Manning 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 Manning 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 Manning 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

A3 Waterway classification

For this study, an updated waterways spatial dataset was developed for the Manning 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 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.

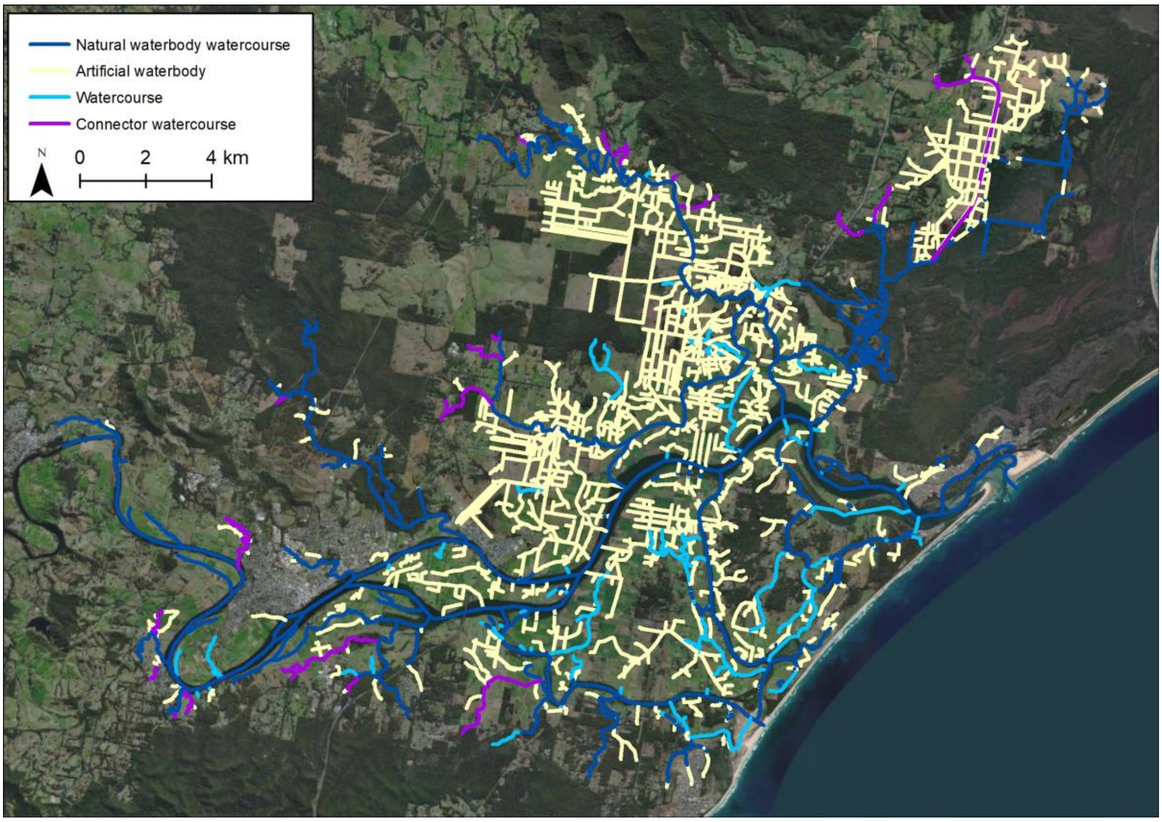

Figure A-1: Manning River floodplain waterways

A4 Drainage density

The drainage density of each subcatchment 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 Manning 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**
Big Swamp	106,882	43.95	2,432	10
Bukkan Bukkan Creek	44,100	11.02	4,002	5
Cattai Creek	34,405	18.93	1,818	12
Coopernook	34,938	6.29	5,556	1
Croakers Creek	21,260	10.41	2,043	11
Dawson River	10,423	7.84	1,330	15
Dumaresq Island	17,299	5.98	2,892	7
Ghinni Ghinni	106,251	24.53	4,332	3
Glenthorne	24,385	8.62	2,830	8
Jones Island	30,627	6.49	4,717	2
Mambo Island	12,353	3.02	4,096	4
Mitchells Island	55,041	20.67	2,663	9
Moto	137,603	35.61	3,864	6
Pampoolah	16,257	10.16	1,600	13
Taree Estate	1,537	1.15	1,341	14

* 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.

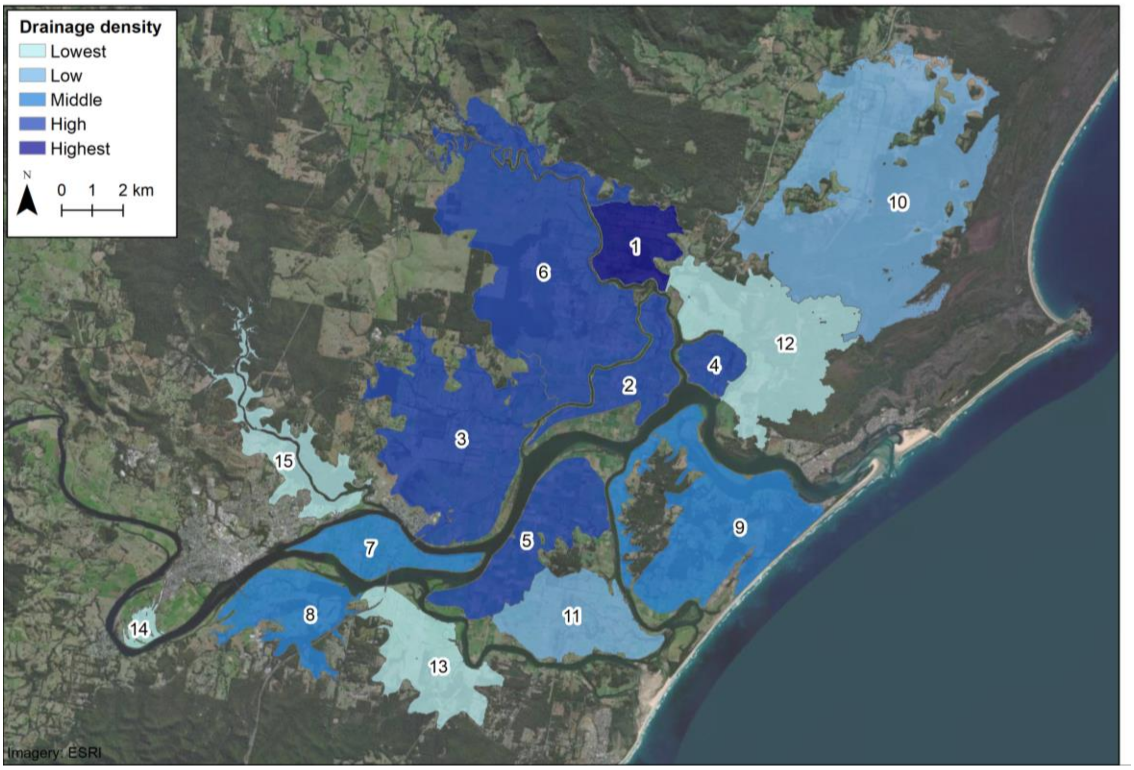

Figure A-2: Floodplain drainage density ranking

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 Manning 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 calculate 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 Manning River floodplain is shown in Figure B-1.

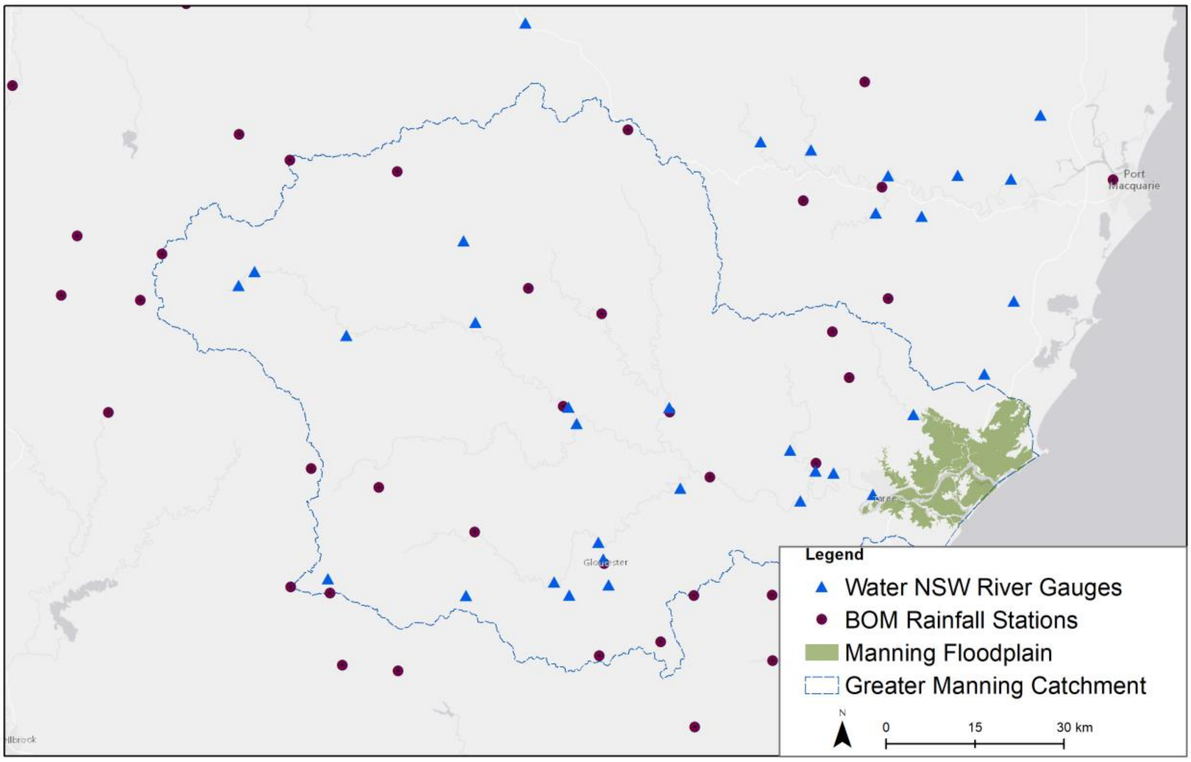

Figure B-1: Manning River Floodplain location of rainfall and runoff stations

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 station 208015 was selected for the Manning River Floodplain assessment. The upstream contributing area of this site was 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 to weight the total rainfall to the upstream area. The location of the gauging site, upstream catchment area of the gauging site, and the BOM rainfall contribution (shown in parenthesis) used in the analysis are summarised in Figure B-2.

