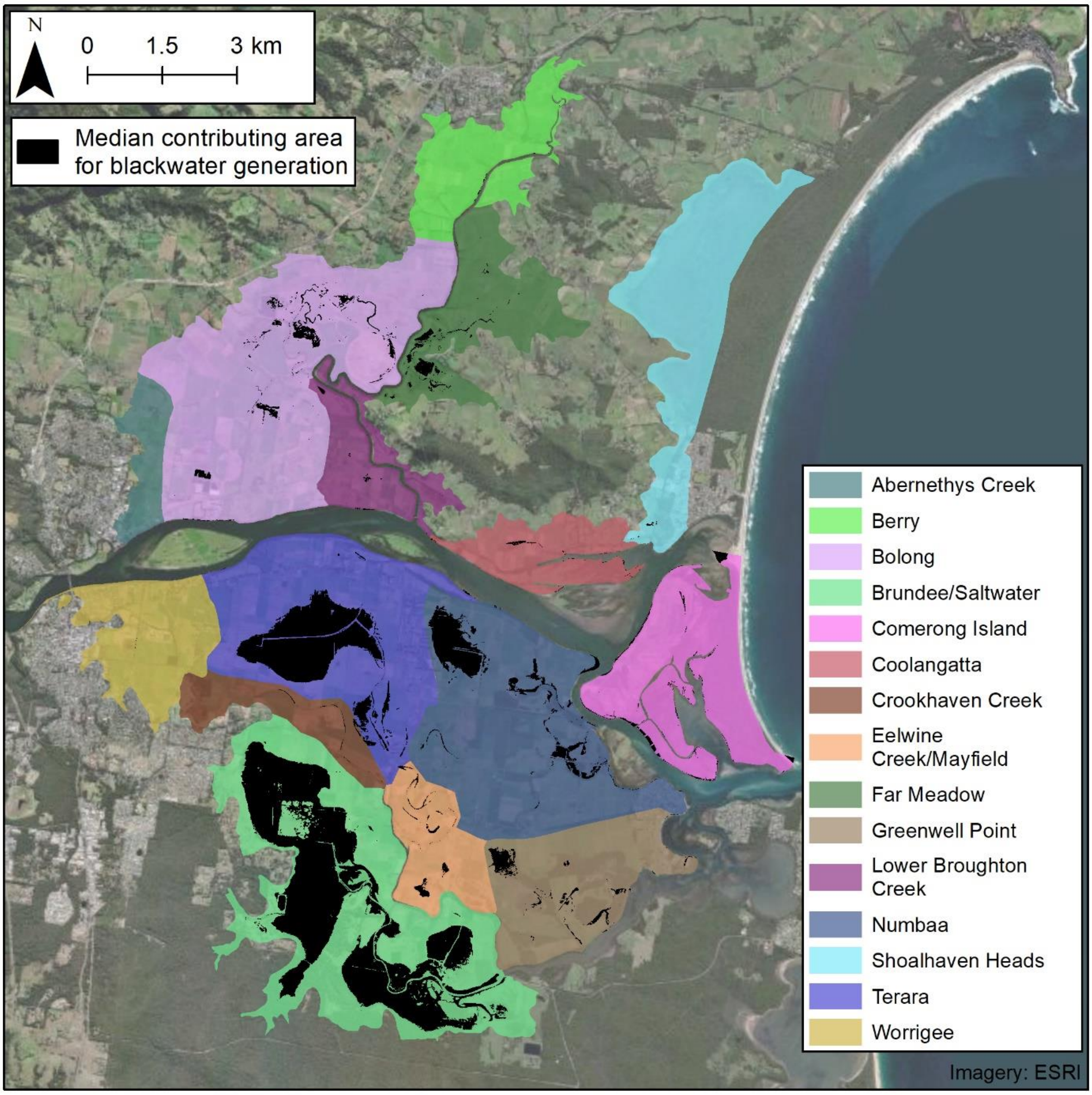


Figure E-2: Areas in the Shoalhaven River floodplain below the median elevation threshold

Appendix F Floodplain infrastructure

F1 Preamble

A range of floodplain infrastructure exists across the Shoalhaven River floodplain for the purpose of drainage and inundation protection (tidal and flooding). Included within this infrastructure is a number of structures that have been modified to improve water quality and aquatic connectivity across the floodplain. Floodplain infrastructure includes:

- Floodgates;
- Culverts or pipes;
- Weirs; and
- Levees.

The following section provides information on floodplain infrastructure for the Shoalhaven River floodplain. This includes the data identified and collected by Glamore et al. (2016) as well as data collected for this study in 2019/2020. Data tables containing information on floodplain infrastructure are provided.

F2 Infrastructure tenure

All end of system infrastructure identified on the Shoalhaven River floodplain is owned and managed by Shoalhaven City Council.

F3 Infrastructure terminology

The following section provides a number of figures which describe common types of floodplain infrastructure used to control water movement across the floodplain. These figures include descriptions for common terminology used to describe infrastructure.

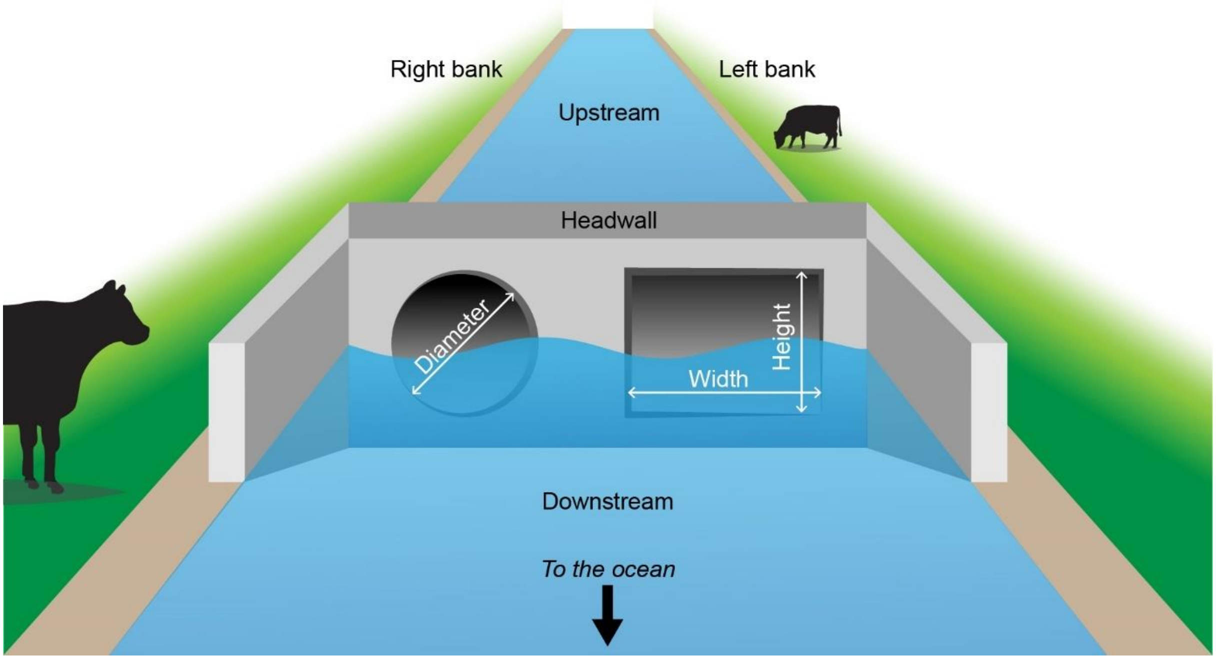


Figure F-1: Example of culverts controlling water in an agricultural drain

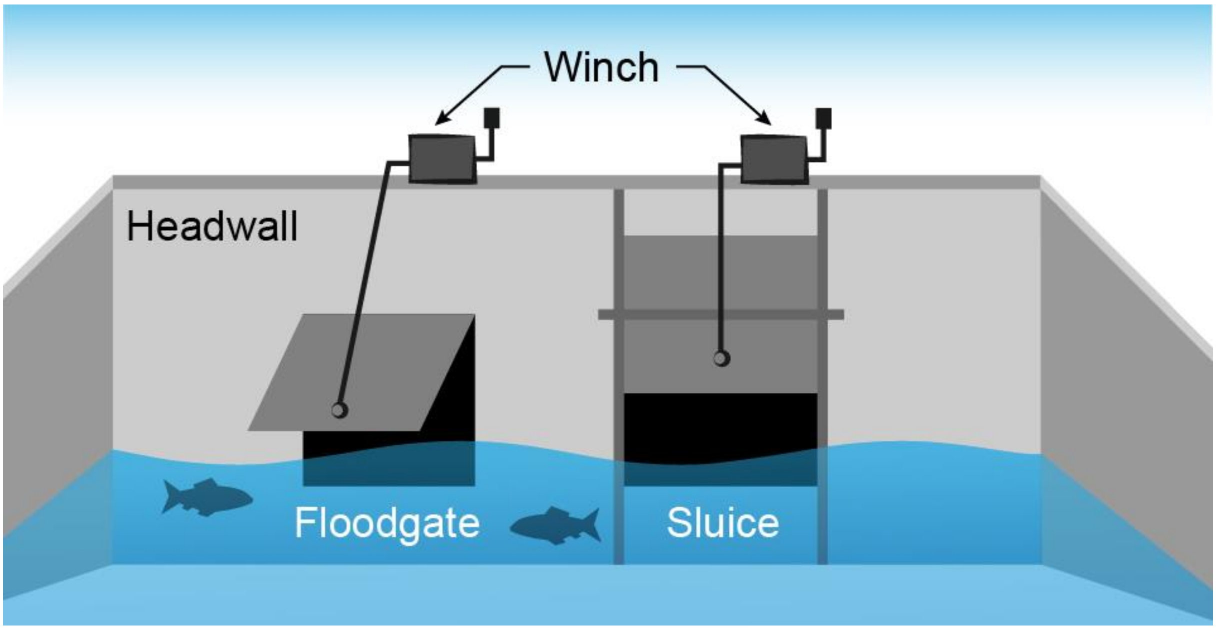


Figure F-2: Example of floodgate and sluice structures which can be fitted to culverts to control flow using a winch

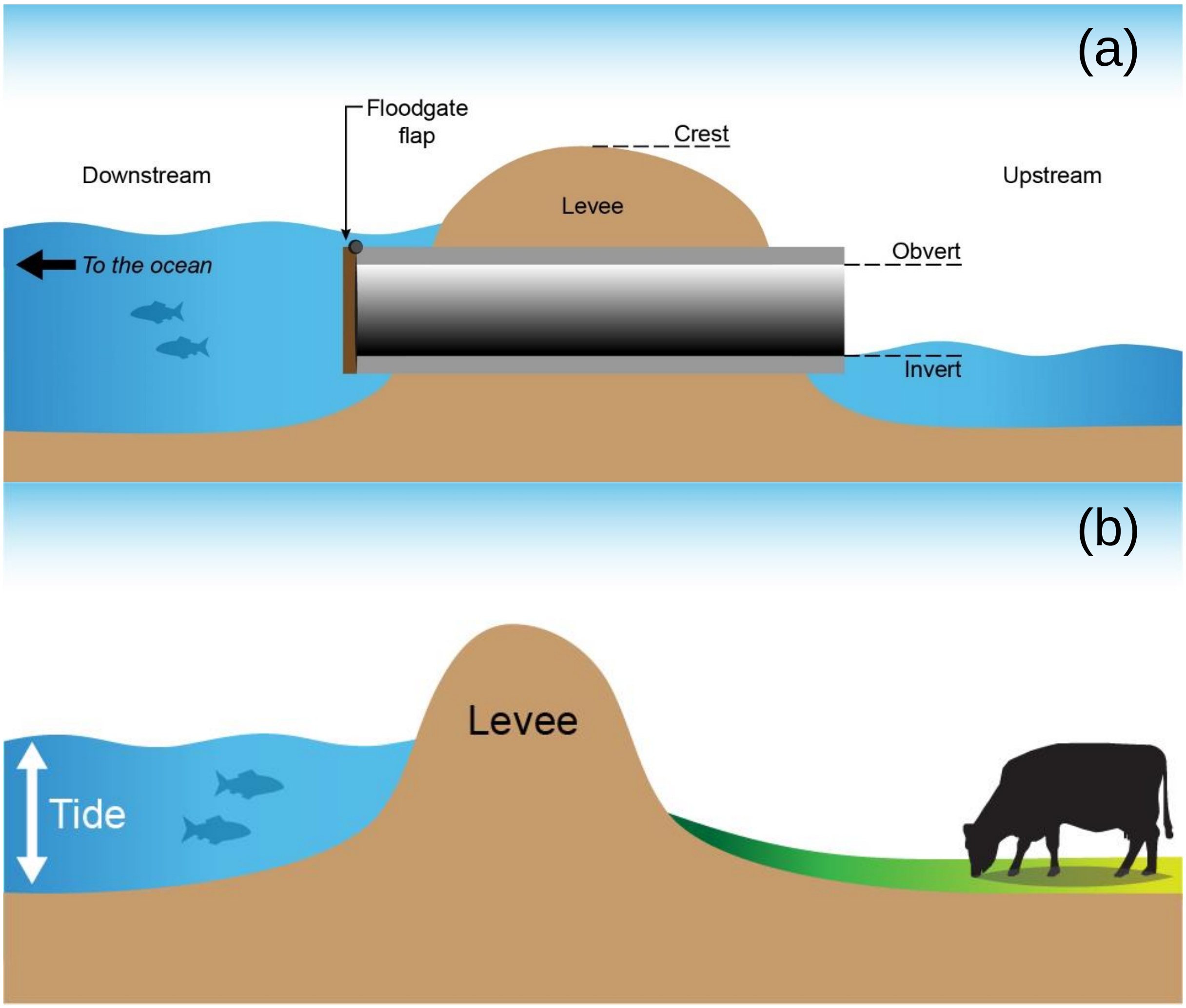


Figure F-3: Example of (a) a floodgate structure ensuring water levels upstream of a levee remain at the low tide level and (b) a levee preventing tidal inundation of the floodplain

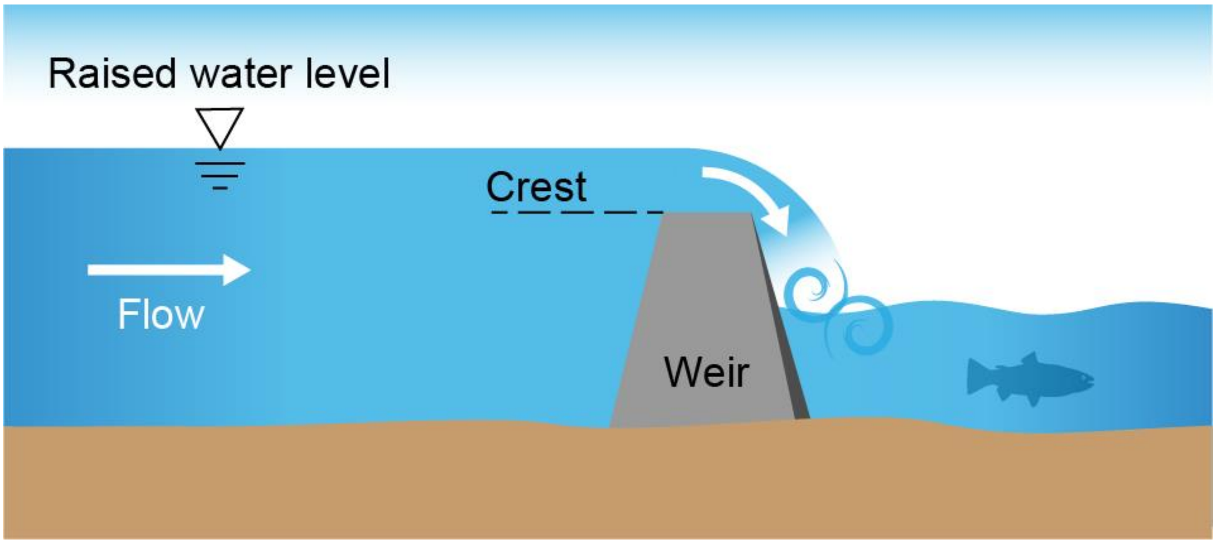


Figure F-4: Example of a weir ensuring a raised water level on the upstream side

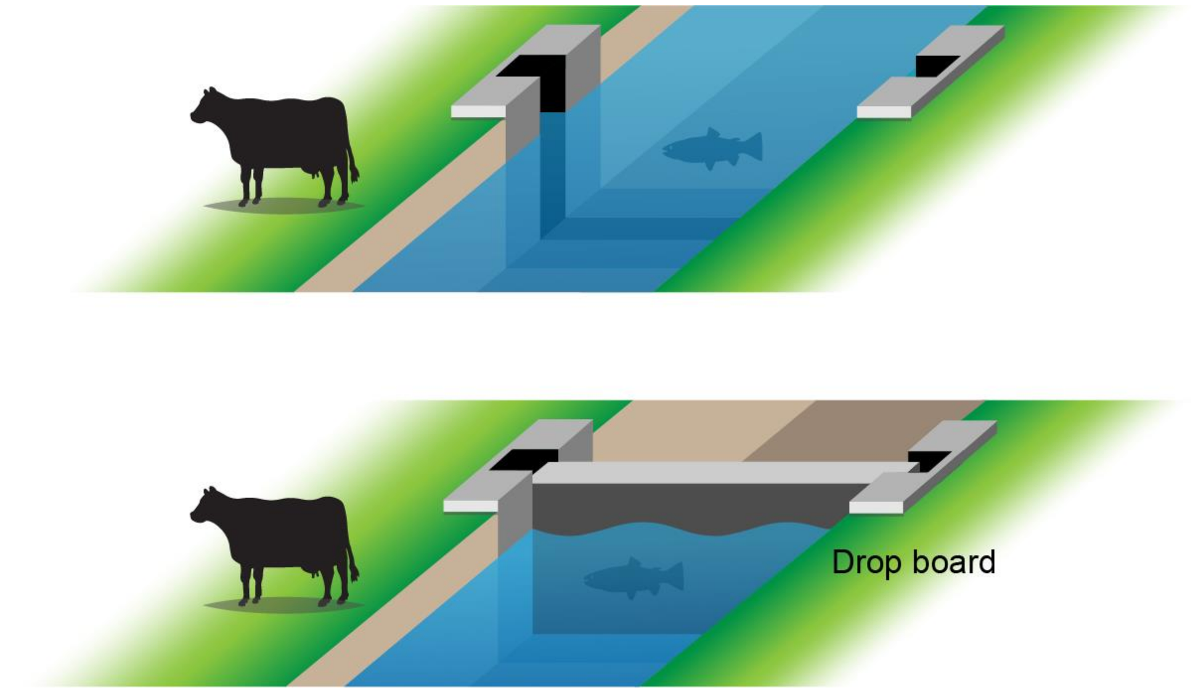


Figure F-5: Example of a drop board structure which can be used to control water levels and prevent inundation