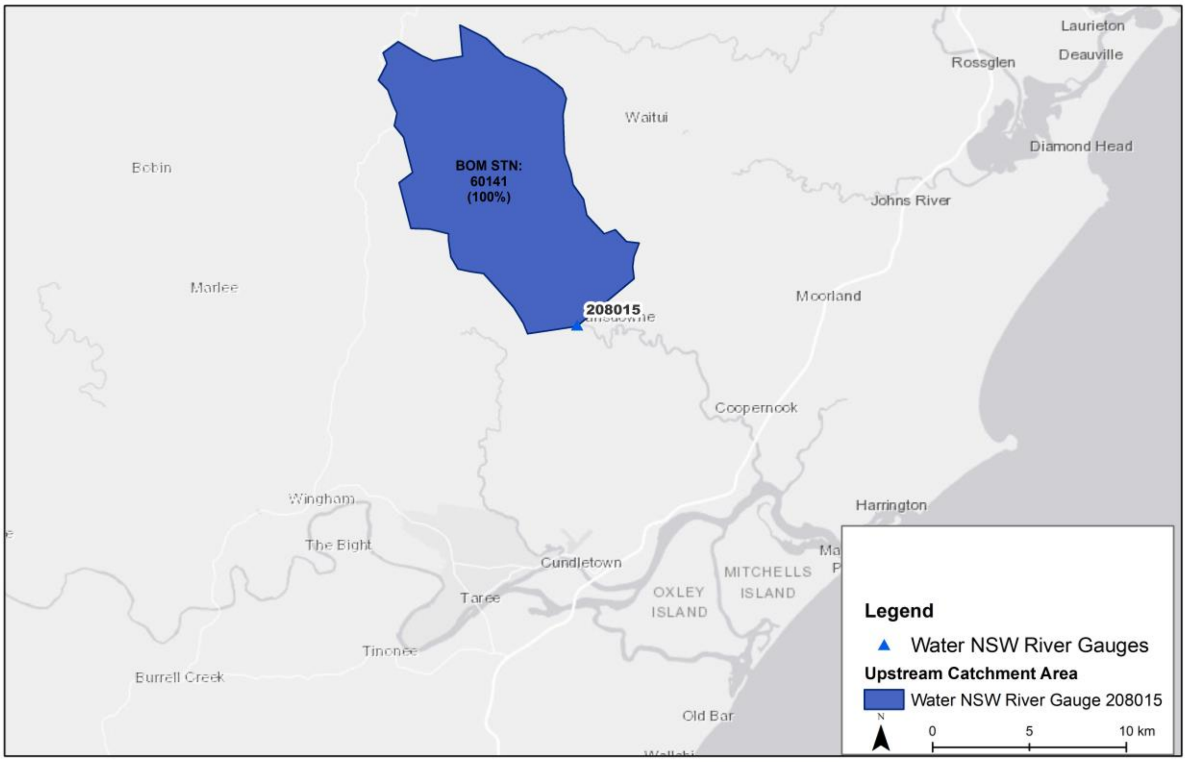

Figure B-2: Upstream catchment of selected flow sites

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 0.43, which was applied to Manning Floodplain subcatchments for the acid prioritisation assessment.

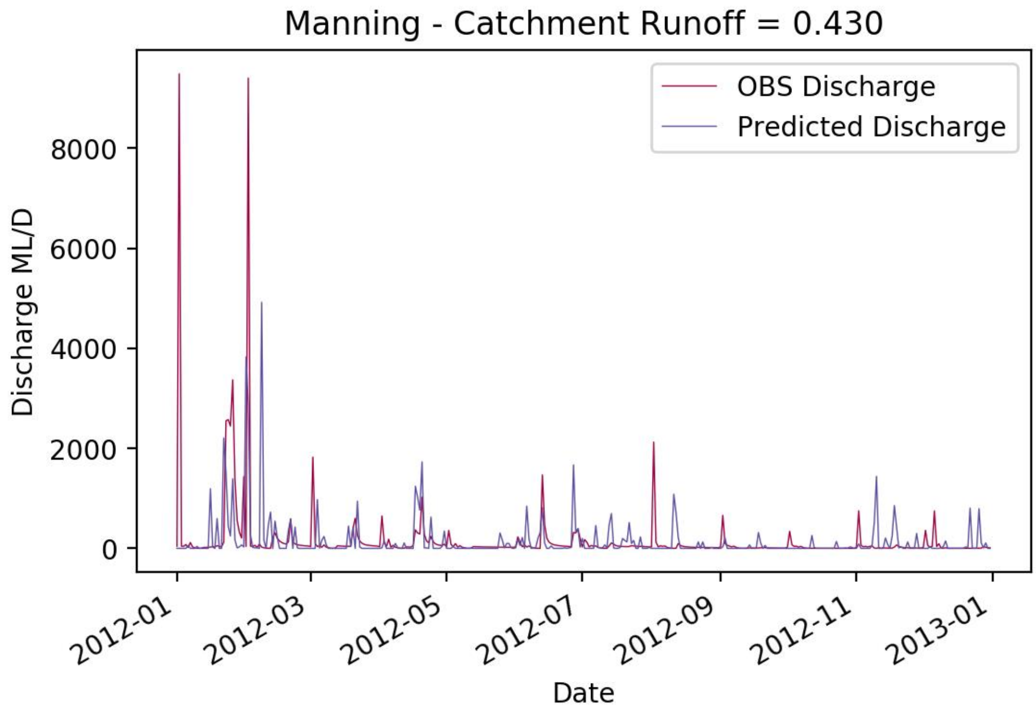

Figure B-3: Predicted and observed runoff for the catchment area upstream of river gauging station 208015

B3 Catchment size factor

The size of the subcatchment 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.

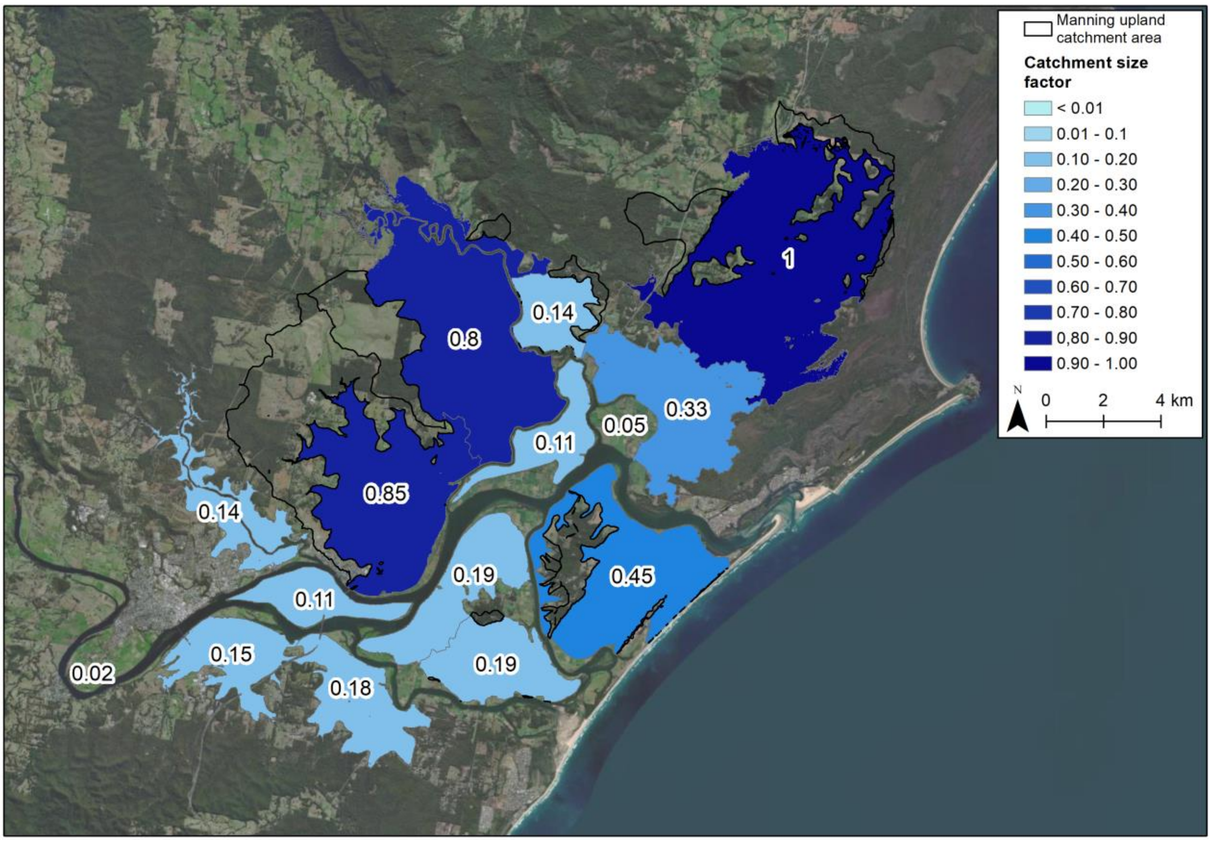

Figure B-4: Catchment size factor for each subcatchment in the Manning Estuary

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.