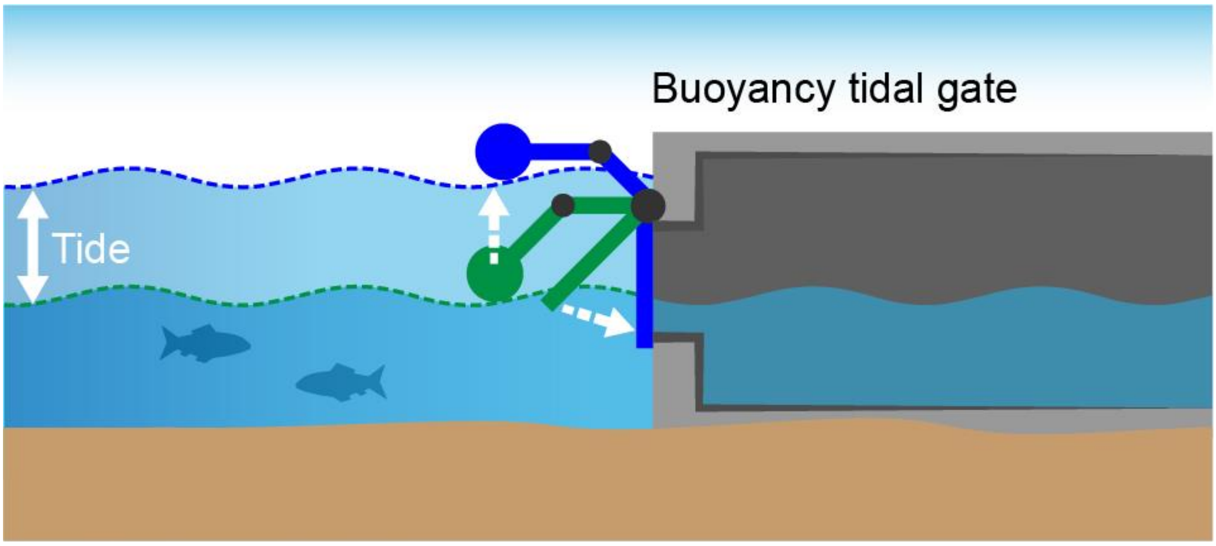


Figure F-6: Example of a buoyancy tidal gate that lets a controlled level of tidal water upstream of the structure (green) before closing due to a buoyancy mechanism and preventing further water ingress (blue)

F4 Floodplain infrastructure data tables

Floodgates were surveyed by Shoalhaven City Council surveyors in 2021. Table F-1 summarises the data available for floodgate infrastructure on the Shoalhaven floodplain. Floodgate condition and other comments have been inferred from photos provided by the Shoalhaven City Council. All floodplain infrastructure is managed by Council. Structures without good quality survey data are presented in Table F-2.

Table F-1: Summary of structures based on surveys from Shoalhaven City Council

Structure ID*	Date of Survey	Type	# of Culverts	Flap?	Diameter (m)	Width (m)	Height (m)	Easting (m) GDA94	Northing (m) GDA94	Upstream invert (m AHD)	Downstream invert (m AHD)	Condition	Category	Comment
CULRD1	17/06/2021 11:00	Floodgate	1	Y	0.45			288674	6132876	0.61	0.31	Poor	Secondary	Mangroves immediately downstream, restricting flow
CULRD2	17/06/2021 11:30	Floodgate	1	Y	0.45			288980	6132722	0.95	0.88	Fair	Secondary	Dry downstream, partially blocked upstream
GPINV1	15/06/2021 1:30	Floodgate	1	?	450			292570	6135458		-1.1		Secondary	
MAYRD1	16/06/2021 3:30	Floodgate	1	Y		0.6	0.3	287379	6133554	0.57	0.36		Secondary	
P10G1	17/06/2021 12:00	Floodgate	3	Y		1.7	1.8	289433	6131523	-0.53	-0.8	Good	Primary	
P12D1G1	1/06/2021 10:15	Floodgate	2	Y		1.8	1.27	280604	6139182		0.99	Good	Primary	
P12D1G1	1/06/2021 10:15	Floodgate	2	Y		1.8	1.27	280604	6139182		0.98	Good	Primary	
P13G1	15/06/2021 10:00	Floodgate	1	Y	0.75			282924	6139454		0	Poor	Secondary	Blocked
P13G10	22/06/2021 10:00	Floodgate	2	Y	0.75			293775	6140825	0.2	-0.08		Secondary	
P13G11	11/06/2021 8:00	Floodgate	1	Y	0.375			280954	6139299		3.2	Good	Secondary	
P13G12	11/06/2021 9:00	Floodgate	1	Y	0.375			281070	6139327		0.62	Poor	Secondary	
P13G13	11/06/2021 9:45	Floodgate	1	Y	0.375			281316	6139353		0.15	Fair	Secondary	
P13G14	11/06/2021 10:00	Floodgate	1	Y	0.525			281526	6139358		0.5	Fair	Secondary	
P13G15	11/06/2021 10:30	Floodgate	1	Y	0.375			281549	6139362		0.74	Fair	Secondary	
P13G16	11/06/2021 11:00	Floodgate	1	Y	0.375			281736	6139386		0.4	Fair	Secondary	
P13G2	11/06/2021 1:00	Floodgate	1	Y	0.375			283195	6139514		2.15	Fair	Secondary	
P13G3	15/06/2021 10:00	Floodgate	1	Y	0.6			283697	6139629		0.63		Secondary	
P13G4	15/06/2021 3:00	Floodgate	1	Y	750			292725	6134062		-0.07	Good	Secondary	
P13G5	15/06/2021 2:30	Floodgate	1	Y	0.9			292843	6135317		-0.23	Good	Primary	
P13G7	11/06/2021 11:45	Floodgate	2	Y	0.9			280217	6139361		-0.85	Fair	Secondary	wedged open
P13G8	16/06/2021 3:00	Floodgate	1	Y		0.6	0.3	287510	6133867	0.34	0.15	Good	Secondary	
P13G9	17/06/2021 9:30	Floodgate	1	N		0.6	0.3	287250	6133253	0.43	0.41	Fair	Secondary	Mangroves immediately downstream, restricting flow
P13G9	17/06/2021 9:30	Floodgate	1	Y	0.375			287250	6133253		0.32	Fair	Secondary	
P1D1G1	1/06/2021 11:15	Floodgate	3	Y		2.16	2.16	282226	6139181	-0.36	-0.67	Fair	Primary	
P2D2G1	1/06/2021 2:30	Floodgate	4	Y		1.53	1.53	287102	6135331	-0.94	-1.26	Fair	Primary	
P2D3G1	1/06/2021 1:30	Floodgate	1	Y	1.2			286705	6139885	-0.74	-0.94	Good	Primary	

P2G1	6/06/2021 2:30	Floodgate	5	Y	1.2			287102	6135331	-0.56	-0.7	Fair	Secondary	
P2G1D1	1/06/2021 11:45	Floodgate	4	Y		2.14	2.14	286697	6139664	-1.21		Good	Primary	
P2G2	15/06/2021 11:00	Floodgate	1	Y	0.675 or 0.75			283937	6139702		0		Secondary	
P3D10G1	22/06/2021 2:30	Floodgate	1	Y	0.675			285710	6143424	-0.38	-0.41	Fair	Secondary	Mangroves upstream
P3D4G1	24/06/2021 9:30	Floodgate	3	Y		1.53	1.53	285939	6144021	-0.98	-1.32	Good	Primary	Auto-tidal floodgate on centre gate
P3D5G1	24/06/2021 9:00	Floodgate	3	Y		1.53	1.53	286932	6143282	-1.06	-1.29	Good	Primary	
P3D6G1	23/06/2021 2:15	Floodgate	3	Y		1.53	1.53	287453	6144204	-0.98	-1.18	Good	Primary	Auto-tidal floodgate on centre gate
P3D7G1	23/06/2021 1:45	Floodgate	3	Y		1.53	1.53	287742	6144920	-0.8	-1.25	Fair	Primary	
P4D1G1	22/06/2021 2:00	Floodgate	4	Y		2.3	2.15	285485	6143709	-0.89	-1.22	Good except tidal gate	Primary	Auto-tidal gate on centre gate. Does not look like it is still functional
P4D2G1	24/06/2021 3:00	Floodgate	2	Y		1.53	1.53	281865	6140188	-0.33	-0.63	Good	Primary	
P4D3G1	24/06/2021 10:30	Floodgate	2	Y		1.53	1.53	286802	6141750	-0.95	-1.2	Good	Primary	
P4D4G1	24/06/2021 11:00	Floodgate	1	Y	0.75			287640	6140956	0.77	0.65	Good	Secondary	
P5D1G1	17/06/2021 3:00	Floodgate	4	Y		2.3	1.5	290627	6136706	-0.88	-1.23	Good	Primary	
P5D3G1	16/06/2021 12:00	Floodgate	3	Y		1.5	1.5	291548	6135708	-0.96	-1.3		Primary	
P6D1G1	23/06/2021 11:30	Floodgate	2	Y		1.53	1.53	288919	6147004	-0.87	-1.3	Good	Secondary	Looks like winch installed on right floodgate
P6D2G1	24/06/2021 1:30	Floodgate	2	Y		1.73	1.53	288559	6145950	0	0	Good	Primary	
P6D2G2	24/06/2021 2:00	Floodgate	1	Y	0.6			288562	6145935	-0.58	-0.6	Fair	Secondary	Wedged open
P6D4G1	23/06/2021 1:15	Floodgate	2	Y	1.35			287863	6144834	-0.34	-0.39	Good	Secondary	
P6D5G1	24/06/2021 8:00	Floodgate	4	Y		1.53	1.53	287447	6143613	-0.94	-1.24	Good	Primary	
P6D6G1	24/06/2021 8:30	Floodgate	1	Y	0.6			287216	6143299	-0.67	-0.51	Fair	Secondary	
P6D7G1	18/06/2021 10:00	Floodgate	2	Y		1.5	1.5	288431	6146726	-0.75	-0.86	Poor	Primary	Winched installed, gate not closing
P6D8G1	18/06/2021 11:30	Floodgate	2	Y		1.5	1.5	288871	6147174	-1.18	-1.3	Good	Secondary	
P6G1	18/06/2021 10:30	Floodgate	1	Y	0.45			288448	6146729	0.46	0.35	Good	Secondary	
P6G2	18/06/2021 9:00	Floodgate	1	Y	1.35			289200	6147764		-0.32	Fair	Primary	partially blocked upstream
P7G1D2	1/06/2021 3:00	Floodgate	4	Y		2.9	1.55	287289	6132988	-0.93	-1.28	Good	Primary	
P8D2G1	16/06/2021 10:00	Floodgate	2	Y		1.5	1.5	291007	6132096	-0.9	-1.22	Fair	Secondary	
P8G1	15/06/2021 3:30	Floodgate	1	Y	1.2			291941	6133241	-0.88	-0.88	Fair	Primary	
P8G1D1	16/06/2021 9:00	Floodgate	1	Y	0.6			291610	6132540	-0.65	-0.74	Poor	Primary	Covered in oysters
P8G2	16/06/2021 10:30	Floodgate	1	Y	0.6			290388	6131843	0.05	0.03	Good	Secondary	

P8G3	16/06/2021 11:00	Floodgate		Y	1.2			289811	6131990	-0.31	-0.44	Good	Primary	
P8G3D1	17/06/2021 10:15	Floodgate	1	Y	1.2			288259	6133213	-0.95	-1.14	Poor	Secondary	Mangroves immediately downstream, restricting flow
P8G4	17/06/2021 9:30	Floodgate		Y	1.2			287563	6134072	-0.86	-1.25	Fair	Primary	
P9D1G1	22/06/2021 11:15	Floodgate	4	Y		2.3	1.55	292448	6140231	-1.48	-1.53	Fair	Primary	Some oysters downstream
P9D2AG1	22/06/2021 12:00	Floodgate	1	Y	1.35			292225	6140215	-1.27	-1.6	Poor	Secondary	Auto-tidal gate installed, but covered in oysters, with floats removed. Doesn't look like it still functions
P9G1	22/06/2021 10:30	Floodgate	1	Y	0.6			292759	6140258	0.17	0.17	Good	Secondary	
P9G2	22/06/2021 12:45	Floodgate	2	Y		1.53	1.53	290651	6139958	-1.1	-1.32	Good	Secondary	
UNI1	18/06/2021 12:00	Floodgate	1	Y	0.9			286403	6144642	-0.77	-0.82	Good	Secondary	
UNI2	18/06/2021 12:30	Floodgate	1	Y	1350			286418	6144656	-0.96	-1.1	Good	Secondary	
UNI3	18/06/2021 1:00	Floodgate	1	Y	1.2			286434	6144652	-1.15	1.24	Fair	Secondary	wedged open, partially blocked upstream

* Structure ID's have been provided by Shoalhaven City Council.

Table F-2 Summary of unsurveyed structures

Structure ID	Easting	Northing	Sub-catchment	Comment
P13G17	281547.7	6139364	Worrigee	Not inspected
P3D9G1	286452.4	6142745	Lower Broughton Creek	Not inspected
P6D3G1	288296.7	6144948	Far Meadow	Not inspected
P6D9G1	288567	6146094	Far Meadow	Not inspected

Appendix G Water Quality

G1 Preamble

Water quality data presented in this section is based on the summary provided by Glamore and Rayner (2014). The water quality data focuses on capturing acid events to define indicative acid levels in each flood mitigation drainage area. Acid discharge events occur following large rainfall events, typically occurring following events greater than the one (1) year average recurrence interval (ARI) event. These events are large enough to cause significant inundation of the floodplain/backswamp areas and flushing of buffering capacity from the estuary. Johnston et al. (2003) identified that 90 % of the total pollutant load is discharged during the last 10% of the flood hydrograph. This occurs approximately 5 to 14 days following the peak of the flood hydrograph. Subsequently, capturing acid flux (concentration*discharge) from acid affected drains can be problematic due to the event uncertainty.

G2 Broughton Creek Floodplain Water Quality

Following the acid events of 1991 and 1992 on Broughton Creek, a large scale monitoring program was initiated to undertake monthly monitoring of drain water quality (Figure G-1). This monitoring program on Broughton Creek continued at most monitoring locations until approximately the early 2000s with ongoing monitoring continuing at several key locations. Regular monitoring of drain discharge captured some acid discharge events, with low pH water being measured (~ pH 3 to 4) with general drain pH being higher (~ pH 6). Where possible, wet weather event pH was used to prioritise drain water quality. Poor water quality resulting from wet weather events were checked by comparing water quality records with rainfall and modelled sub-catchment discharges.

Some Broughton Creek drains, however, were not monitored during the 1990s, with acid event water quality lacking. Dry weather drain pH was used where wet weather pH was absent, with upstream drain pH used in preference to minimise buffering effects near the structure caused by leaking floodgates. Shoalhaven City Council undertook a survey of dry weather drain water quality in March 2013 (Table G-2) to supplement existing data.

G3 Crookhaven River Floodplain Water Quality

Whilst Broughton Creek has been extensively monitored, water quality data collection on the Crookhaven River floodplain and estuary has historically not targeted acid drainage with monitoring locations focused on capturing generally, open-waterway health. Subsequently, the majority of Shoalhaven City Council water quality monitoring locations cannot be used to assign typical acid event pH to individual drains. Lawrie and Eldridge (2006) undertook sampling of drain and groundwater pH during an intensive, floodplain wide acid sulfate soil assessment.