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

The inflow factors for each Manning 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
Coopernook	0.43	1,423,181	7,711,852	0.136	0.059
Cattai Creek	0.43	0	18,926,269	0.334	0.144
Big Swamp	0.43	12,705,174	56,656,336	1.000	0.430
Mambo Island	0.43	0	3,015,945	0.053	0.023
Moto	0.43	9,876,289	45,487,419	0.803	0.345
Jones Island	0.43	0	6,492,462	0.115	0.049
Dawson River	0.43	0	7,838,355	0.138	0.059
Ghinni Ghinni	0.43	23,527,559	48,055,194	0.848	0.365
Dumaresq Island	0.43	0	5,982,609	0.106	0.045
Mitchells Island	0.43	5,084,254	25,755,489	0.455	0.195
Bukkan Bukkan Creek	0.43	0	11,019,231	0.194	0.084
Croakers Creek	0.43	406,196	10,812,287	0.191	0.082
Taree Estate	0.43	0	1,146,063	0.020	0.009
Pampoolah	0.43	0	10,157,787	0.179	0.077
Glenthorne	0.43	0	8,615,837	0.152	0.065

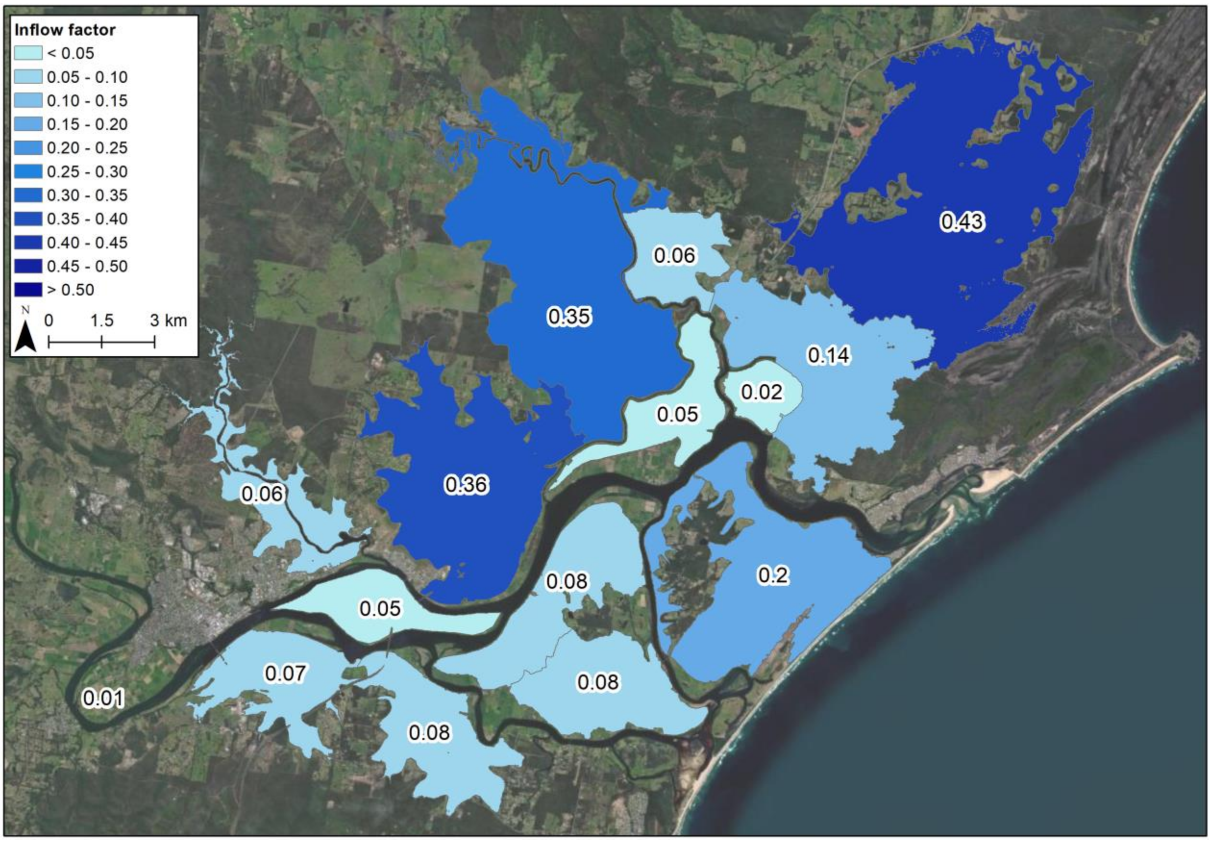

Figure B-5: Subcatchment inflow factors

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 Manning 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 et al. (2016), field measurements of insitu saturated hydraulic conductivity across the subcatchments of the Manning River floodplain were limited. Whilst widespread soil profile investigations had been undertaken, limited resources were allocated to investigate insitu saturated hydraulic conductivity. Existing data showed a large variability in K_{sat} across the floodplain, with a range between <0.0001 m/day (i.e. extremely low) to >100 m/day (i.e. extremely high). Reviewed sources of insitu saturated hydraulic conductivity data included:

- Johnston (2007);
- Hirst et al. (2009); and
- Glamore et al. (2014).

The insitu hydraulic conductivity data from these sources is provided in Tables C-1 to C-3. The locations of the measurements are provided in Figure C-1. Note that the K-values presented are considered estimates of the average saturated hydraulic conductivity of the soil profile at the measurement locations. The categories for each measurement listed in Tables C-1 to C-3 are inferred from the field assessment guidelines outlined in Johnston and Slavich (2003), and are presented for comparison with insitu hydraulic conductivity measurements collected during the field assessment component of this study.

Table C-1: Summary of insitu hydraulic conductivity data collected by Johnston (2007)

ID	Catchment	Easting (m)	Northing (m)	Estimated K_{sat} (m/day)	Category	pH
P1	Big Swamp	468214.8	6479921	2.1	Moderate	3.14
P2	Big Swamp	468116.4	6479913	6.9	Moderate	3.15
P3	Big Swamp	468078.3	6479771	18	High	3.46
P4	Big Swamp	469474.2	6480872	29	High	-

Table C-2: Summary of insitu hydraulic conductivity data collected by Hirst et al. (2009)

ID	Catchment	Easting (m)	Northing (m)	Estimated K_{sat} (m/day)	Category
Templeman-1	Moto	461526	6477589	3.2	Moderate
Templeman-2	Moto	461401	6477411	14.7	Moderate
Templeman-3	Moto	461336	6477492	8.6	Moderate
Roche-1	Moto	459935	6478536	0.8	Low
Roche-2	Moto	459544	6478481	6.26	Moderate
Roche-3	Moto	459222	6478454	11.28	Moderate
Roche-4	Moto	459351	6478264	11.12	Moderate
Roche-5	Moto	459885	6478303	21.8	High
Roche-6	Moto	459939	6478496	0.8	Low
Roche-7	Moto	459935	6478545	9.31	Moderate
Roche-8	Moto	459941	6478551	29.03	High
Roche-9	Moto	459955	6478536	8.87	Moderate
Cattai-1	Cattai Creek	465959	6477643	1.07	Low
Cattai-2	Cattai Creek	465939	6477632	3.36	Moderate
Cattai-3	Cattai Creek	465483	6477572	1.88	Moderate
Cattai-4	Cattai Creek	465164	6477277	1.5	Low
Cattai-5	Cattai Creek	465321	6477131	<0.0001	Extremely Low
Cattai-1a	Cattai Creek	466234	6477980	10.86	Moderate

Table C-3: Summary of insitu hydraulic conductivity data collected by Glamore et al. (2014)

ID	Catchment	Easting (m)	Northing (m)	Estimated K_{sat} (m/day)	Category	pH
1	Big Swamp	469062	6480970	60	High	-
2	Big Swamp	469243	6481231	20	High	-
3	Big Swamp	469435	6482521	15	High	-
4	Big Swamp	467979	6479503	35	High	4.0
5	Big Swamp	469668	6484688	>100	Extremely High	4.8
6	Big Swamp	469797	6483516	60	High	3.4
7	Big Swamp	470084	6483083	30	High	3.4
8	Big Swamp	469483	6481467	90	High	3.8
9	Big Swamp	468888	6480137	70	High	4.4
10	Big Swamp	469172	6480564	15	High	4.3
11	Big Swamp	470570	6483794	8	Moderate	3.7