Table G-1: 2013 Dry Weather Drain WQ Survey

Drain	Upstream or Downstream	Date	Time	Temperature (^{O}C)	Conductivity (ms/cm)	Salinity (PPT)	pH	Turbidity (NTU)
P4D3	US	26/03/2013	14:15:25	24.19	37.8	23.93	6.4	8.7
P4D3	DS	26/03/2013	14:18:17	24.45	26.7	16.35	6.45	1.5
P3D9	US	26/03/2013	14:29:41	24.51	17.1	10.03	6.22	2
P3D9	DS	26/03/2013	14:33:37	25.0	13.7	7.91	6.57	-0.2
P3D10	US	26/03/2013	14:47:41	25.08	12.1	6.9	6.93	7.6
P3D10	DS	26/03/2013	14:49:16	25.03	12.3	7.00	6.86	56.6
P4D1	US	26/03/2013	14:57:45	23.16	5.2	2.82	6.54	2.5
P4D1	DS	26/03/2013	15:00:06	24.58	9.7	5.45	6.88	1.5
P3D4	US	26/03/2013	15:12:13	20.47	7.6	4.2	3.85	5.6
P3D4	DS	26/03/2013	15:15:19	24.26	9.8	5.51	5.89	2.3
P3D5	DS	26/03/2013	15:24:39	24.44	11.3	6.4	6.71	1.5
P6D6	US	26/03/2013	15:32:24	23.97	8.5	4.72	6.56	-0.1
P6D6	DS	26/03/2013	15:33:44	24.48	10.7	6.07	6.77	3.6
P6D5	US	26/03/2013	15:46:37	23.17	13.8	7.94	5.89	15.3
P6D5	DS	26/03/2013	15:49:21	24.2	8.3	4.61	6.45	2.2
P3D6	US	26/03/2013	15:58:38	23.88	8.3	4.62	6.58	1.3
P3D6	DS	26/03/2013	15:59:47	24.22	17.1	10.03	6.54	1.3
P3D8	US	26/03/2013	16:11:56	23.02	9.2	5.15	6.15	2.2
P3D8	DS	26/03/2013	16:13:50	22.66	6.3	3.43	5.6	2.3

G4 Water Quality Data Sources

Water quality sources for the lower Shoalhaven River estuary include:

- Historical (State of the Environment reporting) and ongoing monitoring by Shoalhaven City Council;
- Ongoing monitoring of Crookhaven River estuary by Shoalhaven City Council;
- Monitoring of marine aquaculture lease sites by NSW Food Authority;
- Research monitoring by Ana Rubio (University of Wollongong); and,
- NSW Office of Environment and Heritage (OEH) Monitoring, Evaluation and Reporting (MER) program during summer months.

All water quality monitoring sites are presented in Figure G-1. Indicative drain water quality (pH) = for each drainage area is presented in Table G-2. Where no soil profile data is available, this has been used in the prioritisation.

Table G-2: Indicative water quality in each flood mitigation drainage area

Drain	Wet pH (downstream)	Wet pH (upstream)	Dry pH (downstream)	Dry pH (upstream)	Borehole pH	Data Source
P1D1			6.82		3.63	511 (Lawrie & Eldridge)
P1D1a			6.82		3.63	511 (Lawrie & Eldridge)
P1D1b			6.82		3.63	511 (Lawrie & Eldridge)
P1D1c			6.82		3.63	511 (Lawrie & Eldridge)
P2D1			7.51		5.88	512 (Lawrie & Eldridge)
P2G1					6.6	REMS (BH002)
P2D2			7.1			510 (Lawrie & Eldridge)
P2D3						
P3D1	3.87	5.5				375 (SCC)
P3D1a	3.87	5.5				375 (SCC)
P3D1b	3.87	5.5				375 (SCC)
P3D2	3.85	5.2				348 & 373 (SCC)
P3D3	3.87					375(SCC)
P3D4	3.4	3.85	5.89	3.85		510 & 348(SCC)
P3D5	5.28		6.71			350(SCC)
P3D6	2.8		6.54	6.45		448(SCC)
P3D7	6					355(SCC)
P3D8	6		5.6	6.15		355(SCC)
P3D9			6.57	6.93		SCC 2013 Dry Survey
P3D9a			6.57	6.93		SCC 2013 Dry Survey
P3D10			6.86	6.93		SCC 2013 Dry Survey
P4D1	3.87					375(SCC)
P4D2	2.8	6	6.88	6.54		461(SCC)
P4D3	5.4		6.45	6.4		347(SCC)
P4D3a	5.4		6.45	6.4		347(SCC)
P4D4	4.61					10(SCC)
P5D1					6.15 4.19	504 (Lawrie & Eldridge) 509(SCC)
P5D2					6.15 4.19	504 (Lawrie & Eldridge) 509(SCC)
P5D3					5.85	503 (Lawrie & Eldridge)
P5D3a					5.85	503 (Lawrie & Eldridge)
P6D1	4.16					444(SCC)
P6D2	2.8					354(SCC)
P6D3	5.4					353(SCC)
P6D4	3					446(SCC)
P6D5	3.4		6.45	5.89		351(SCC)
P6D5a	3.4		6.45	5.89		351(SCC)
P6D6			6.77	6.56		SCC 2013 Dry Survey
P6D7	3.65	6				363 (SCC)
P6D8	2.8	6				443 (SCC)
P6D8a	2.8	6				443 (SCC)
P6D9	4.99					356 (SCC)
P7D1					6.95	506 (Lawrie & Eldridge)
P8D1			7.5			515 (Lawrie & Eldridge)
P8D2					5.89	505 (Lawrie & Eldridge)
P8D2a					5.89	505 (Lawrie & Eldridge)
P8D3			6.76		3.88	508 (Lawrie & Eldridge)
P9D1					4.5	SALIS
P9D2			4.6		4.5	SALIS
P9D2a			4.6		4.5	SALIS
P10D1			7.57			507 (Lawrie & Eldridge)
P12D1						

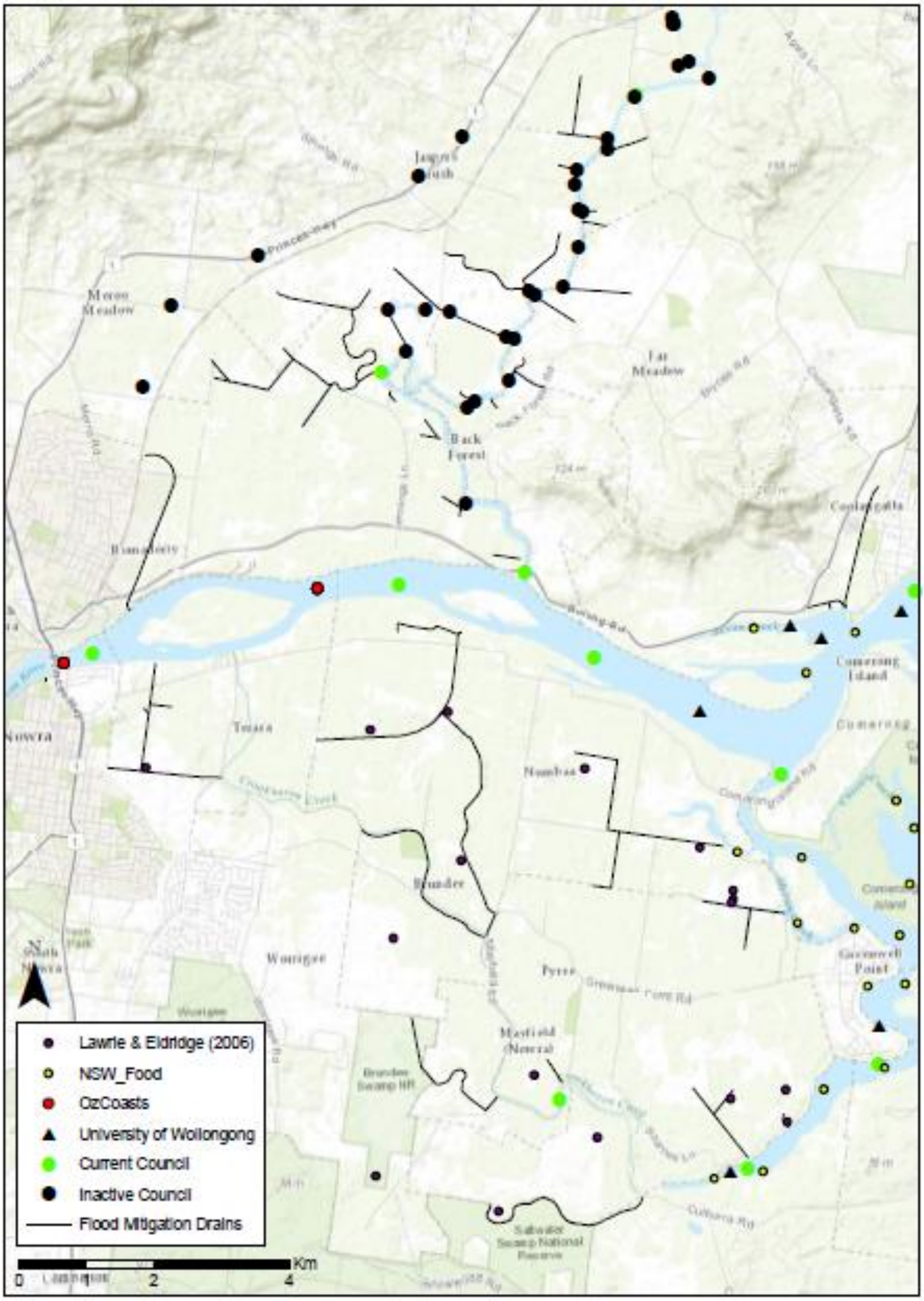


Figure G-1: Water quality monitoring locations

Appendix H Hydrodynamic Modelling

H1 Preamble

The following section provides a summary of the hydrodynamic numerical model adopted for the Shoalhaven River estuary. Results of the hydrodynamic modelling were used for the floodplain vulnerability assessments, detailed in Section 11 of the Methods report (Rayner et al., 2023).

H2 Hydrodynamic model

Hydrodynamics is the study of water movement. In an estuary, three (3) main elements control the movement of water (tidal hydrodynamics). This includes, estuary geometry, upstream catchment inflows and downstream ocean tides. The geometry of an estuary is defined by its width, length, depth or the shape and storage of sidearms. Upstream catchment inflows are based on rainfall and runoff and downstream tidal inflows are based on the water levels in the ocean.

H2.1 Numerical model

Numerical modelling of the Shoalhaven River estuary tidal hydrodynamics was undertaken using the RMA modelling suite (King, 2015). The RMA-2 hydrodynamic model solves the shallow water wave equations and is suitable for the simulation of flow in vertically, well-mixed water bodies such as, estuaries. RMA-2 uses the principles of conservation of mass and momentum, and represents typical processes of bed and bank friction, turbulence and wind stress.

RMA-2 calculates a finite element solution of the Reynolds-form of the Navier-Stokes equations for turbulent flows. The main internal model parameters applied to the model are eddy viscosity, bed friction and turbulent mixing. The horizontal eddy viscosity (ε) is specified in terms of a scaled velocity and element size as presented in Equation H-2:

$$\varepsilon_{xy} = \alpha(x,y,t) \cdot V(x,y,t) \cdot \Delta_{elt}(x,y)$$

Equation H-2

Where:

- ε = horizontal eddy viscosity (m^2/s)
- V = velocity (m/s)
- α = non-dimensional scaling factor
- Δ_{elt} = is a length representative of the element size (m)

The RMA-2 model utilises a finite element mesh consisting of an irregular connection of nodes and elements to represent the model domain. Finite elements are suitable to model complex estuaries as the elements can vary in size and shape to represent the geometry of the waterbody. Accurate representation of the waterway geometry is important as it is a major factor in replicating and predicting tidal hydrodynamics.

Water levels and flow velocities are predicted at every node within the finite element mesh of the model. One dimensional (1-D) elements are used to represent channel flow velocities in one-horizontal direction (i.e. upstream to downstream and where flow occurs perpendicular to the channel cross section), whereas two dimensional (2-D) elements represent depth-averaged flow velocities in two-horizontal directions (i.e. x-y plane). RMA-2 simulates the process of bank wetting and drying as the water level changes through the use of marshing elements. Marshing simulates drying by approximating elements with a smaller width and higher friction for water transfer thereby effectively preventing flow in those elements while conserving mass.

H2.2 Model domain

A 1-D/2-D RMA-2 hydrodynamic model of the Shoalhaven River Floodplain was adopted from (Glamore et al., 2015) and used to simulate the typical tidal water level variations within the estuary. This numerical model had been previously calibrated against water levels and tidal discharge throughout the estuary. The model domain extended across the major tidal regions of the Shoalhaven River up to the tidal limit at Burrier as well as Crookhaven River and Broughton Creek[1]. The hydrodynamic model was extended using 1-D elements to simulate tidal currents through Crookhaven Creek, to ensure model data was available downstream of each floodgate. The updated model area is shown in Figure H-1.

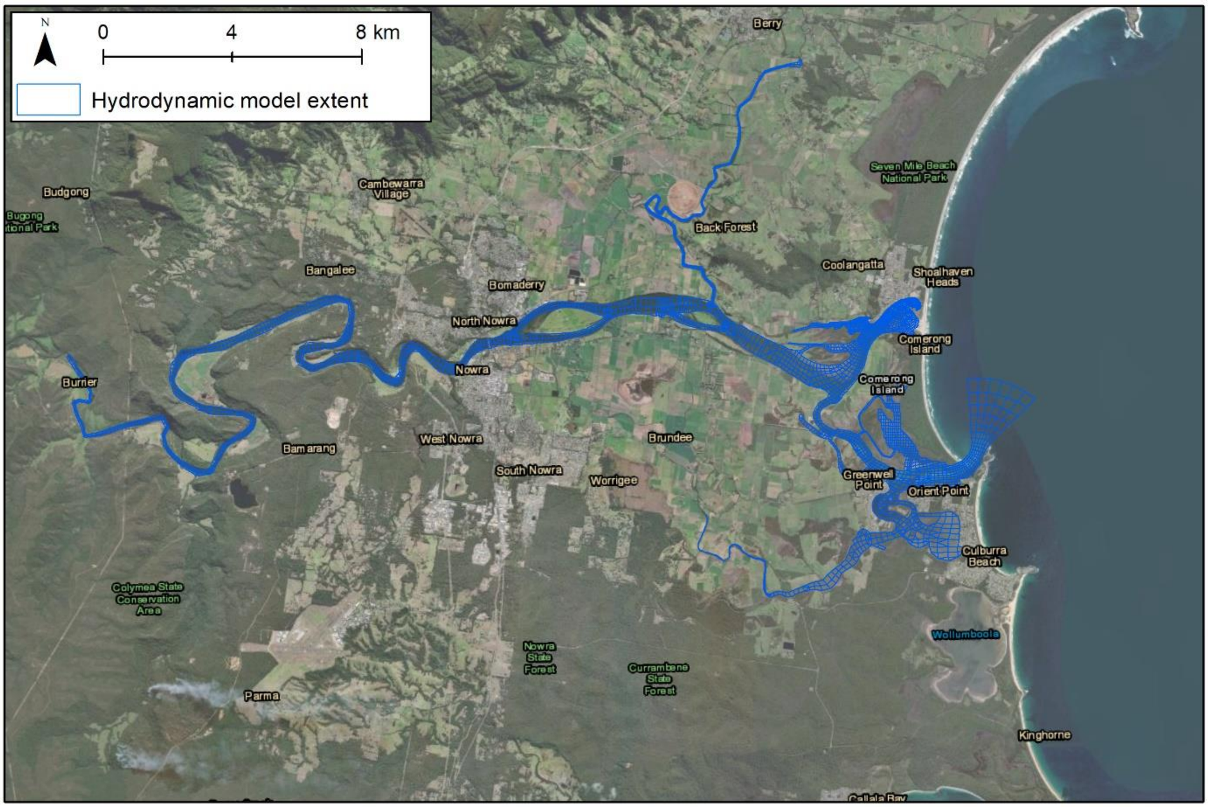


Figure H-1: Shoalhaven River estuary – tidal hydrodynamic model extent

[1] In this particular hydrodynamic model the Shoalhaven Heads Entrance was assumed to be closed. Entrance conditions can significantly impact the tidal water levels throughout the entire estuary and therefore it is recommended that future studies investigate the sensitivity of this assumption further.

H2.3 Model inputs

The hydrodynamic model comprised of three (3) main inputs, including channel geometry, downstream ocean tidal water levels and upstream catchment inflows.

Upstream channel bathymetry was based on the previous modelling of the Shoalhaven River Estuary (Glamore et al., 2015).

Catchment inflows were based on observed river flow data from WaterNSW gauging stations in the upper Shoalhaven River catchment as shown in Figure H-2. A summary table of the upstream inflow boundaries are provided in Table H-1. Localised floodplain subcatchment runoff inflows were excluded from the model as sensitivity testing indicated that day-to-day water levels in the lower reaches of the estuary were found to be dominated by tidal fluctuations. The downstream ocean tidal boundary of the model was based on the observed water levels from the MHL station at Crookhaven Heads (Station Number 215408).