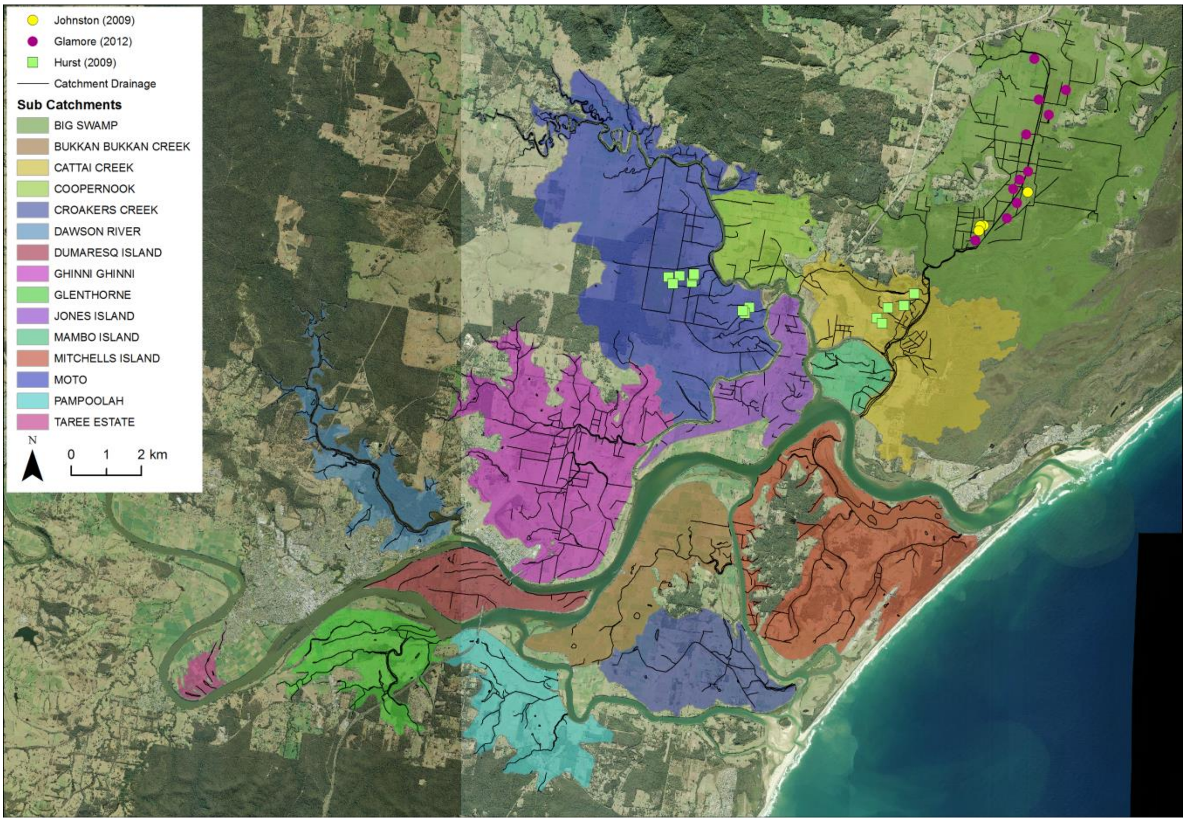

Figure C-1: Previously published insitu saturated hydraulic conductivity measurement sites

C3 Data collection from Glamore et al. (2016)

Due to the paucity of hydraulic conductivity data in the many subcatchments of the Manning River floodplain, Glamore et al. (2016) completed field investigations to collect insitu hydraulic conductivity data to undertake the priority assessment. The Johnston and Slavich (2003) open pit methodology was applied to measure hydraulic conductivity in the field. Location and results of the field measurements are provided in Figure C-2 and Table C-4.

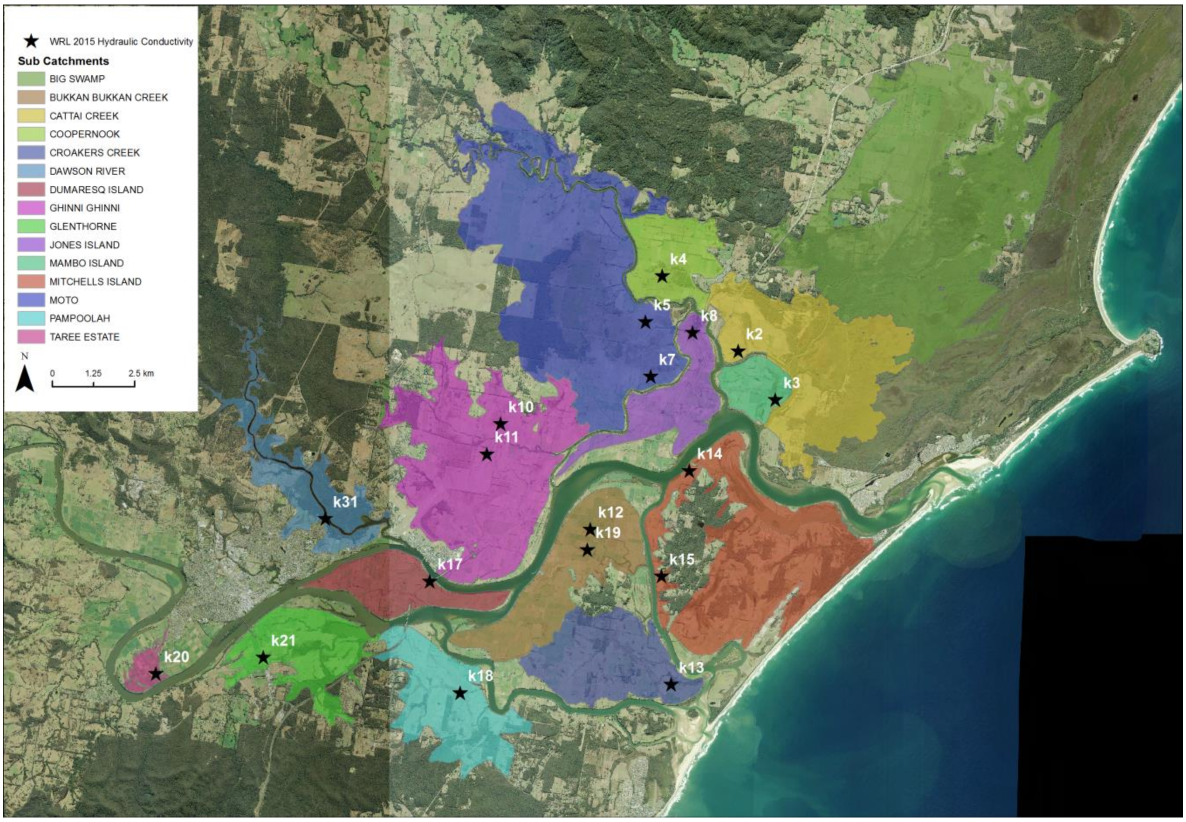

Figure C-2: 2015 field assessment locations of hydraulic conductivity

Table C-4: Summary of 2015 insitu hydraulic conductivity data

Site	Subcatchment	Easting (m)	Northing (m)	$K_{sat(H)}$ Category	Rating	pH	EC (µS/cm)
k12	Bukkan Bukkan Creek	459426	6471361	Extremely High	5	3.74	9,890
k21	Glenthorne	449479	6467467	Extremely High	5	3.98	668
k15	Mitchells Island	461586	6469935	High	4	4.65	29,000
k19	Bukkan Bukkan Creek	459339	6470738	High	4	3.60	9,223
k18	Pampoolah	455470	6466388	High	4	4.22	11,900
k11	Ghinni Ghinni	456278	6473648	High	4	3.88	1,277
k7	Moto	461267	6476013	High	4	3.70	n.s.
k5	Moto	461105	6477666	High	4	3.95	9,312
k20	Taree Estate	446217	6466969	Moderate	3	n.s.	747
k10	Ghinni Ghinni	456692	6474571	Moderate	3	3.72	1,288
k2	Cattai Creek	463920	6476781	Moderate	3	5.95	13,020
k4	Coopernook	461608	6479066	Moderate	3	3.64	17,430
k3	Mambo Island	465049	6475304	Low	2	5.65	35,300
k8	Jones Island	462539	6477342	Extremely Low	1	4.62	18,820
k31	Dawson River	451360	6471681	Extremely Low	1	N/A	N/A
k17	Dumaresq Island	454543	6469781	Extremely Low	1	N/A	N/A
k13	Croakers Creek	461883	6466644	Extremely Low	1	N/A	N/A
k14	Mitchells Island	462432	6473145	Extremely Low	1	N/A	N/A

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 and extremely high equating to a risk rating of five. 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 subcatchment in the Manning River floodplain

Subcatchment	K_{sat} Category	Risk Rating
Moto	Moderate	3
Ghinni Ghinni	Moderate	3
Big Swamp	High	4
Glenthorne	High	4
Coopernook	Moderate	3
Pampoolah	Moderate	3
Bukkan Bukkan Creek	High	4
Dawson River	Extremely Low	1
Cattai Creek	Moderate	3
Mitchells Island	Moderate	3
Croakers Creek	Extremely Low	1
Taree Estate	Moderate	3
Jones Island	Extremely Low	1
Mambo Island	Extremely Low	1
Dumaresq Island	Extremely Low	1

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 Manning River floodplain. This includes existing data available on the NSW Government eSPADE database and data in published literature where applicable (Section D3). 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 D4.

D2 Preamble

This section provides an overview of the soil profile data, such as surface elevation, profile depths and minimum pH available within the Manning River floodplain. This includes existing data available on the NSW Government eSPADE database and data in published literature where applicable (Section D3). 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 D4.

D3 Existing soil profile data

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

- eSPADE Database (DPIE, 2020);
- Glamore et al. (2014);
- WRL (2019); and
- Ruprecht et al. (2020b).

D3.1 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 Manning 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 Manning 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.