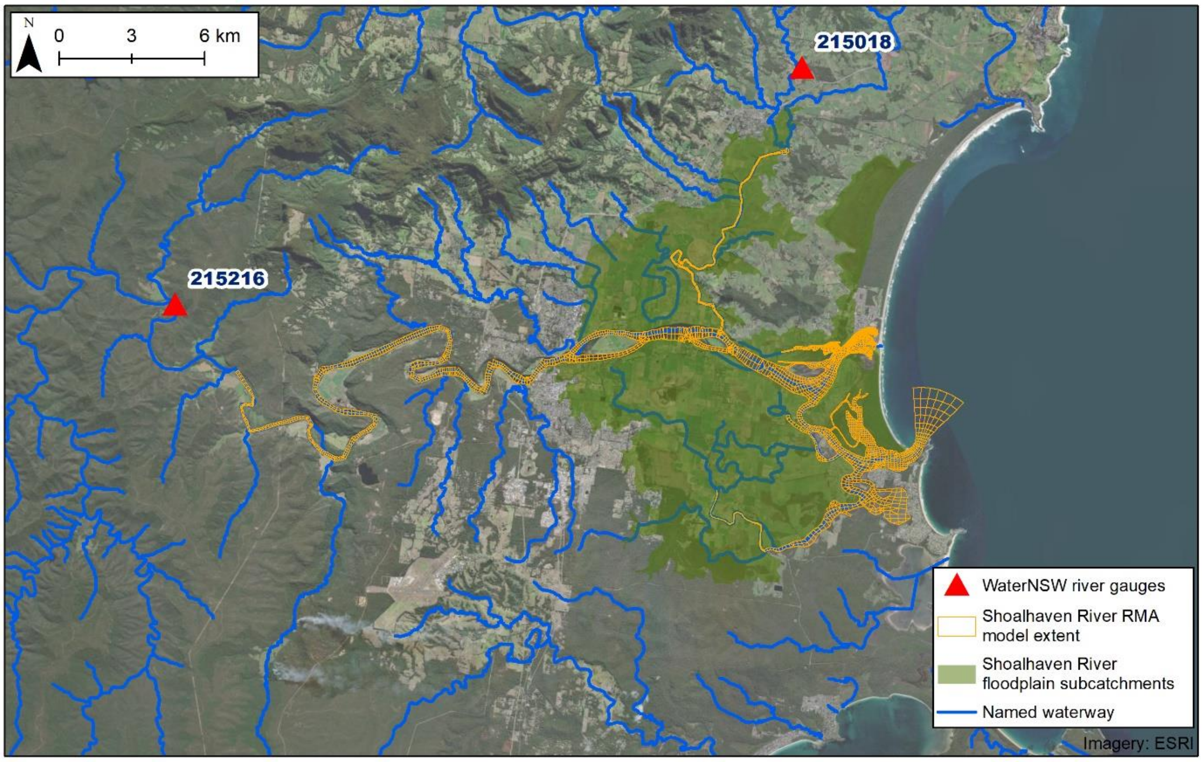


Figure H-2: Location of WaterNSW river flow gauges with relation to the hydrodynamic model extent

Table H-1: Summary of model boundary conditions

Gauging Station Name	Data Source	Station Number	Scale Factor
Shoalhaven River at Grassy Gully	WaterNSW	215216	1
Broughton Creek at Broughton Vale	WaterNSW	215018	1
Crookhaven Heads	MHL	215408	NA

H2.4 Model calibration

The hydrodynamic model for the Shoalhaven River estuary was calibrated to selected water level and tidal flow gauging stations for 2005. The year 2005 was selected based on short-term tidal flow gauging of the Shoalhaven Estuary which were recorded at various locations within the estuary on 21 September 2005 (MHL, 2005). These locations are shown in Figure H-3. Water level data was sourced from NSW DPIE Manly Hydraulics Laboratory (MHL). These locations are shown in Figure H-4.

The main internal model parameters for hydrodynamic calibrations in the RMA-2 model are eddy viscosity and friction (applied as Manning's n). The model was calibrated by adjusting the Manning's n value to match the observed flow, tidal ranges and phasings throughout the estuary. A Manning's n value of 0.23 was adopted throughout the entire model domain.

The flow calibration results are shown in Figure H-5 to Figure H-11. The water level calibration results for an 8-day window during this period are shown in Figure H-12 to Figure H-16. The model was calibrated (for dry weather periods) to less than 0.2 m for the entire estuary.

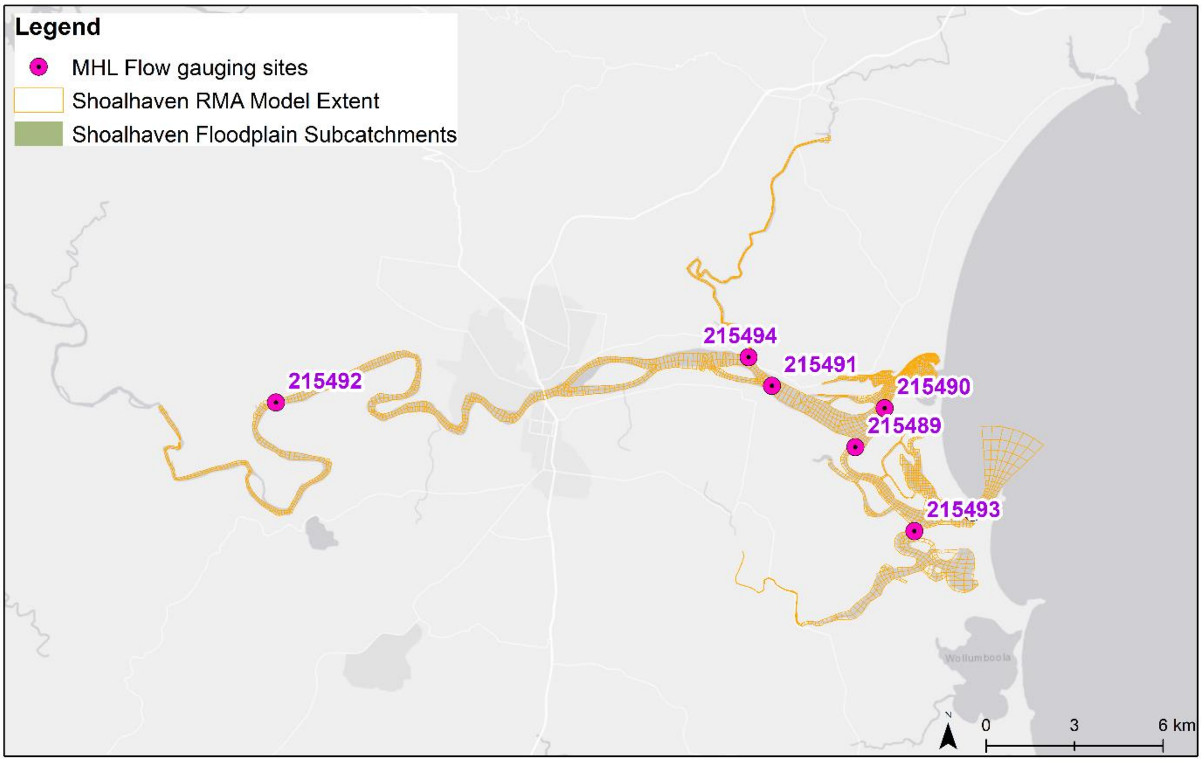


Figure H-3: Location of selected tidal flow gauging stations used for calibration of the Shoalhaven River estuary hydrodynamic model

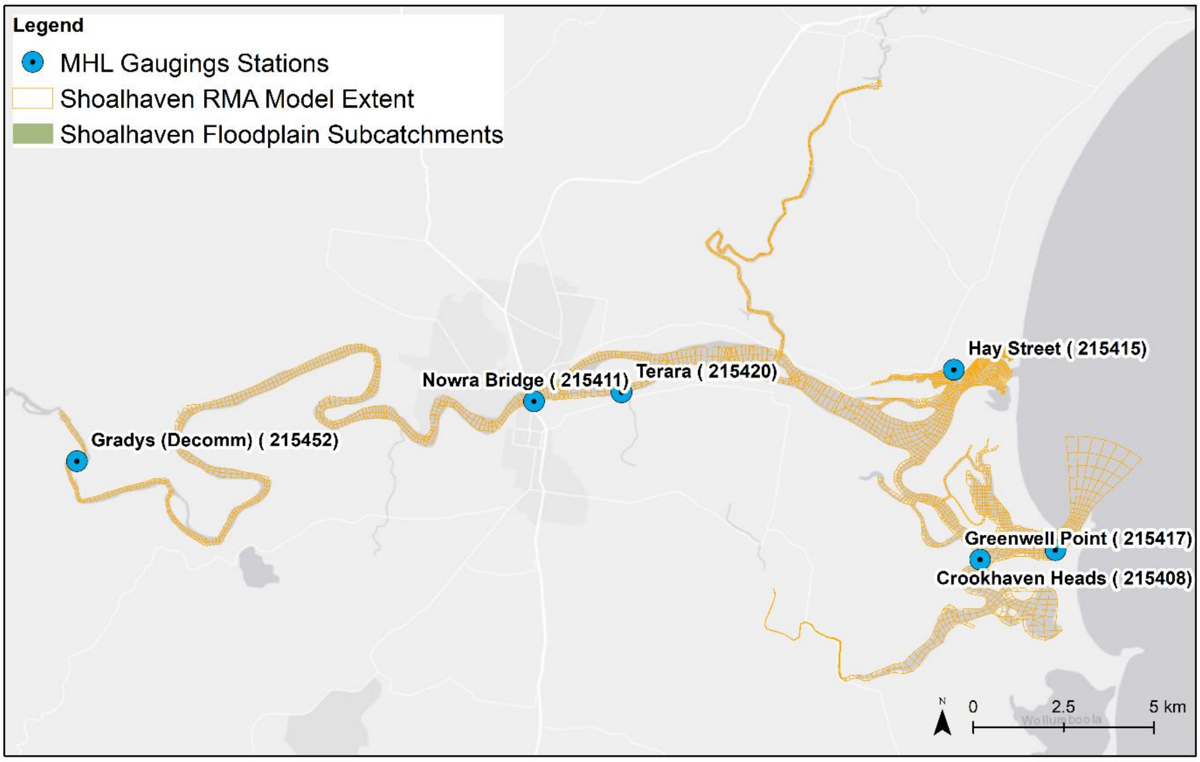


Figure H-4: Location of selected water level stations used for calibration of the Shoalhaven River estuary hydrodynamic model

H2.5 Model verification

The calibrated model was then used to simulate a representative 'wet' year (i.e. more rain than average across the catchment) and a representative 'dry' year (i.e. less rain than average across the catchment) based on analysis of BOM rainfall records in Northern NSW. For this study, 2013 and 2019 were selected as the wet and dry years respectively. The model results from these simulations were then used to verify the tidal water calibrations throughout the estuary. Tidal water level verification plots for a 10-day window for the Shoalhaven River estuary for 2013 and 2019 are provided in Figure H-17 to Figure H-26.