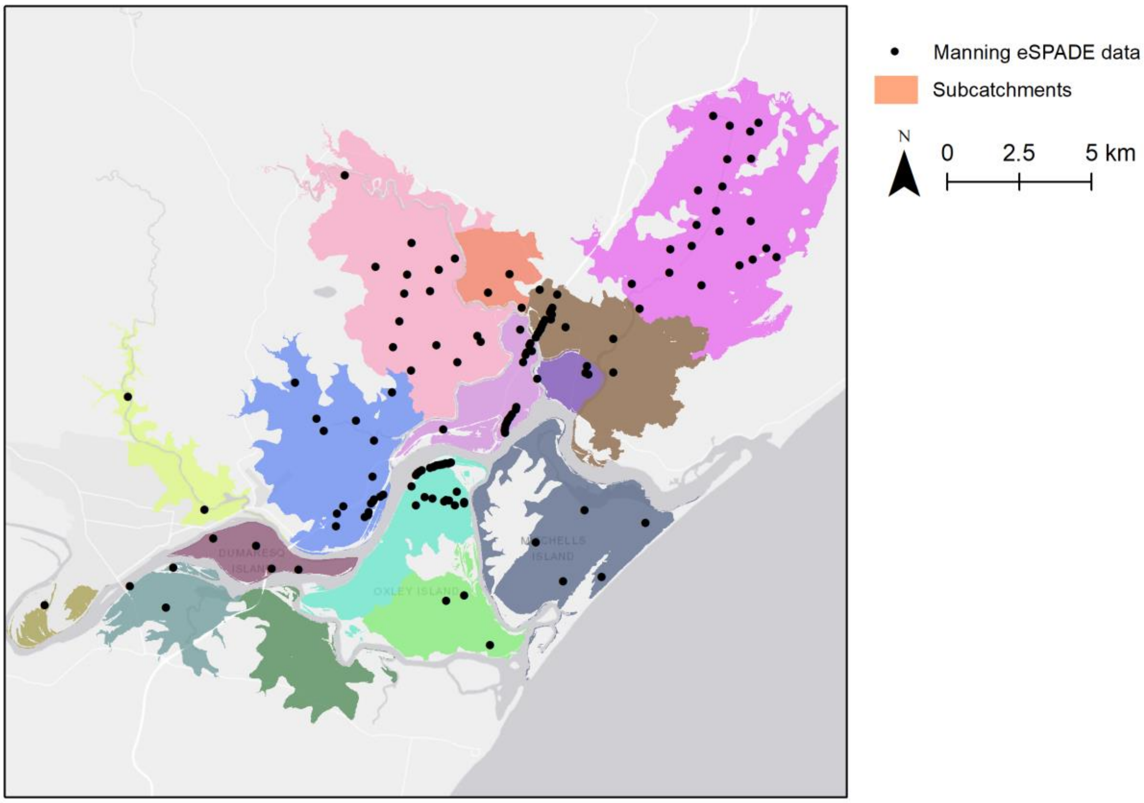

Figure D-1: Location of applicable eSPADE soil profiles in the study region

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	Subcatchment	Easting	Northing	Surface elevation (m AHD)*	Total profile depth (m)	Minimum pH**
24280	Big Swamp	470754	6483339	1.42	1.3	5.5
24281	Big Swamp	469924	6483319	0.86	1.9	3.5
24282	Big Swamp	469754	6482379	1.03	1.5	3
24283	Big Swamp	469654	6480819	0.65	1.3	3
24284	Big Swamp	468684	6480309	0.66	1.4	3
24285	Big Swamp	467904	6479389	0.51	2	3
24286	Big Swamp	468854	6481039	0.72	2	3
24287	Big Swamp	468904	6482249	1.03	2	3
24294	Big Swamp	470004	6484489	0.66	2.5	4.5
24295	Big Swamp	471004	6484589	1.3	1.9	4
24296	Big Swamp	470704	6484289	1.5	1.2	3
24297	Big Swamp	467934	6480189	0.59	2	3

eSPADE Profile ID	Subcatchment	Easting	Northing	Surface elevation (m AHD)*	Total profile depth (m)	Minimum pH**
24300	Big Swamp	466604	6478989	0.94	1.4	6
24307	Big Swamp	470804	6479839	1.53	1.6	5
24308	Big Swamp	470344	6479639	1.23	0.9	3.5
33384	Big Swamp	469014	6478946	2.23	1.3	7.5
33385	Big Swamp	471624	6479929	2.28	1.5	7
16441	Big Swamp	469418	6484829	0.91	1.85	5
16442	Big Swamp	471275	6480232	1.21	2.6	4
16491	Big Swamp	470737	6481171	1.54	3.05	4.5
16492	Big Swamp	469523	6481527	1.12	3.15	4.5
24278	Bukkan Bukkan Creek	460154	6471489	0.63	2	3
24279	Bukkan Bukkan Creek	460254	6471459	1.14	1.5	3
16447	Bukkan Bukkan Creek	459099	6471289	0.67	1.6	5
22646	Bukkan Bukkan Creek	460779	6471359	0.95	2	5.7
22647	Bukkan Bukkan Creek	460786	6471409	0.94	1.92	4.8
22648	Bukkan Bukkan Creek	460467	6471290	0.68	1.4	3.8
22649	Bukkan Bukkan Creek	460520	6471773	0.98	1.4	3.6
22650	Bukkan Bukkan Creek	460094	6471439	0.61	1.5	3.6
22651	Bukkan Bukkan Creek	459674	6471534	0.51	2.5	3.5
22652	Bukkan Bukkan Creek	459404	6471589	0.71	2	3.4
24930	Bukkan Bukkan Creek	458962	6471953	2.96	2.5	5.7
24935	Bukkan Bukkan Creek	459098	6472353	0.59	2.2	6.2
24936	Bukkan Bukkan Creek	459160	6472413	0.79	2	6.2
24937	Bukkan Bukkan Creek	459220	6472462	2.35	2	6.9
24938	Bukkan Bukkan Creek	459308	6472515	1.6	1.5	6.6
24941	Bukkan Bukkan Creek	459602	6472603	2.04	2.5	7.5
24942	Bukkan Bukkan Creek	459722	6472631	2.24	2.5	7.4
24943	Bukkan Bukkan Creek	459825	6472678	1.84	2	8.2
24944	Bukkan Bukkan Creek	459941	6472702	1.65	1.5	7.7
24945	Bukkan Bukkan Creek	460044	6472725	1.54	2	6.6
24946	Bukkan Bukkan Creek	460134	6472746	1.49	2	8.4

eSPADE Profile ID	Subcatchment	Easting	Northing	Surface elevation (m AHD)*	Total profile depth (m)	Minimum pH**
24947	Bukkan Bukkan Creek	460239	6472748	1.25	2.5	7.9
24948	Bukkan Bukkan Creek	460326	6472789	1.68	1.5	6.9
7934	Cattai Creek	464304	6477489	0.96	0.6	4.5
24299	Cattai Creek	465954	6475909	1.02	1.3	3.5
24301	Cattai Creek	466874	6478139	1.09	1.25	5
24302	Cattai Creek	465964	6477089	0.92	2.3	5
20523	Cattai Creek	463404	6478789	1.27	0.65	5.5
21571	Cattai Creek	463791	6477752	1.73	1.4	5.7
21572	Cattai Creek	463594	6477751	0.83	1.7	5.2
21573	Cattai Creek	463340	6477271	1.27	2	6
21574	Cattai Creek	463344	6477269	1.21	2.5	6.2
21585	Cattai Creek	463264	6477137	2.38	2.2	4.1
21586	Cattai Creek	463390	6477347	1.05	1.1	6.2
21587	Cattai Creek	463430	6477427	1.18	1.1	6.7
21588	Cattai Creek	463477	6477525	1.1	1.5	4.5
21589	Cattai Creek	463528	6477629	0.95	1.6	5.1
21591	Cattai Creek	463753	6477993	1.47	1.4	4.9
21592	Cattai Creek	463794	6478076	1.3	1.8	4.9
21593	Cattai Creek	463838	6478159	1.41	1.6	6.4
21598	Cattai Creek	464007	6478626	1.24	1	3.7
21606	Cattai Creek	463827	6477925	0.98	1.4	3.3
24314	Coopernook	462354	6479339	0.51	1.75	4
24315	Coopernook	461604	6478689	0.59	1.9	3.5
21575	Coopernook	462782	6478168	0.56	0.65	4.3
7986	Croakers Creek	460779	6468164	2.2	2.1	5
16446	Croakers Creek	460154	6467989	0.48	2.28	4.5
16512	Croakers Creek	461674	6466449	1.55	2.7	5
19017	Dawson River	451764	6471139	1.15	3	5.5
19018	Dawson River	449114	6475064	2.94	2.1	6
16450	Dumaresq Island	453552	6469884	0.56	2.9	5
19016	Dumaresq Island	452074	6470139	1.43	3.1	5
22337	Dumaresq Island	455029	6469064	1.46	1.22	6
22338	Dumaresq Island	454104	6469089	1.11	1	6
24303	Ghinni Ghinni	455654	6474309	0.99	1.25	3.5
24304	Ghinni Ghinni	455904	6473889	0.91	1.7	3.5
24305	Ghinni Ghinni	457024	6474239	0.71	1.55	4
24306	Ghinni Ghinni	457654	6473539	0.92	1.6	4
16444	Ghinni Ghinni	458284	6475218	0.96	3.6	4
16448	Ghinni Ghinni	456366	6471005	1.02	2.13	4.5
16508	Ghinni Ghinni	454904	6475564	1.17	2.6	3.5
22336	Ghinni Ghinni	456333	6470564	1.78	0.93	7
22342	Ghinni Ghinni	457604	6472289	1.71	1.03	8

eSPADE Profile ID	Subcatchment	Easting	Northing	Surface elevation (m AHD)*	Total profile depth (m)	Minimum pH**
22343	Ghinni Ghinni	457329	6470889	1.26	1	6
22347	Ghinni Ghinni	456579	6471264	1.25	1.03	6
24914	Ghinni Ghinni	457451	6470953	2.58	3	7.5
24915	Ghinni Ghinni	457467	6471061	2.37	1.5	7.3
24918	Ghinni Ghinni	457558	6471358	2.39	2	8.9
24919	Ghinni Ghinni	457609	6471429	1.75	2.4	6.2
24920	Ghinni Ghinni	457646	6471492	2.74	2.5	7.8
24923	Ghinni Ghinni	457874	6471604	1.72	1.5	7.4
24924	Ghinni Ghinni	457976	6471663	0.62	2.8	6.3
73173	Glenthorne	449176	6468485	2.42	2.3	5
19014	Glenthorne	450434	6467744	0.96	2.8	4
19015	Glenthorne	450684	6469139	1.52	2.95	6.5
7983	Jones Island	460054	6473939	1.82	2.1	7
16443	Jones Island	462731	6477397	0.66	2.58	4.5
21576	Jones Island	462832	6476275	1.75	1.1	3.5
21578	Jones Island	462907	6476517	2.13	1.8	4.8
21579	Jones Island	462945	6476606	2.04	2.6	4.5
21581	Jones Island	463049	6476856	1.07	1.2	3.6
21582	Jones Island	463086	6476932	1.77	1.8	5.6
21583	Jones Island	463127	6476659	1.01	0.7	4.2
24970	Jones Island	462202	6473995	1	2.5	5.5
24971	Jones Island	462218	6474082	1.18	2	5.8
24972	Jones Island	462273	6474186	1.28	2	6.5
24973	Jones Island	462312	6474273	1.14	2	5.7
24974	Jones Island	462373	6474367	0.92	1.5	6.3
24975	Jones Island	462435	6474463	0.81	1.5	6.3
24977	Jones Island	462571	6474634	0.69	2	5.1
24978	Jones Island	462592	6474708	0.38	1.5	5.9
24979	Jones Island	462206	6473825	1.9	2	6.1
24982	Jones Island	462189	6473909	0.97	1.1	6.1
33389	Mambo Island	463320	6475699	2.88	2.15	7
16495	Mambo Island	464988	6475903	0.86	2.2	5
16496	Mambo Island	465099	6475849	0.41	1.4	4
70311	Mambo Island	465044	6476129	0.69	1.1	6
16452	Mitchells Island	467079	6470686	1.5	0.9	8.5
16453	Mitchells Island	465554	6468814	1.68	1.1	6
16454	Mitchells Island	464223	6468659	1.14	1.75	6
16510	Mitchells Island	463269	6470019	1.2	2.2	4.5
16511	Mitchells Island	464954	6471124	2.18	2.2	5.5
24289	Moto	458304	6476789	1.12	1.9	3.5
24290	Moto	461354	6476989	0.6	1.2	3
24291	Moto	459604	6478739	1.03	1.4	3
24292	Moto	459904	6479489	0.89	2	3.5
24293	Moto	458954	6480409	1.26	1.8	3.5

eSPADE Profile ID	Subcatchment	Easting	Northing	Surface elevation (m AHD)*	Total profile depth (m)	Minimum pH**
24309	Moto	458804	6479309	0.8	1.9	3.5
24310	Moto	458704	6478649	0.79	2	3.5
24311	Moto	458524	6477689	0.95	1.5	3.5
24312	Moto	457704	6479589	1.43	1.85	5
24313	Moto	459824	6476859	0.82	1.2	3.5
16445	Moto	458929	6475988	1.66	1.57	5
16461	Moto	460452	6479869	1.26	2.4	4.5
16462	Moto	461235	6477183	0.66	2.65	4
16507	Moto	456629	6482764	1.51	2.9	5.5
70310	Moto	460540	6476279	1.03	1	4.2
73169	Taree Estate	446218	6467829	0.52	1.2	5.5

D3.2 Other literature

Published and grey literature was investigated for other soil profiles within the Manning River floodplain, which included data from previous WRL investigations undertaken on behalf of MidCoast Council (Glamore et al., 2016; Ruprecht et al., 2020b; WRL, 2019). 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 Manning 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.

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

Profile	Subcatchment	Easting	Northing	Surface Elevation (m AHD)	Total Profile Depth (m)	Minimum pH
WRL_2018_1	Big Swamp	471453	6480109	0.87	2	3.98
WRL_2018_2	Big Swamp	470137	6479625	0.86	1.3	4.23
WRL_2018_3	Big Swamp	471182	6480203	0.75	2	4.29
WRL_2018_4	Big Swamp	469436	6480515	0.55	2	4.78
SP01 (Ruprecht et al., 2020b)	Pampoolah	454817	6466654	1.17	2.9	4.3
SP02 (Ruprecht et al., 2020b)	Pampoolah	455082	6466560	1.13	3	5
SP03 (Ruprecht et al., 2020b)	Pampoolah	455675	6466368	0.86	2.5	4.4
SP04 (Ruprecht et al., 2020b)	Pampoolah	454484	6466420	1.06	3	4.8
SP05 (Ruprecht et al., 2020b)	Pampoolah	455037	6467043	1.30	3	4.5
SP06 (Ruprecht et al., 2020b)	Pampoolah	454552	6467533	0.73	3	5.2

D4 Field campaign

Glamore et al. (2016) 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-2, 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 et al. (2016).

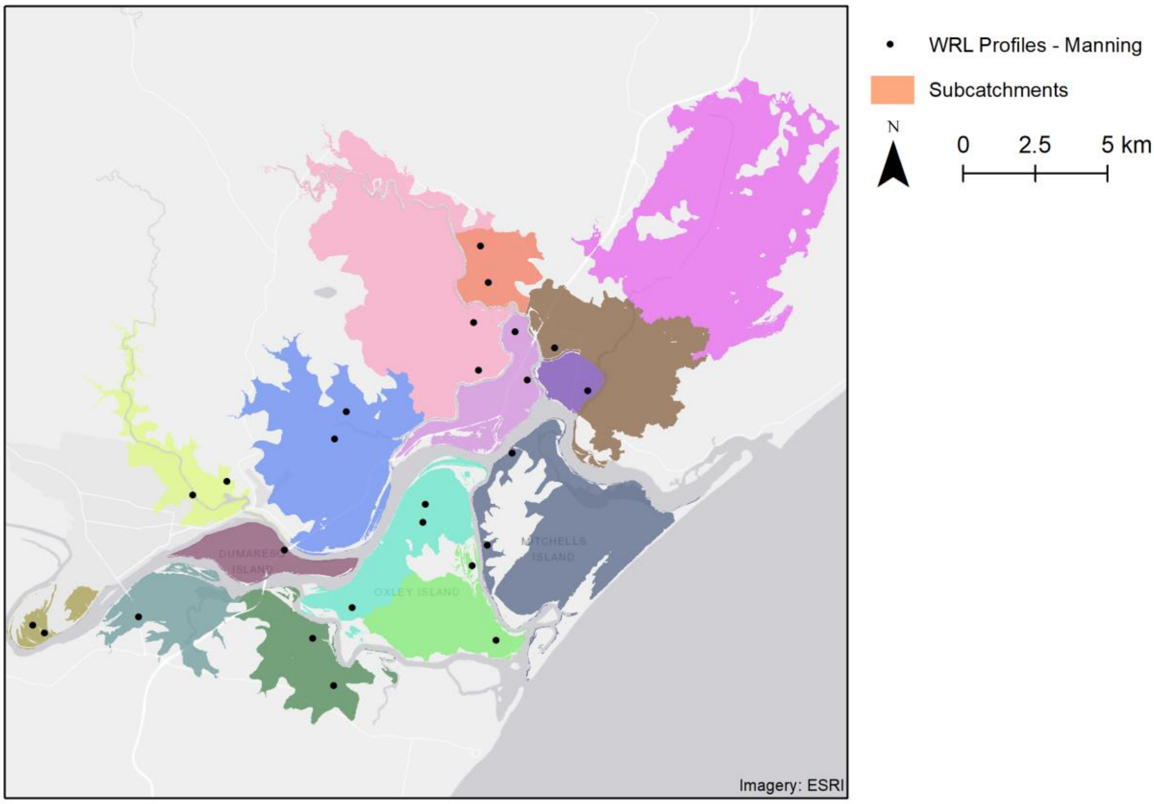

Figure D-2: Location of soil profiles from Glamore et al. (2016) field investigations

Table D-3: Summary of relevant soil profiles from Glamore et al. (2016) field investigations

Profile	Subcatchment	Easting	Northing	Surface Elevation (m AHD)	Total Profile Depth (m)	Minimum pH
P23	Bukkan Bukkan Creek	456883	6467774	0.97	3	5.6
P20	Bukkan Bukkan Creek	459426	6471356	0.29	3.3	4.3
P19	Bukkan Bukkan Creek	459336	6470739	0.45	3	4.4
P02	Cattai Creek	463911	6476789	0.62	3	4.8
P07	Coopernook	461339	6480331	0.75	3	3.7
P06	Coopernook	461607	6479058	0.27	3	3.6
P21	Croakers Creek	461883	6466644	0.77	3	4.1
P32	Dawson River	452535	6472162	1.16	2.4	4.4
P31	Dawson River	451360	6471681	0.40	2.4	5.3
P28	Dumaresq Island	454543	6469781	0.97	1.6	4.3
P17	Ghinni Ghinni	456277	6473639	0.67	3	3.8
P16	Ghinni Ghinni	456695	6474576	0.70	2.4	3.4
P38	Glenthorne	449483	6467453	1.07	3.5	4.1
P15	Jones Island	462964	6475684	0.35	3	4.2
P13	Jones Island	462540	6477353	0.34	3	3.5
P04	Mambo Island	465067	6475309	0.65	3	4.2

Profile	Subcatchment	Easting	Northing	Surface Elevation (m AHD)	Total Profile Depth (m)	Minimum pH
P35	Mitchells Island	462432	6473145	1.33	2.4	6.2
P34	Mitchells Island	461584	6469935	0.64	3	5.1
P22	Mitchells Island	461054	6469226	0.78	2	6.3
P12	Moto	461105	6477669	0.29	3	3.0
P11	Moto	461266	6476011	0.88	2.4	3.8
P30	Pampoolah	455522	6466707	1.25	3.1	4.9
P29	Pampoolah	456246	6465072	0.97	2.5	4.4
P37	Taree Estate	445804	6467171	2.12	1.7	6.2
P36	Taree Estate	446219	6466901	3.27	2.3	5.8

D5 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 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 Manning River floodplain.