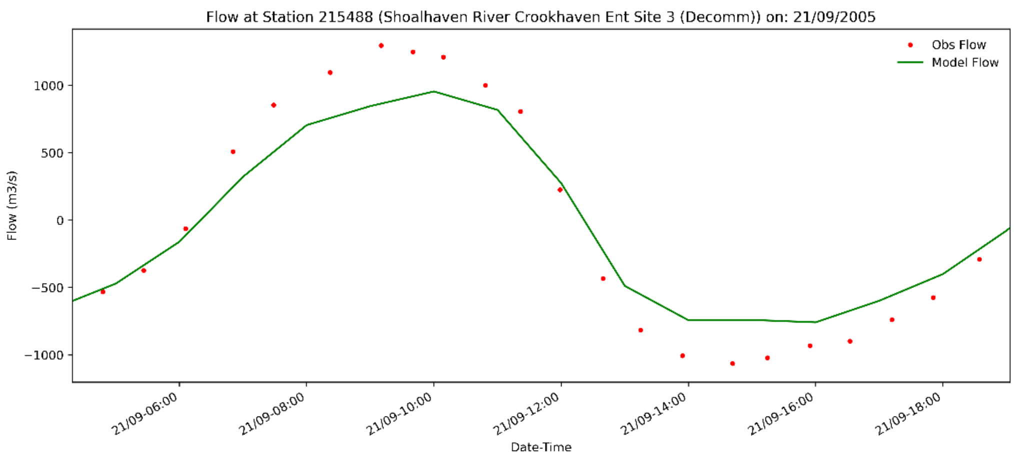


Figure H-5: Shoalhaven hydrodynamic model flow calibrations at Station 215488

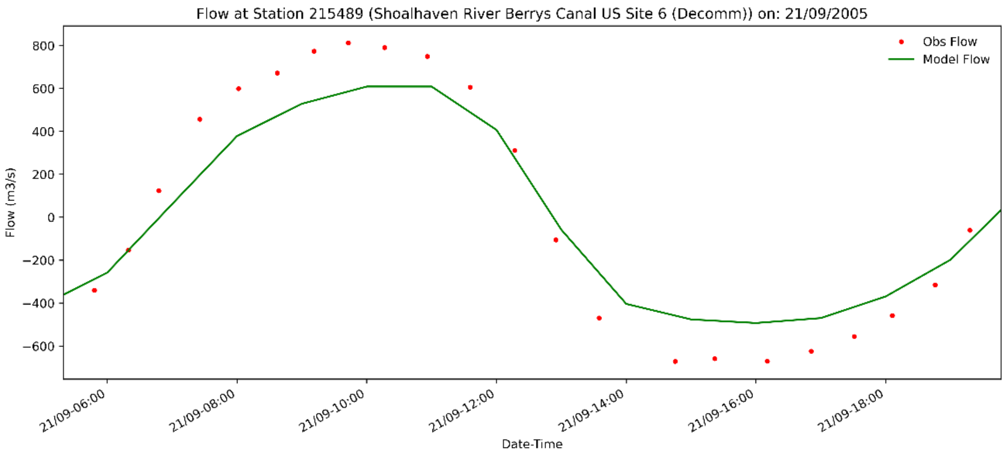


Figure H-6: Shoalhaven hydrodynamic model flow calibrations at Station 215489

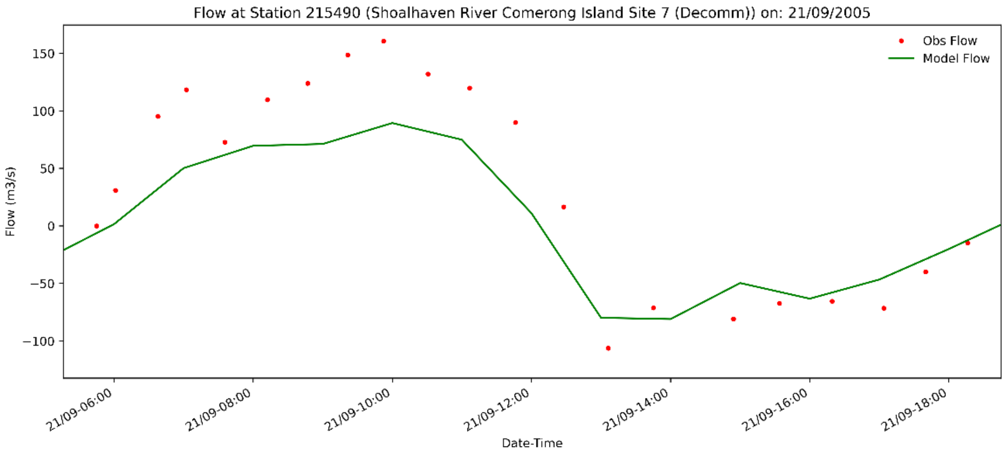


Figure H-7: Shoalhaven hydrodynamic model flow calibrations at Station 215490

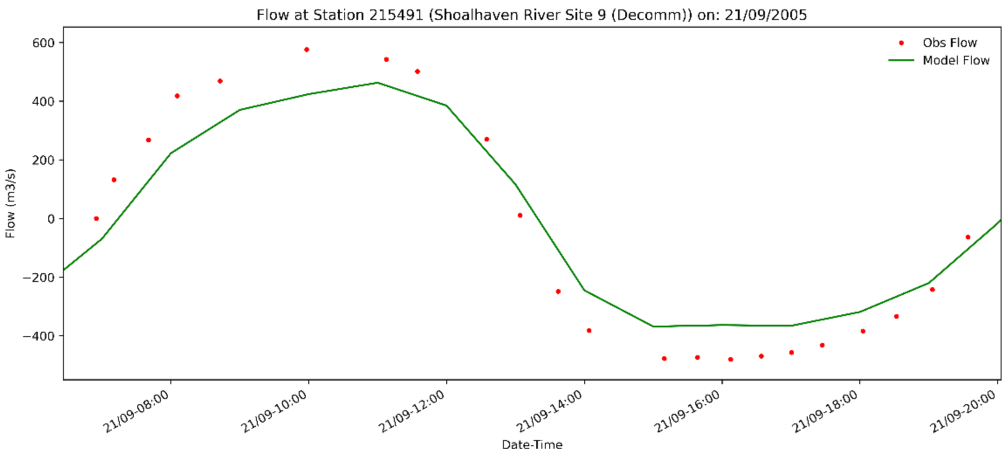


Figure H-8: Shoalhaven hydrodynamic model flow calibrations at Station 215491

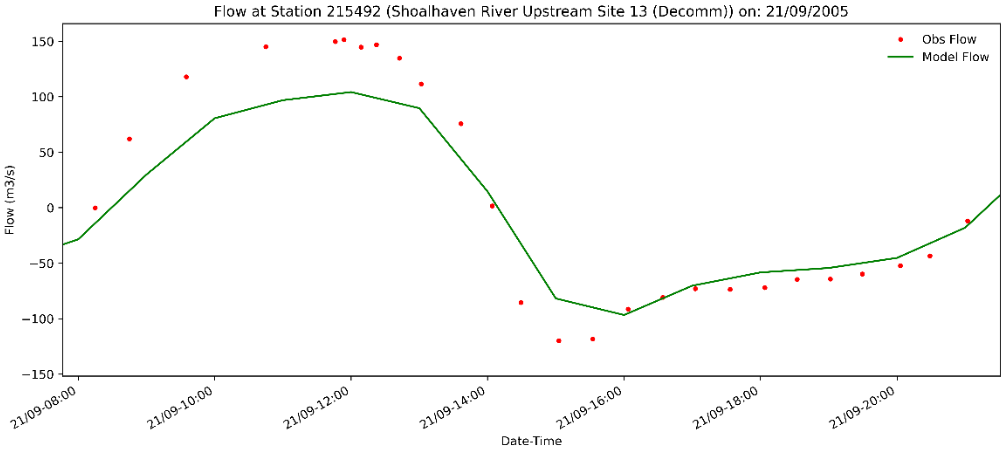


Figure H-9: Shoalhaven hydrodynamic model flow calibrations at Station 215492

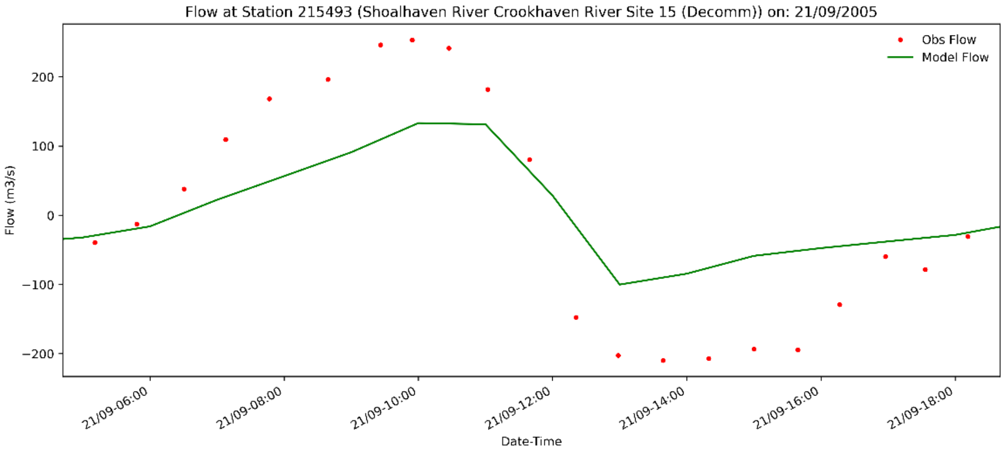


Figure H-10: Shoalhaven hydrodynamic model flow calibrations at Station 215493

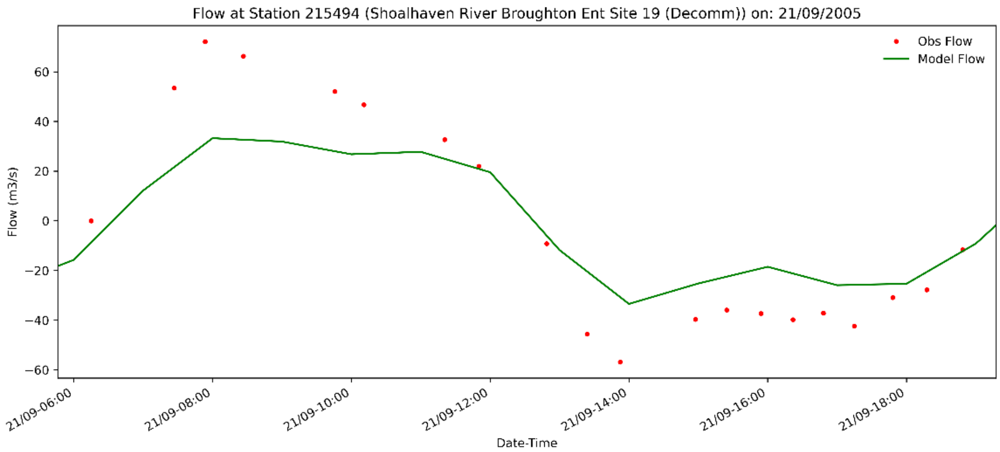


Figure H-11: Shoalhaven hydrodynamic model flow calibrations at Station 215494

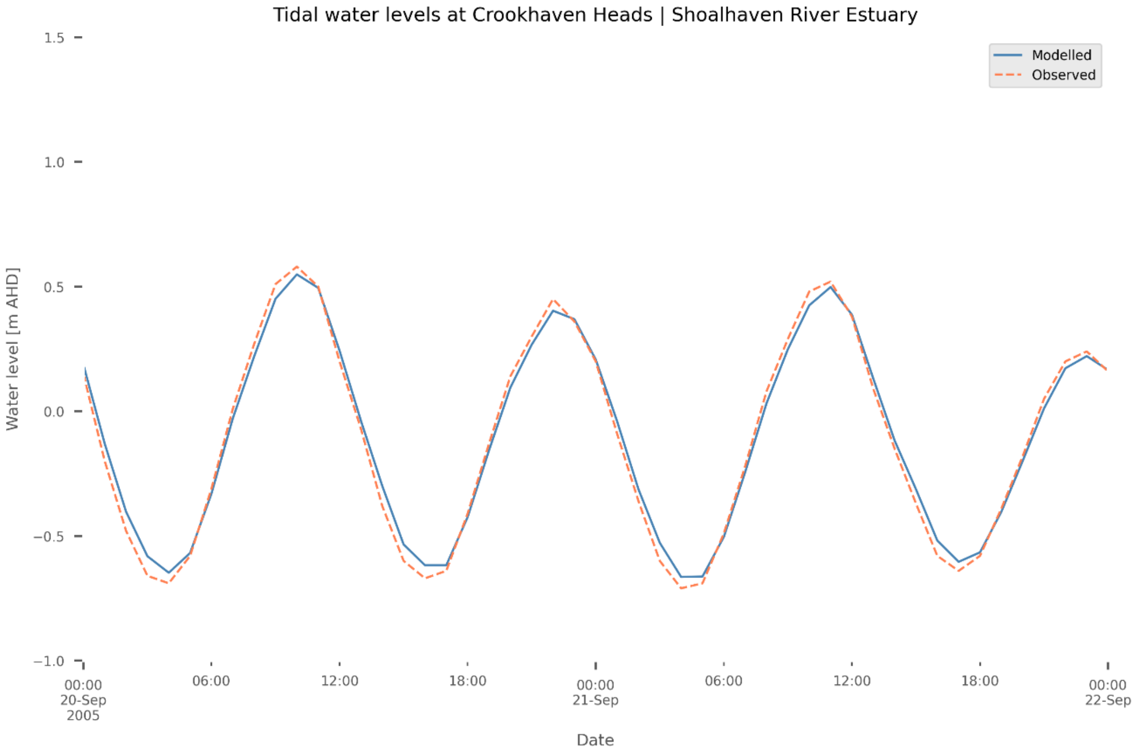


Figure H-12: Shoalhaven hydrodynamic model water level calibration results (2005) at Crookhaven Heads (215408)

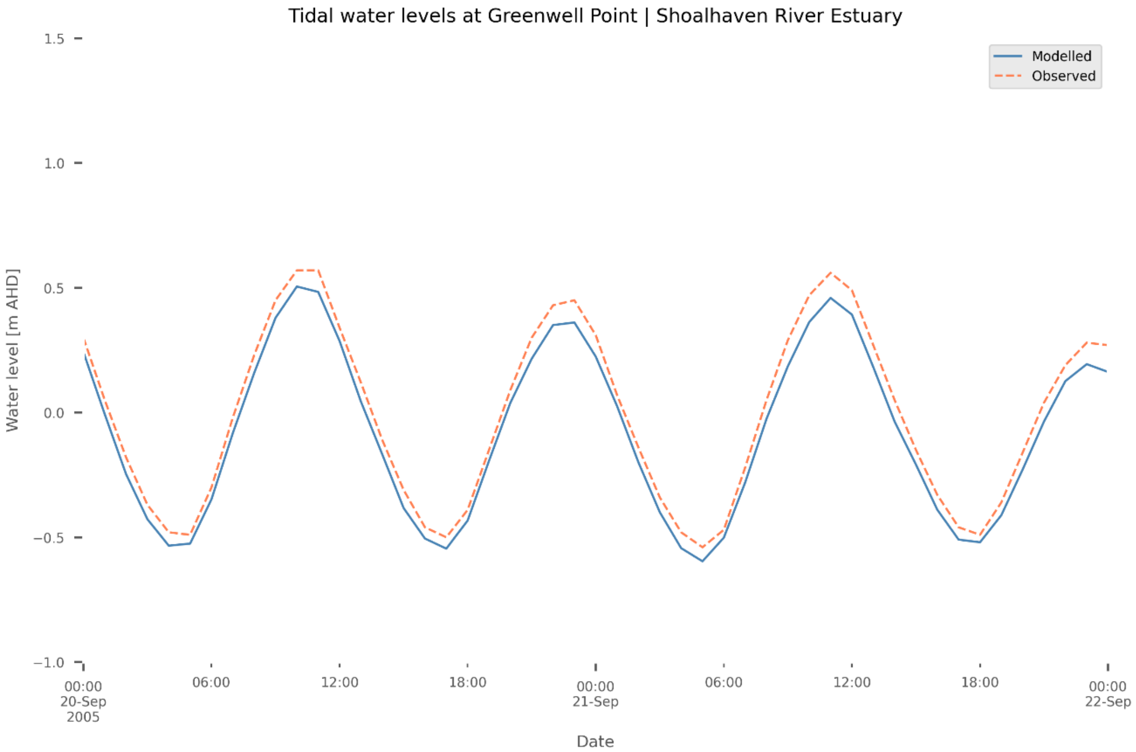


Figure H-13: Shoalhaven hydrodynamic model water level calibration results (2005) at Greenwell Point (215417)

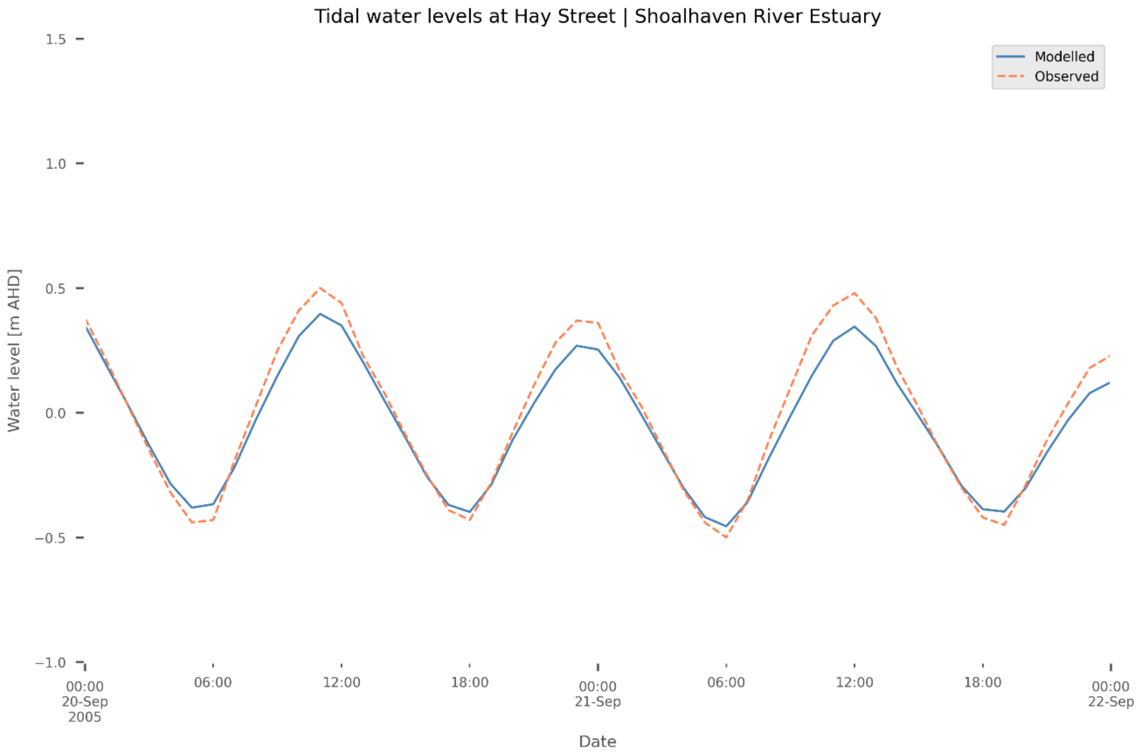


Figure H-14: Shoalhaven hydrodynamic model water level calibration results (2005) at Hay Street (215415)

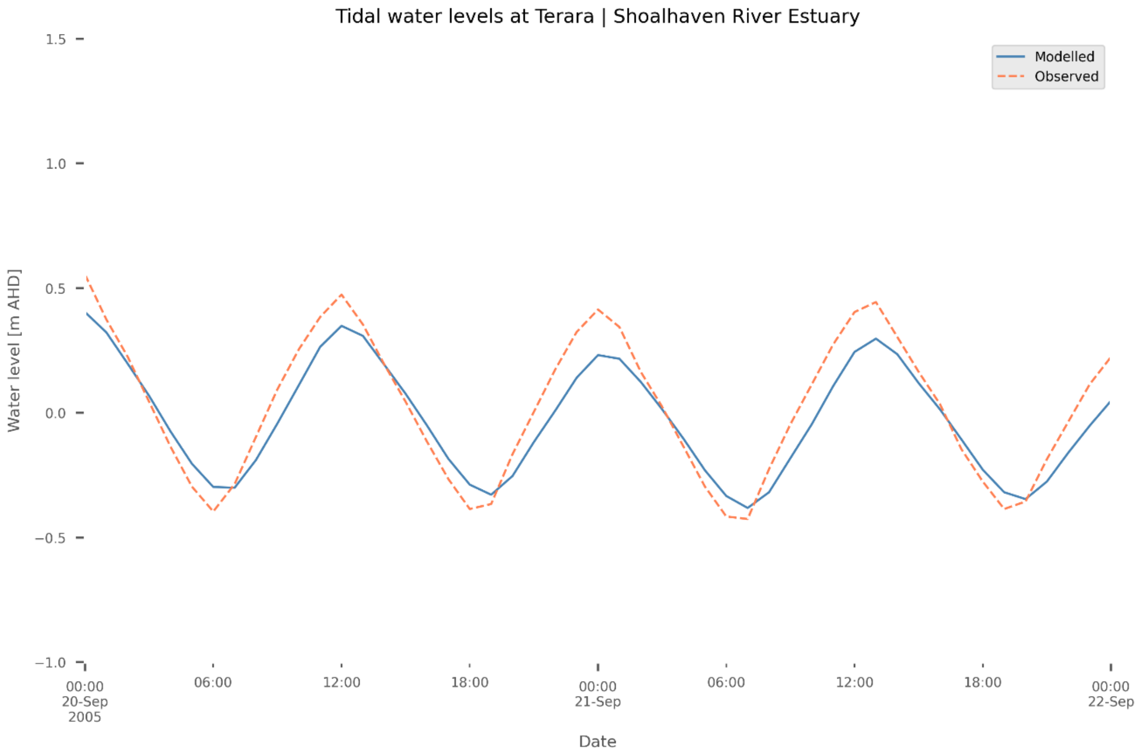


Figure H-15: Shoalhaven hydrodynamic model water level calibration results (2005) at Terara (215420)

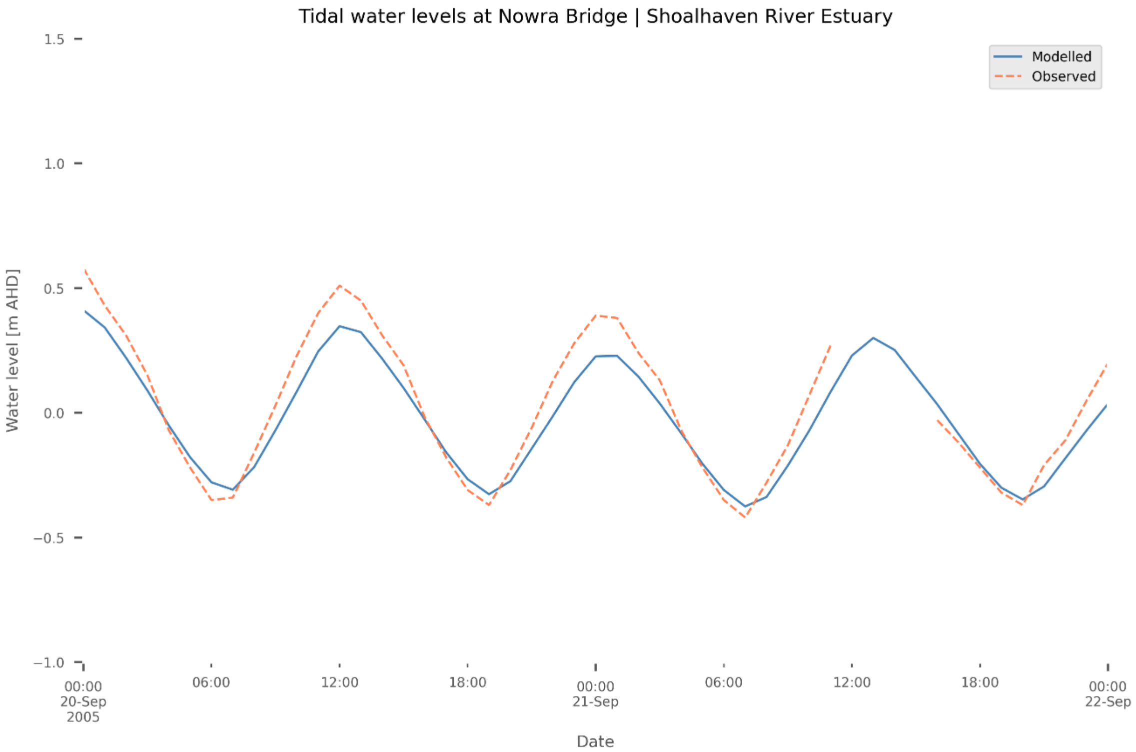


Figure H-16: Shoalhaven hydrodynamic model water level calibration results (2005) at Nowra Bridge (215411)

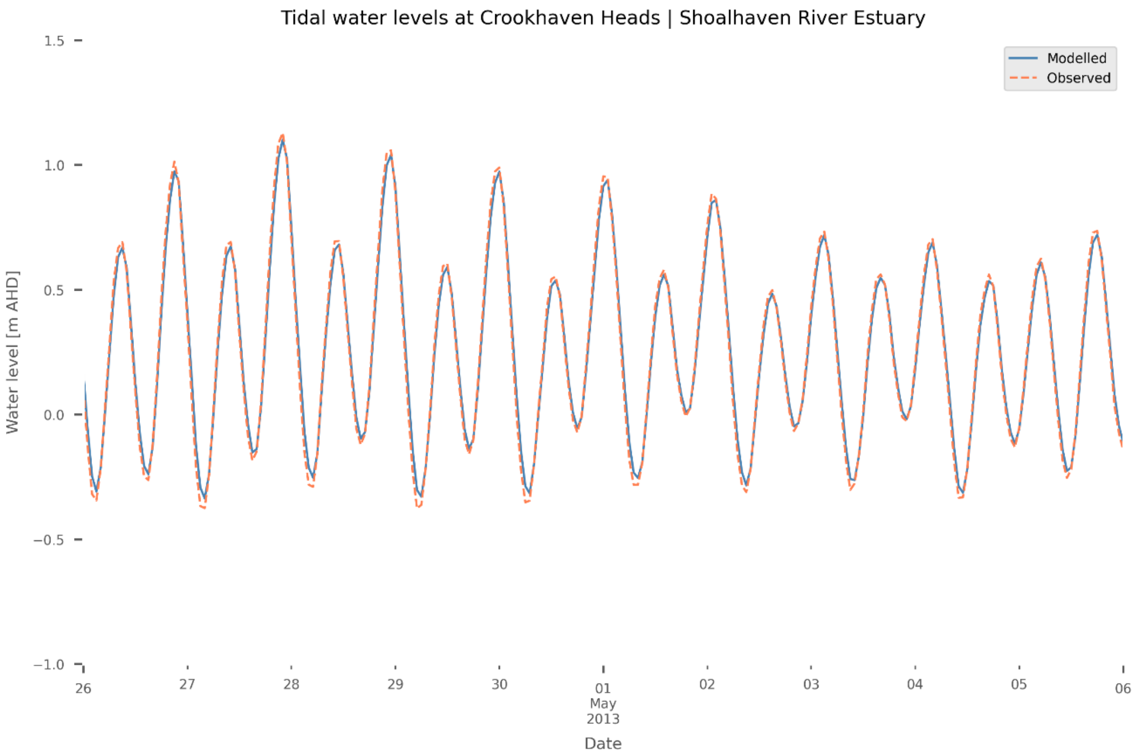


Figure H-17: Shoalhaven hydrodynamic model verification results (2013) at Crookhaven Heads (215408)

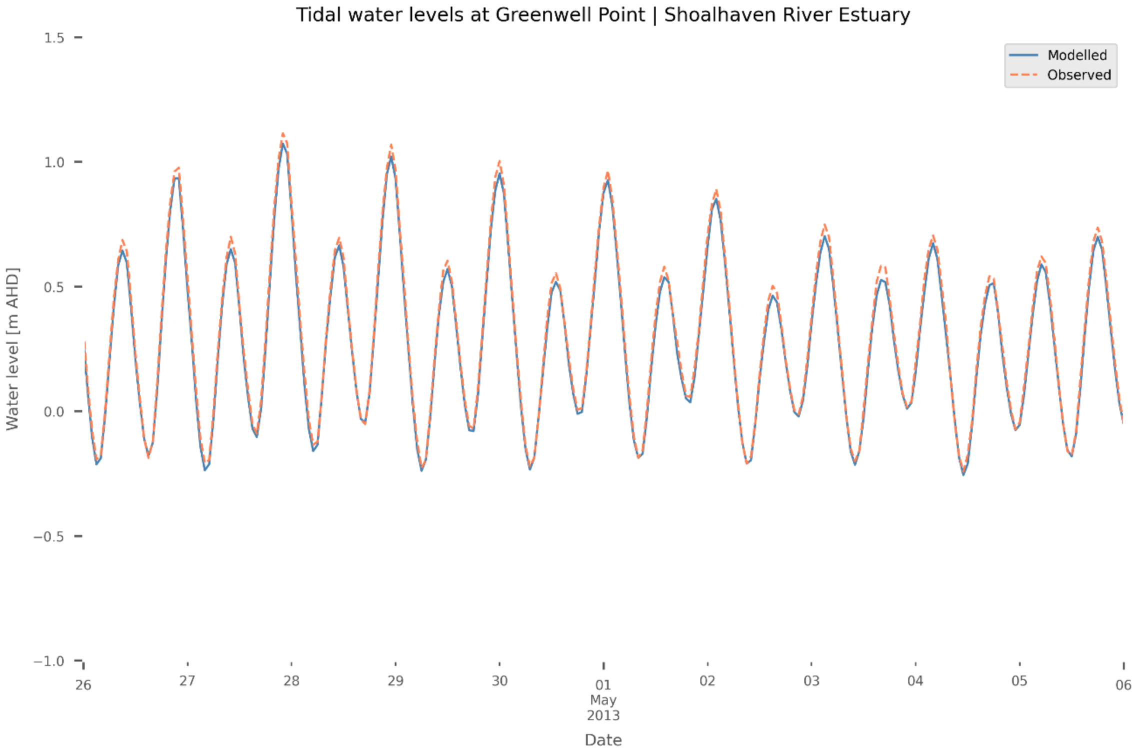


Figure H-18: Shoalhaven hydrodynamic model verification results (2013) at Greenwell Point (215417)

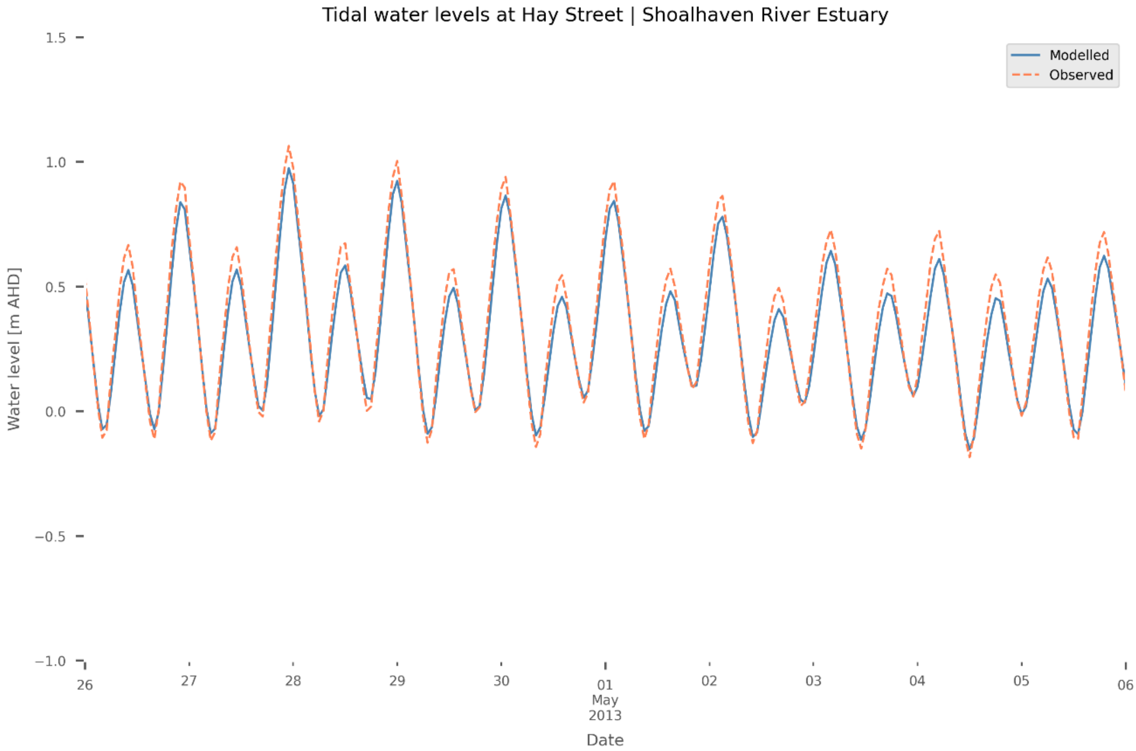


Figure H-19: Shoalhaven hydrodynamic model verification results (2013) at Hay Street (215415)

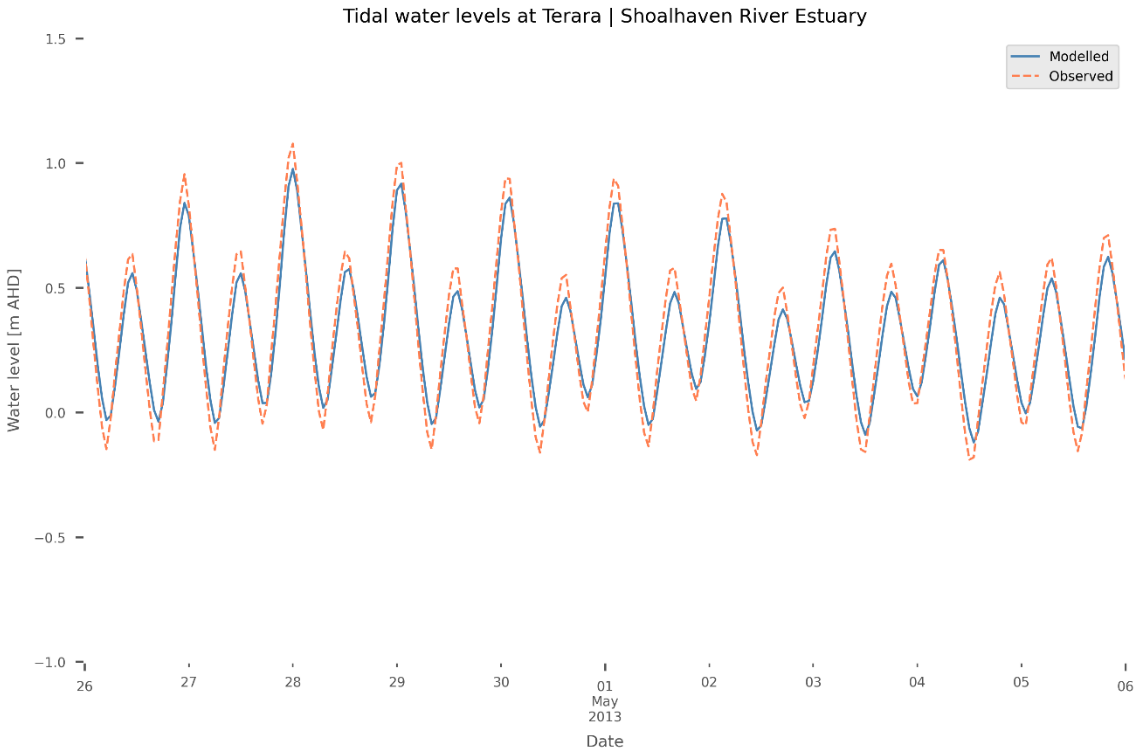


Figure H-20: Shoalhaven hydrodynamic model verification results (2013) at Terara (215420)

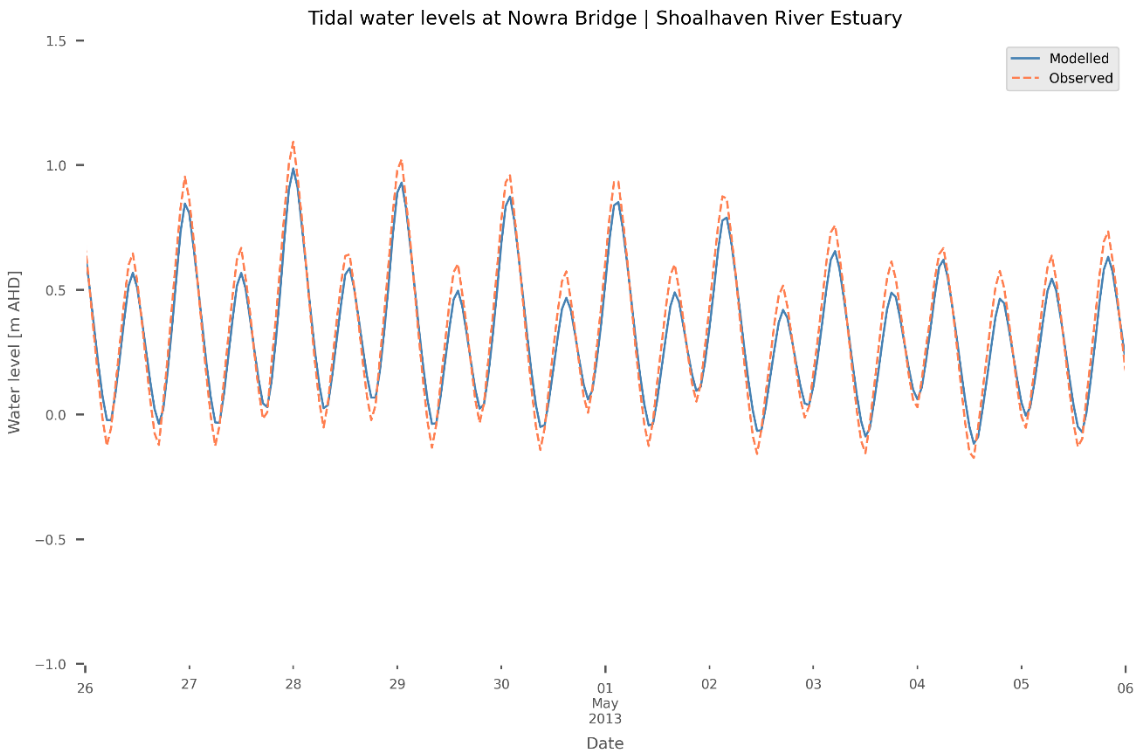


Figure H-21: Shoalhaven hydrodynamic model verification results (2013) at Nowra Bridge (215411)

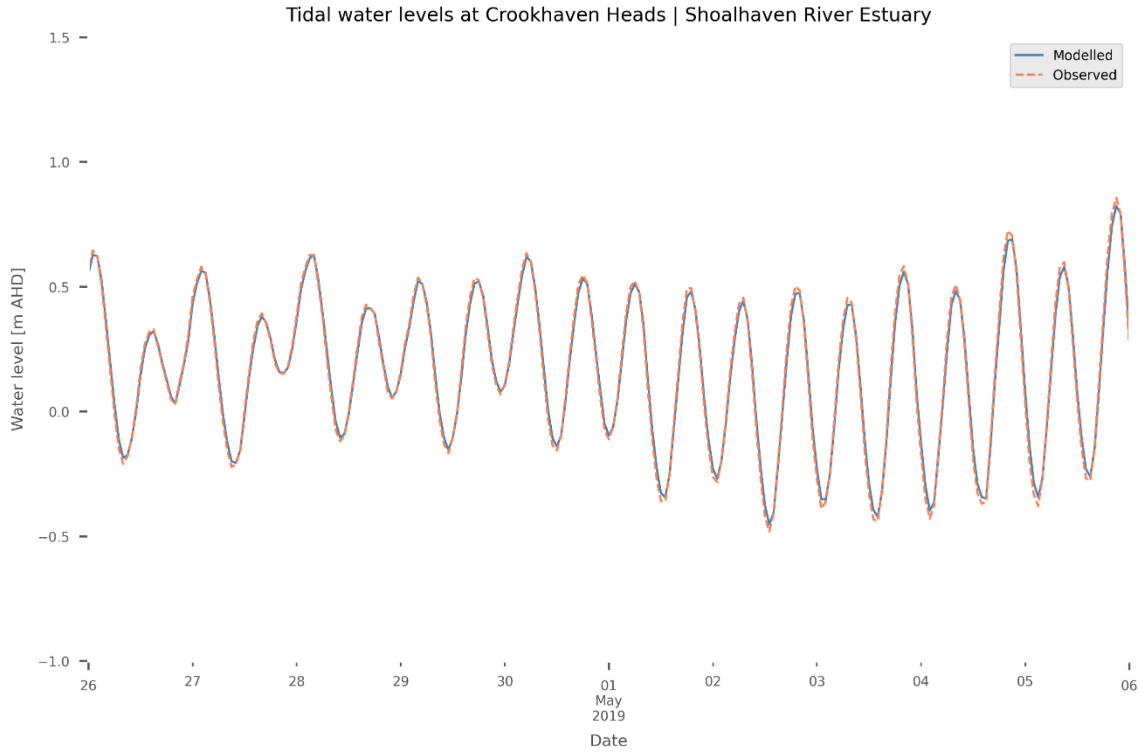


Figure H-22: Shoalhaven hydrodynamic model verification results (2019) at Crookhaven Heads (215408)