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
Big Swamp	198.2	1.2	237.9	25
Bukkan Bukkan Creek	59.3	1.2	71.2	26
Cattai Creek	38.9	1.2	46.7	20
Coopernook	102.8	0.8	82.2	5
Croakers Creek	15.9	1.2	19.1	4
Dawson River	7.2	1.2	8.6	4
Dumaresq Island	3.0	1.2	3.7	5
Ghinni Ghinni	71.5	1.2	85.8	20
Glenthorne	27.7	1.2	33.2	4
Jones Island	31.0	1.2	37.2	20
Mambo Island	14.2	1.2	17.0	5
Mitchells Island	3.9	1.2	4.7	8
Moto	193.7	1.2	232.4	17
Pampoolah	16.6	1.2	19.9	8
Taree Estate	1.3	1.2	1.6	3

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 Manning 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 Manning 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.

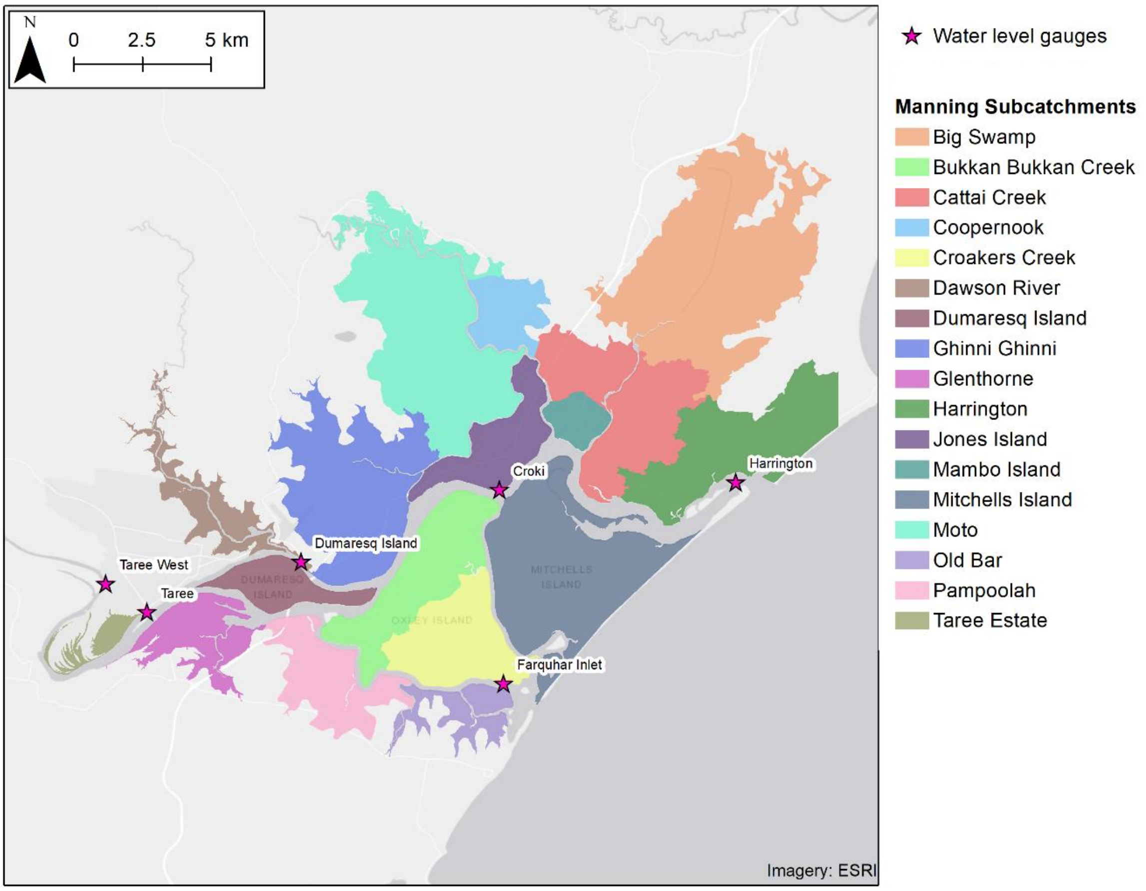

Figure E-1: Locations of water level gauges used for blackwater elevation thresholds

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)
Harrington	0.5 (Manning River)	28.5	0.4
Croki	11.9 (Manning River) 8.6 (Scotts Creek)	27.7	0.4
Dumaresq Island	21.5 (Manning River) 10.8 (South Channel)	17.7	0.4
Taree	27.9 (Manning River)	33.3	0.5
Taree West	36.8 (Manning River)	10.0	0.5
Farquhar Inlet	0 (Scotts Creek) 1.1 (South Channel)	32.0	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)
Harrington	0.4	0.4	0.4	0.5
Croki	0.4	0.6	0.7	1.6
Dumaresq Island	0.4	0.7	0.9	2
Taree	0.5	0.6	0.8	2.2
Taree West	0.5	1	1.6	4.6
Farquhar Inlet	0.4	0.5	0.7	1.3

E3 Subcatchment elevation thresholds

The subcatchments of the Manning 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.

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
Harrington	Harrington
Mitchells Island	0.71 x Harrington + 0.29 x Croki
Cattai Creek	0.30 x Harrington + 0.70 x Croki
Big Swamp*	Assumed the same levels as Cattai Creek
Mambo Island	0.28 x Harrington + 0.72 x Croki
Moto	0.22 x Harrington + 0.78 x Croki
Coopernook*	Assumed to be the same as Moto
Ghinni Ghinni	0.65 x Croki + 0.65 x Dumaresq Island
Jones Island	Croki
Dumaresq Island	Dumaresq Island
Dawson River	Dumaresq Island
Glenthorne	Dumaresq Island
Taree Estate	0.67 x Taree + 0.33 x Taree West
Old Bar	Farquhar Inlet
Croakers Creek	Farquhar Inlet
Bukkan Bukkan Creek	0.34 x Farquhar Inlet + 0.66 x Croki
Pampoolah	0.34 x Farquhar Inlet + 0.66 x Dumaresq Island

* Neither Big Swamp or Coopernook are located on the main river channel or well represented by an individual water level gauge. Both have been assumed to be the same as the closest subcatchment

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

Subcatchment	Minimum level (m AHD)	Median level (m AHD)	Mean level (m AHD)	Maximum level (m AHD)
Harrington	0.4	0.4	0.4	0.5
Mitchells Island	0.4	0.5	0.5	0.8
Cattai Creek	0.4	0.5	0.6	1.3
Big Swamp*	0.4	0.5	0.6	1.3
Mambo Island	0.4	0.5	0.6	1.3
Moto	0.4	0.6	0.7	1.4
Coopernook	0.4	0.6	0.7	1.4
Ghinni Ghinni	0.4	0.7	0.8	1.7
Jones Island	0.4	0.6	0.7	1.6
Dumaresq Island	0.4	0.7	0.9	2
Dawson River	0.4	0.7	0.9	2
Glenthorne	0.4	0.7	0.9	2
Taree Estate	0.5	0.7	1.1	3
Old Bar	0.4	0.5	0.7	1.3
Croakers Creek	0.4	0.5	0.7	1.3
Bukkan Bukkan Creek	0.4	0.6	0.7	1.5
Pampoolah	0.4	0.6	0.8	1.7

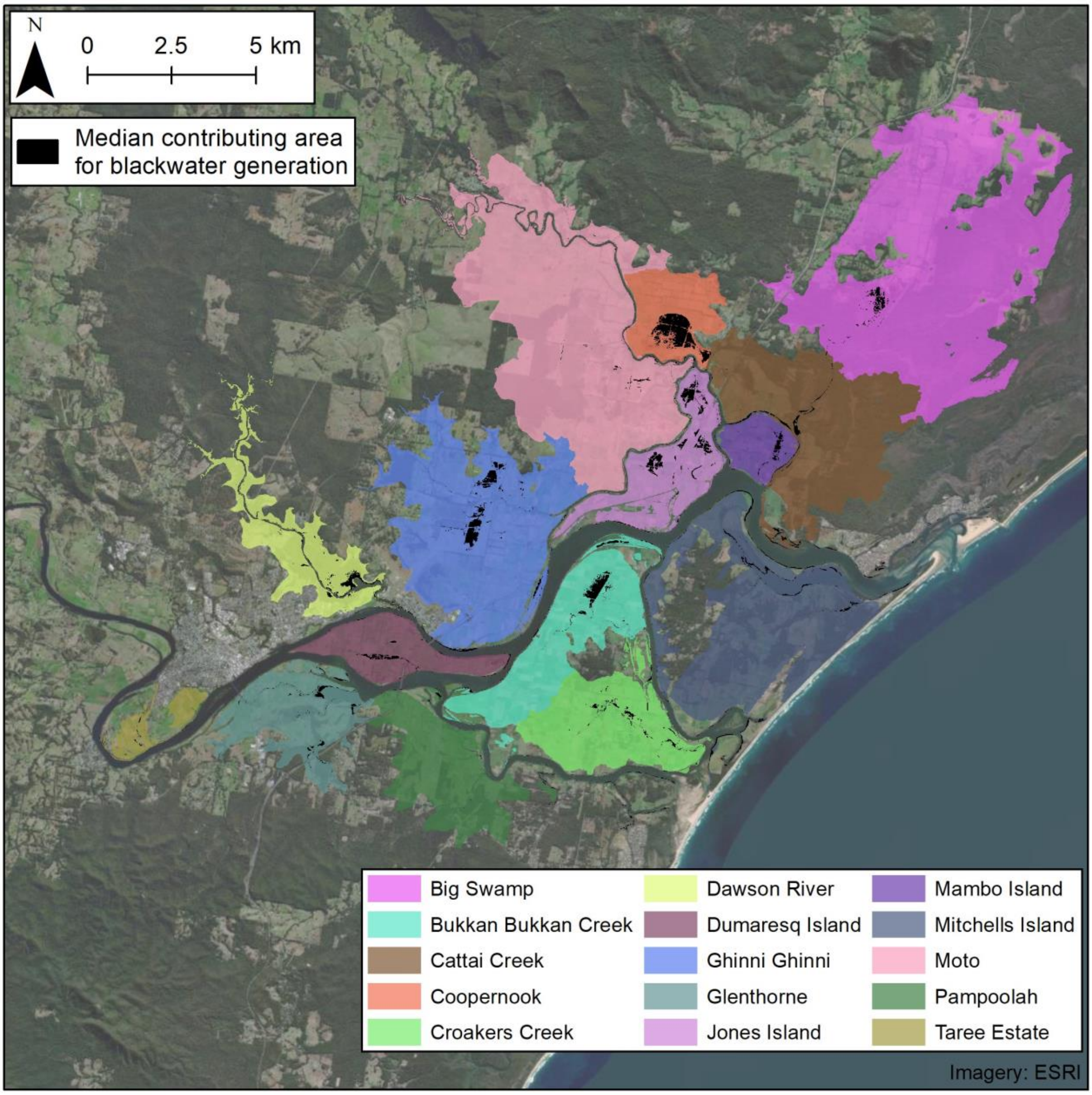

Figure E-2: Areas in the Manning River floodplain below the median elevation threshold

Appendix F Floodplain infrastructure

F1 Preamble

A range of floodplain infrastructure exists across the Manning 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 Manning 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

Information on the tenure of EOS structures across the Manning River floodplain is shown in Figure F-1.