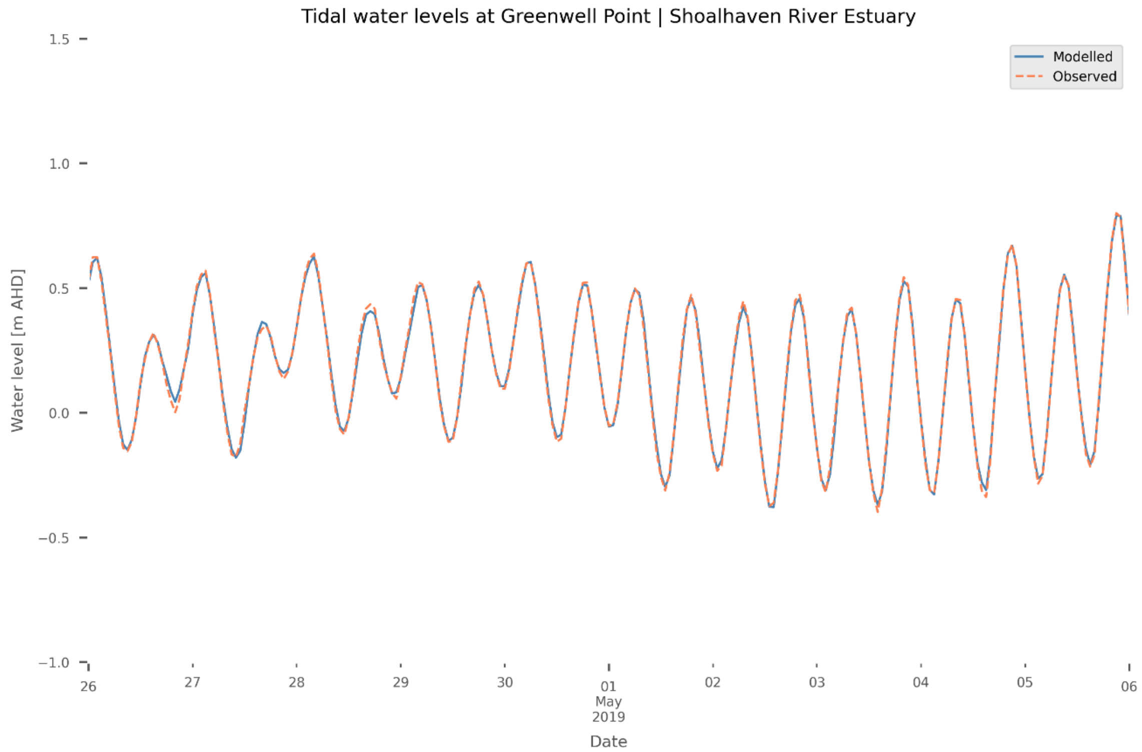


Figure H-23: Shoalhaven hydrodynamic model verification results (2019) at Greenwell Point (215417)

Figure H-24: Shoalhaven hydrodynamic model verification results (2019) at Hay Street (215415)

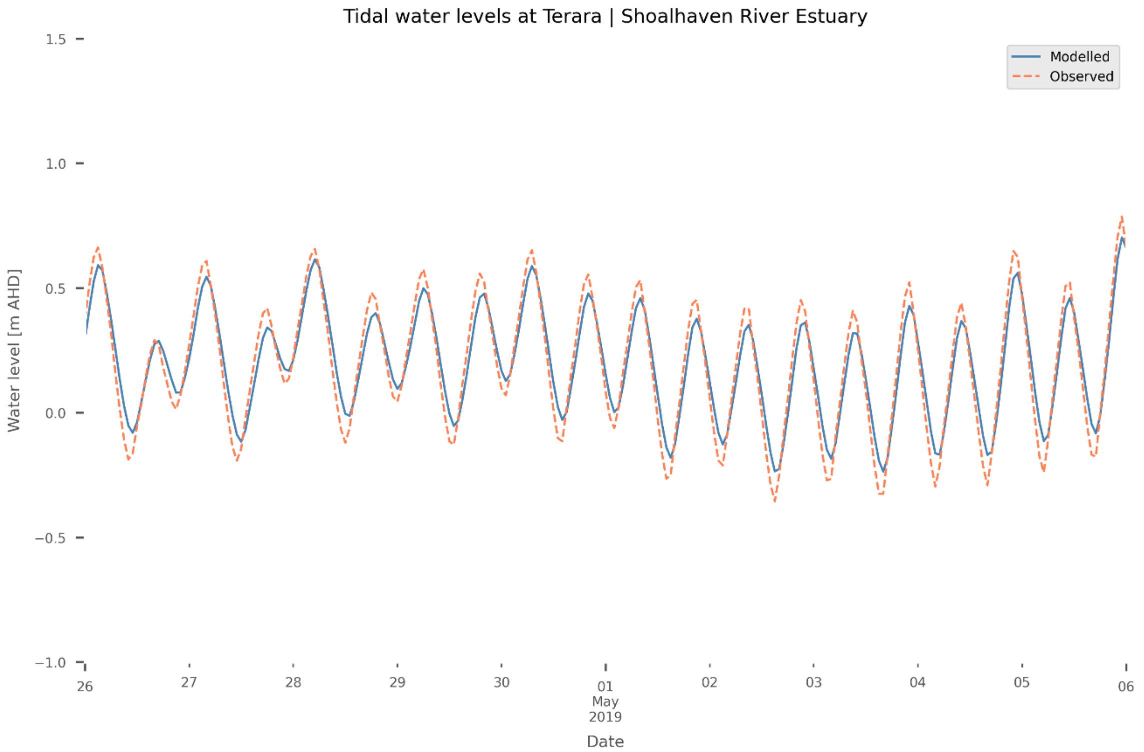


Figure H-25: Shoalhaven hydrodynamic model verification results (2019) at Terara (215420)

Figure H-26: Shoalhaven hydrodynamic model verification results (2019) at Nowra Bridge (215411)

Appendix I Sensitive environmental receivers

I1 Preamble

Acid discharges from ASS-affected floodplains are well reported to cause stress to sensitive environmental receivers (Glamore, 2003; Rayner, 2010; Sammut et al., 1996; Winberg and Heath, 2010). Furthermore, water control structures associated with ASS-affected drains, such as one-way floodgates, prohibit the passage of aquatic species and limit the overall primary production of estuaries (Winberg and Heath, 2010). Sensitive environmental receivers are widespread throughout the Shoalhaven River estuary. This section provides an overview of the proximity of sensitive environmental receivers to acidic drainage areas within the study area, and the information provided in this section was used to inform the prioritisation of each sub-catchment.

I2 Sensitive environmental receivers of the Shoalhaven River Estuary

Several sensitive environmental receivers were identified during the course of this investigation. Both aquatic and terrestrial ecological communities and sensitive locations were identified and mapped as provided in Figures I-1 to I-4, including:

- Key fish habitat relating to the Fisheries Management Act (1994);
- Oyster leases;
- Estuarine macrophytes; and
- Coastal wetlands as defined by the State Environmental Planning Policy (Coastal Management) 2018.

The proximity of each sub-catchment in the study area to downstream stationary sensitive receivers was calculated as provided in Table I-1.

Table I-1: Summary of approximate proximity (in metres) of sensitive environmental receivers (SER) to each subcatchment within the study area

Subcatchment	Oyster leases	Estuarine Macrophytes			Coastal wetlands	SER within subcatchment*
		Saltmarsh	Seagrass	Mangroves		
Abernethys Creek	10,400	4,500	0	0	3,100	Key Fish habitat
Berry	15,600	10,300	2,600	0	3,400	Key Fish habitat
Bolong	7,000	1,200	0	0	0	Key Fish habitat
Brundee/Saltwater	300	0	0	0	0	Coastal wetland, key fish habitat
Comerong Island	0	0	0	0	0	Mangroves, saltmarsh, key fish habitat
Coolangatta	0	0	0	0	0	Coastal wetland, mangroves, saltmarsh, key fish habitat
Crookhaven Creek	6,000	1,800	2,600	0	100	Key Fish habitat
Eelwine Creek/Mayfield	1,400	0	1,200	0	0	Mangroves, saltmarsh, key fish habitat
Far Meadow	12,000	6,800	0	0	0	Key Fish habitat
Greenwell Point	0	0	0	0	0	Coastal wetland, saltmarsh, key fish habitat
Lower Broughton Creek	5,000	100	0	0	0	Key Fish habitat
Numbaa	0	0	0	0	0	Coastal wetland, saltmarsh, key fish habitat
Shoalhaven Heads	0	1,000	0	0	0	Key Fish habitat
Terara	3,500	0	0	0	0	Coastal wetland, mangroves, saltmarsh, key fish habitat
Worrigee	11,100	6,400	0	1,000	5,100	Key Fish habitat

*Note: Within subcatchment does not include SER that may be found on the outside boundary (i.e. downstream of floodgates) of the subcatchment.

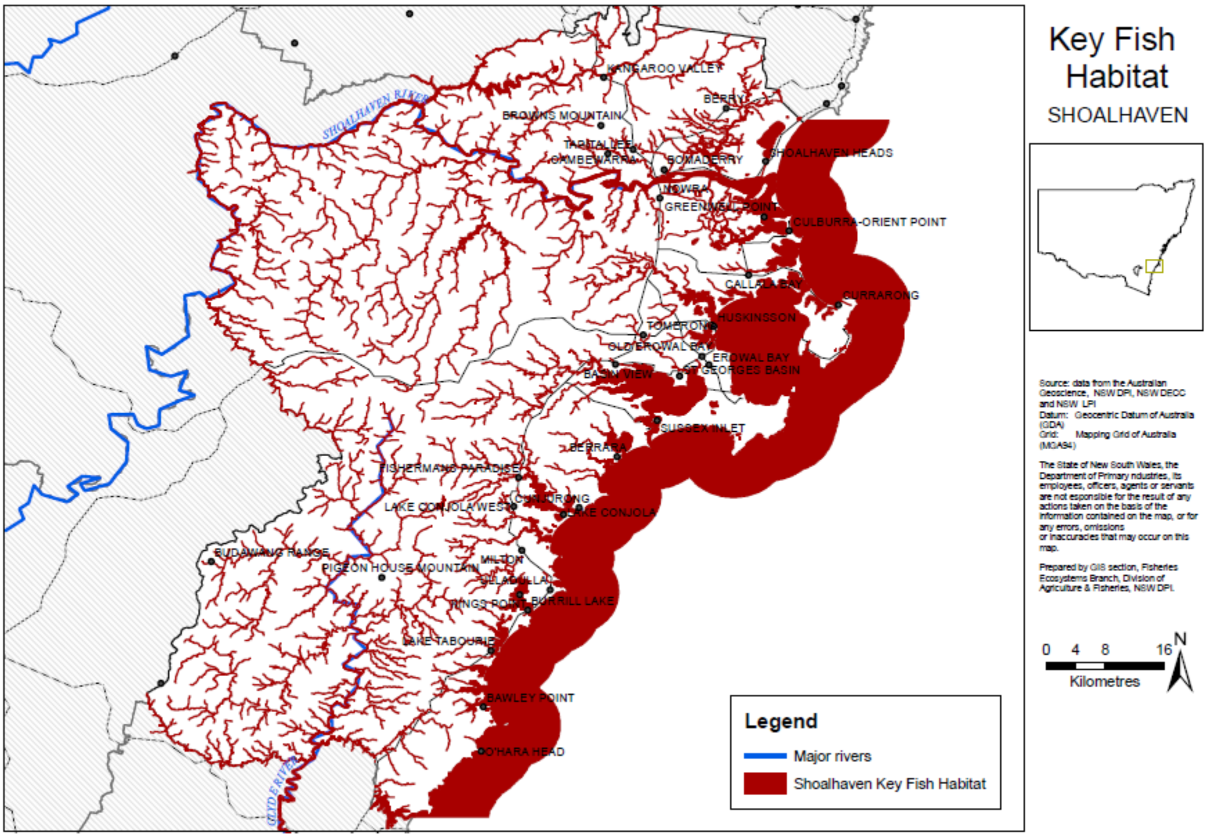


Figure I-1: Key fisheries habitat (Source: NSW DPI Fisheries)

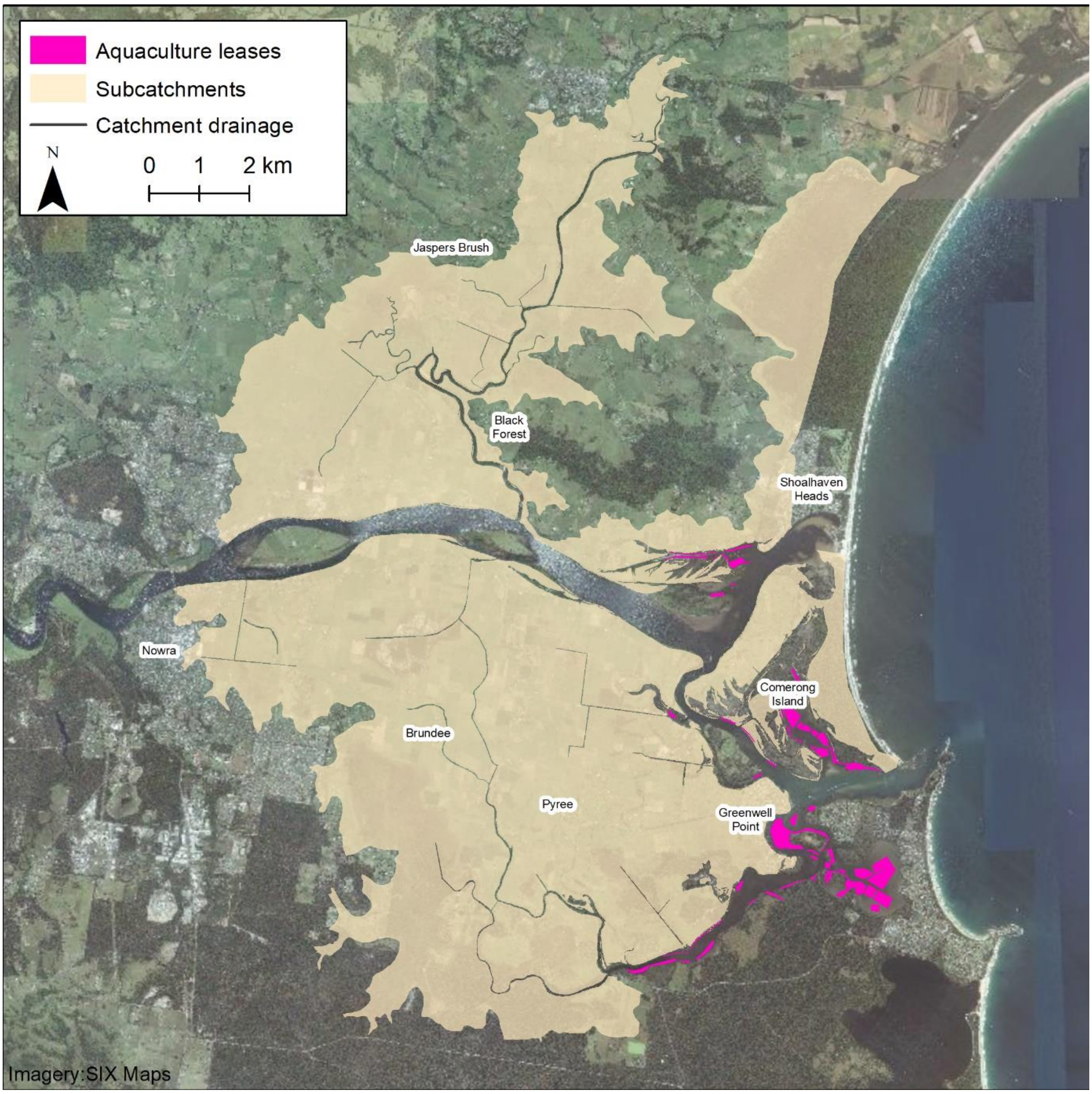


Figure I-2: Priority oyster leases (Source: NSW DPI Fisheries)

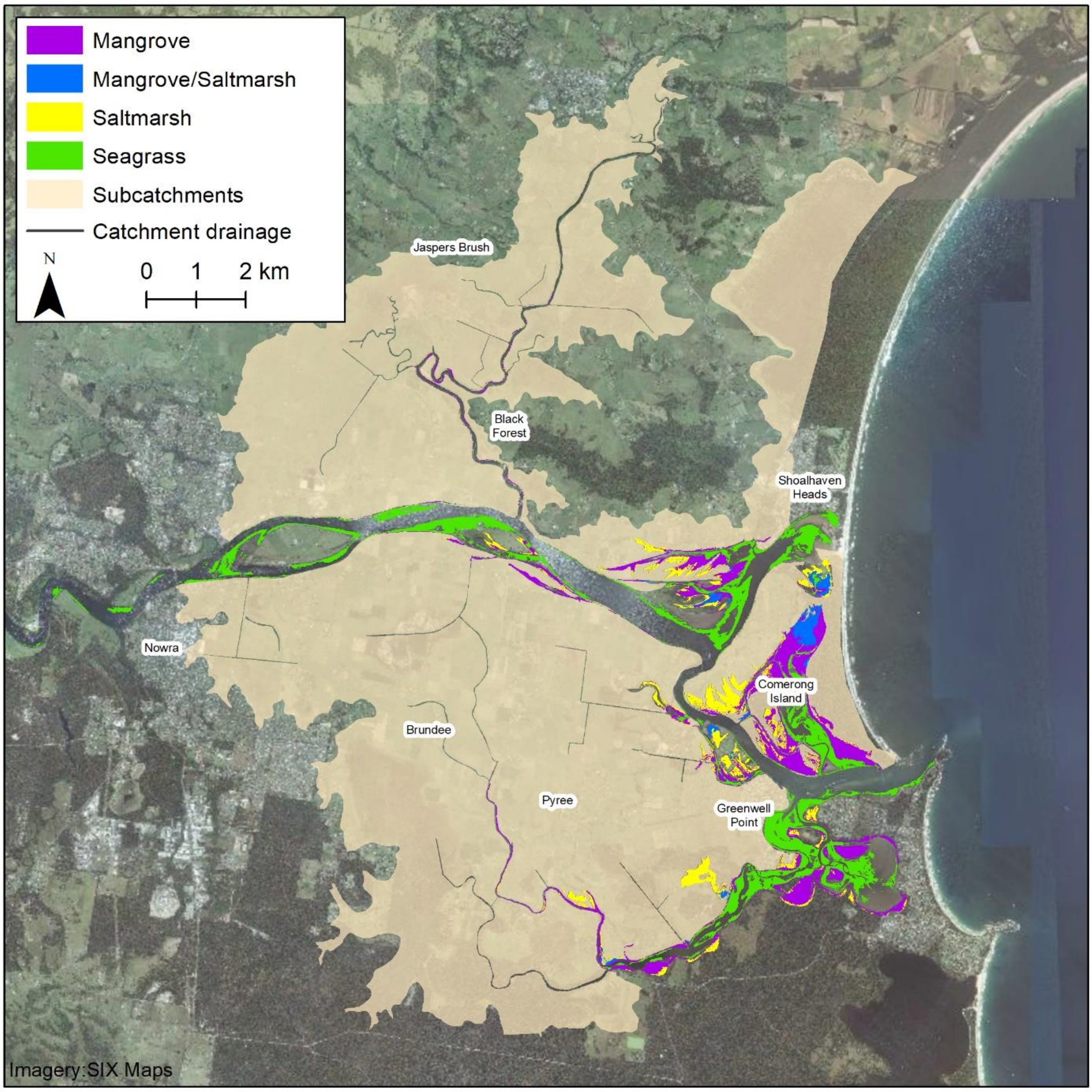


Figure I-3: Estuarine macrophytes (Source: NSW DPI Fisheries)

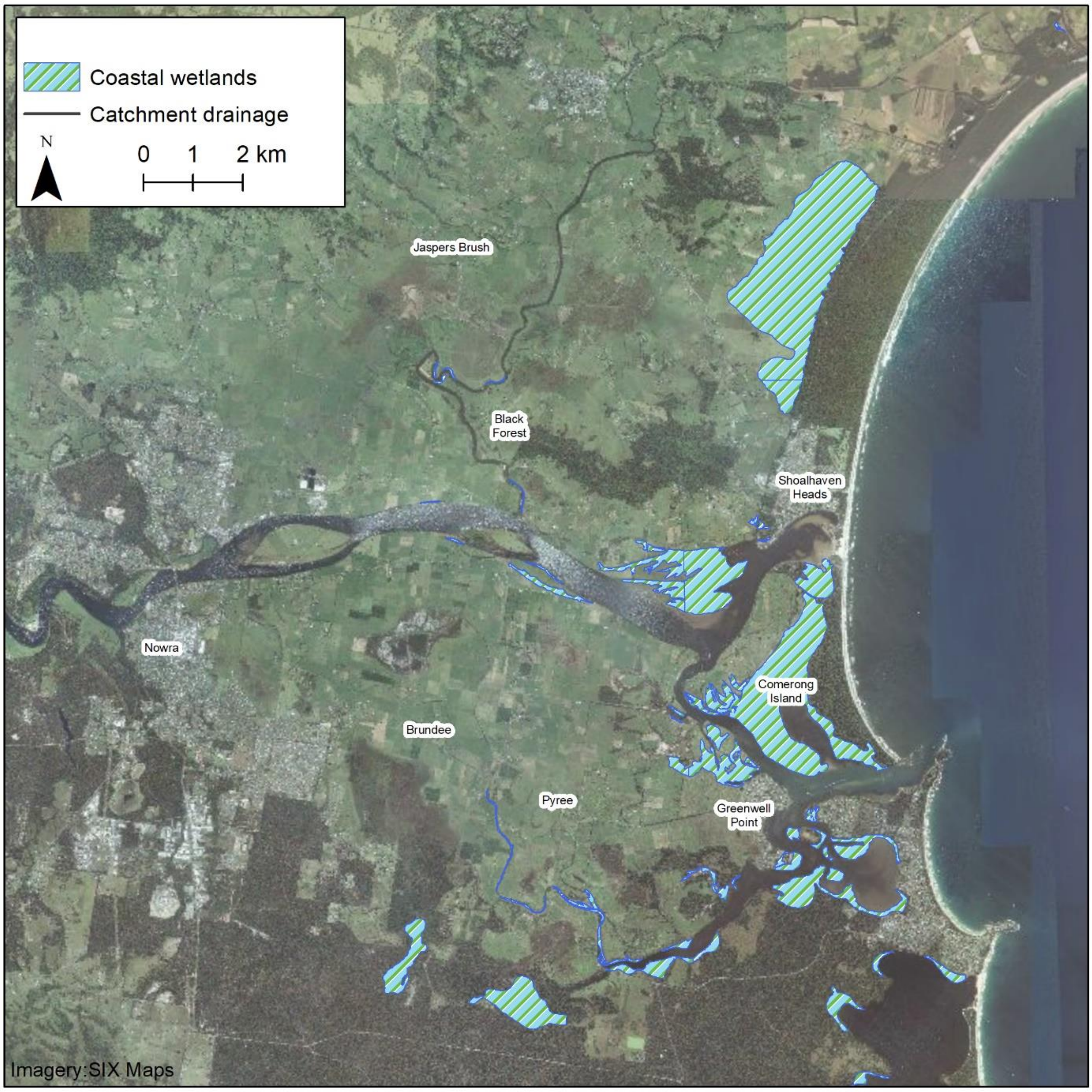


Figure I-4: Coastal Management SEPP coastal wetlands (Source: SEED NSW data portal)[1]

[1] Note that the State Environmental Planning Policy No. 14 (SEPP14) for Coastal Wetlands was repealed by cl 9 (a) of State Environmental Planning Policy (Coastal Management) 2018 (106) with effect from 3.4.2018. This policy aims to promote an integrated and co-ordinated approach to land use planning in the coastal zone to ensure that these areas, including coastal wetlands are preserved and protected in the environmental and economic interests of the State.

Appendix J Heritage

J1 Preamble

Heritage listings in NSW are protected by law under the Heritage Act, 1977 (amended 1998) and the Environmental Planning and Assessment Act 1979. Nationally heritage items are protected under the Environment Protection and Biodiversity Conservation Act 1999. Heritage items protected include:

- Items listed in local councils Local Environmental Plan (LEP) or Regional Environmental Plan (REP);
- Items listed on the State Heritage Register;
- Items listed on State Agency Heritage Registers (under Section 170 of the Heritage Act, 1977);
- Items listed on Interim Heritage Orders;
- Items listed on the Aboriginal Heritage Information Management System (AHIMS);
- Items listed on the Maritime Heritage Database;
- Items listed on the Commonwealth Heritage List; and
- Items listed on the National Heritage List.

Implementation of management options needs to consider any heritage listed items that may be affected during on-ground works. Heritage items fall under the category of implementation constraint in the prioritisation methodology (see Section 2 of the Methods report (Rayner et al., 2023)). Note that new heritage items are continuously being registered. Subsequently, items identified and presented in this section should only be used as a guide and it is encouraged that anyone seeking to identify the most recent information on heritage listed items will need to consult the relevant registers which contain current information.

J2 Aboriginal heritage

Aboriginal sites across the Shoalhaven River floodplain listed within the Aboriginal Heritage Information Management System (AHIMS) have been identified to determine if they affect the implementation of management options. Due to the sensitive nature of this information no data can be presented here, however, some aboriginal heritage items are presented within the NSW State Heritage Inventory where there is no restriction (see Section J3).

Note that for any works that will alter the landscape due diligence may need to be carried out as per the National Parks and Wildlife Act 1974. Searching AHIMS is only part of this due diligence process. Furthermore, AHIMS data sourced for this study is only up to date as of October 2019. Prior to any activities being undertaken such as actions outlined in the management options, a renewed search of AHIMS will need to be undertaken to ensure the most current information is being used.

J3 European heritage

Heritage listed items, including items of European origin, have been identified from the Commonwealth Heritage List, National Heritage List and the NSW State Heritage Inventory, which includes:

- Items listed on the State Heritage Register;

- Listed Interim Heritage Orders; and
- Items listed on State Agency Heritage Registers.

Figure J-1 outlines items that have been identified on the National Heritage List, the NSW State Heritage Register and the NSW Office of Environment and Heritage (OEH) Agency Register, and the Historic Heritage Information Management System (HHIMS). Items listed on the Commonwealth Heritage Register overlap with the NSW State Heritage Register in the study region, so only the NSW State Register items have been displayed. As of June 2020, no Interim Heritage Order items were identified within the study area. Note, prior to any activities being undertaken such as actions outlined in the management options, a renewed search of registers will need to be undertaken to ensure the most current information is being used.

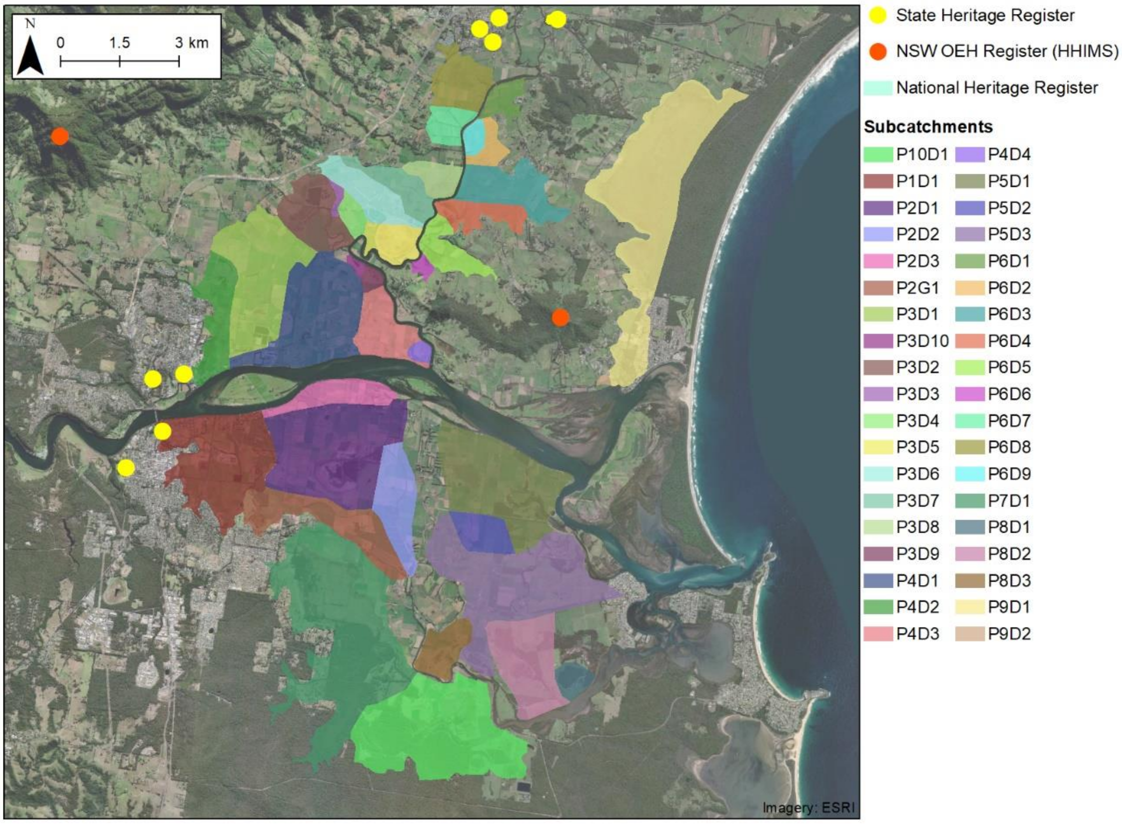


Figure J-1: Heritage items listed on Australian and NSW registers with location information

For an up to date list of these items consult the NSW State Heritage Inventory.

J4 Maritime heritage

In addition to provisions outlined under the NSW Heritage Act 1977, items of maritime heritage are protected by the Commonwealth Underwater Cultural Heritage Act 2018. Maritime heritage items can be found on the following registers:

- The Australian Underwater Cultural Heritage Database (AUCHD); and
- The NSW Maritime Heritage Database.

Items of maritime heritage listed in the aforementioned registers are displayed in Figure J-2. Note that items added after June 2020 are not included in this list and prior to any activities being undertaken, such as actions outlined in the management options, a renewed search of registers will need to be undertaken to ensure the most current information is being used. Furthermore, the Maritime Heritage specialist services team should be contacted to determine if there are any items of importance that have not been listed.

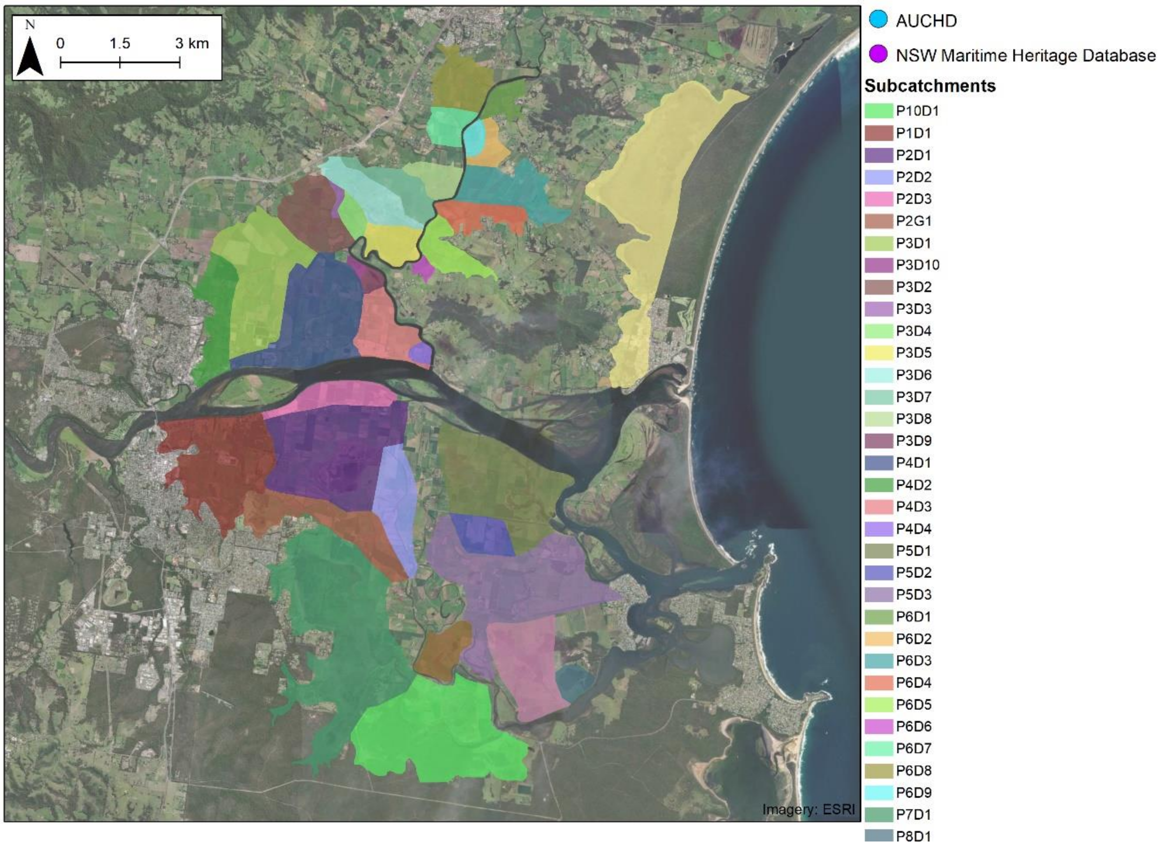


Figure J-2: Maritime heritage items listed on Australian and NSW registers

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