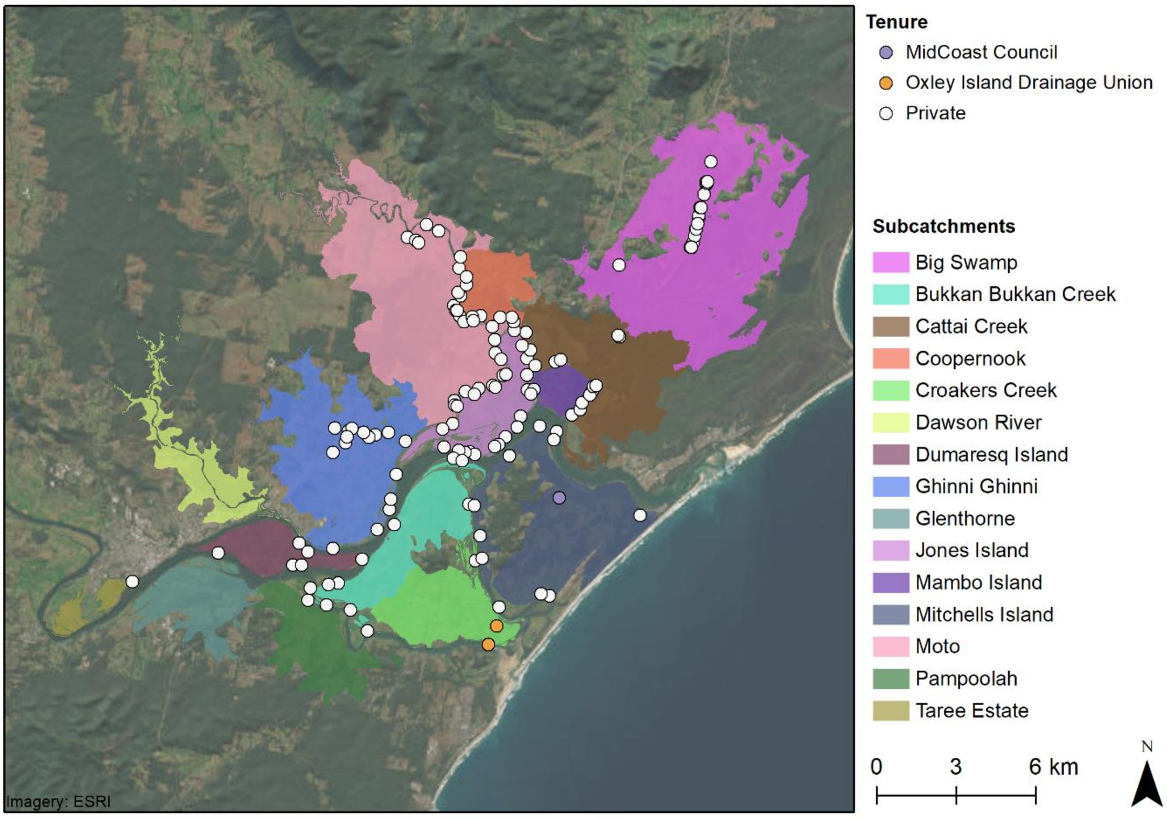

Figure F-1: Tenure of end of system structures on the Manning River floodplain

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.

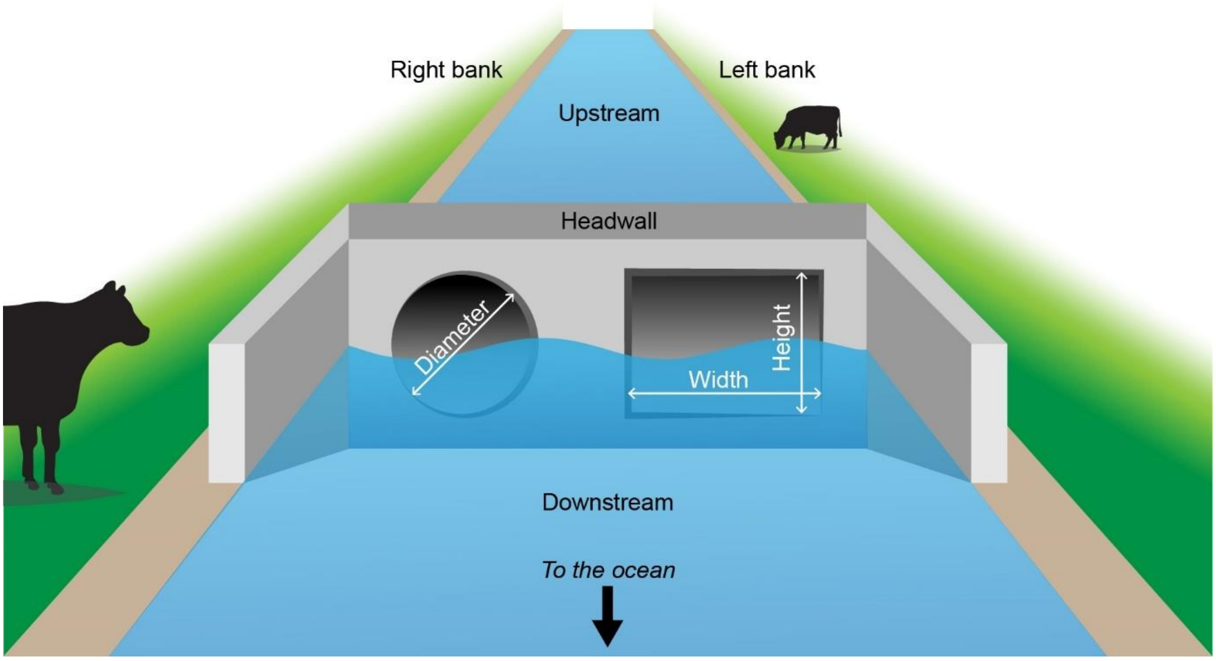

Figure F-2: Example of culverts controlling water in an agricultural drain

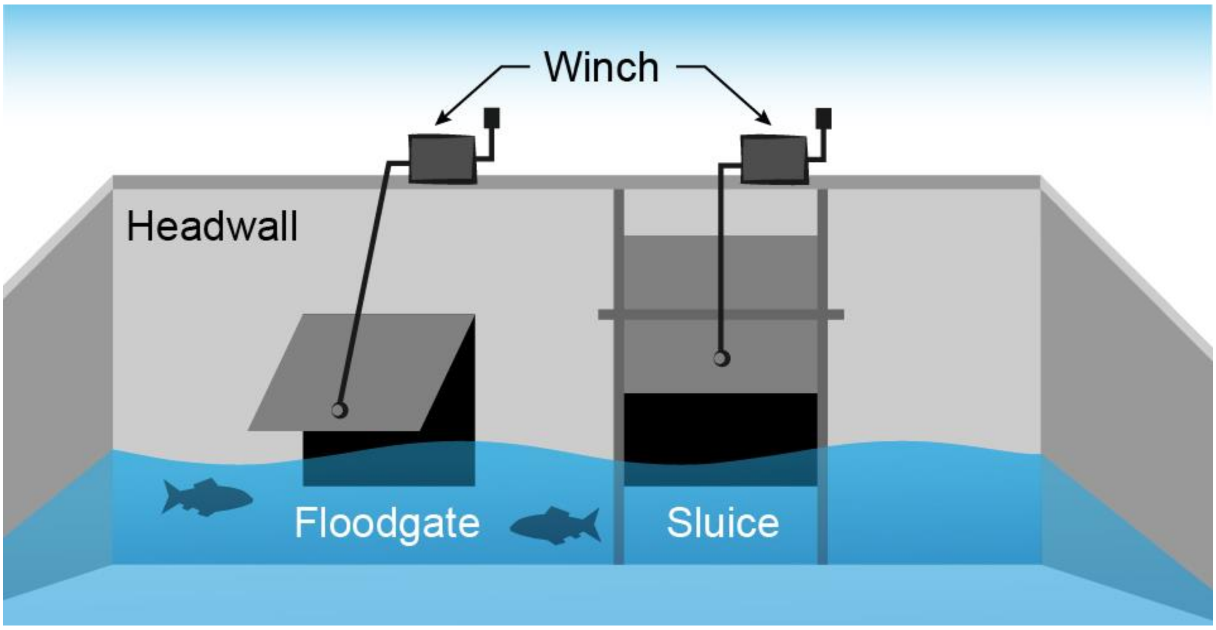

Figure F-3: Example of floodgate and sluice structures which can be fitted to culverts to control flow using a winch

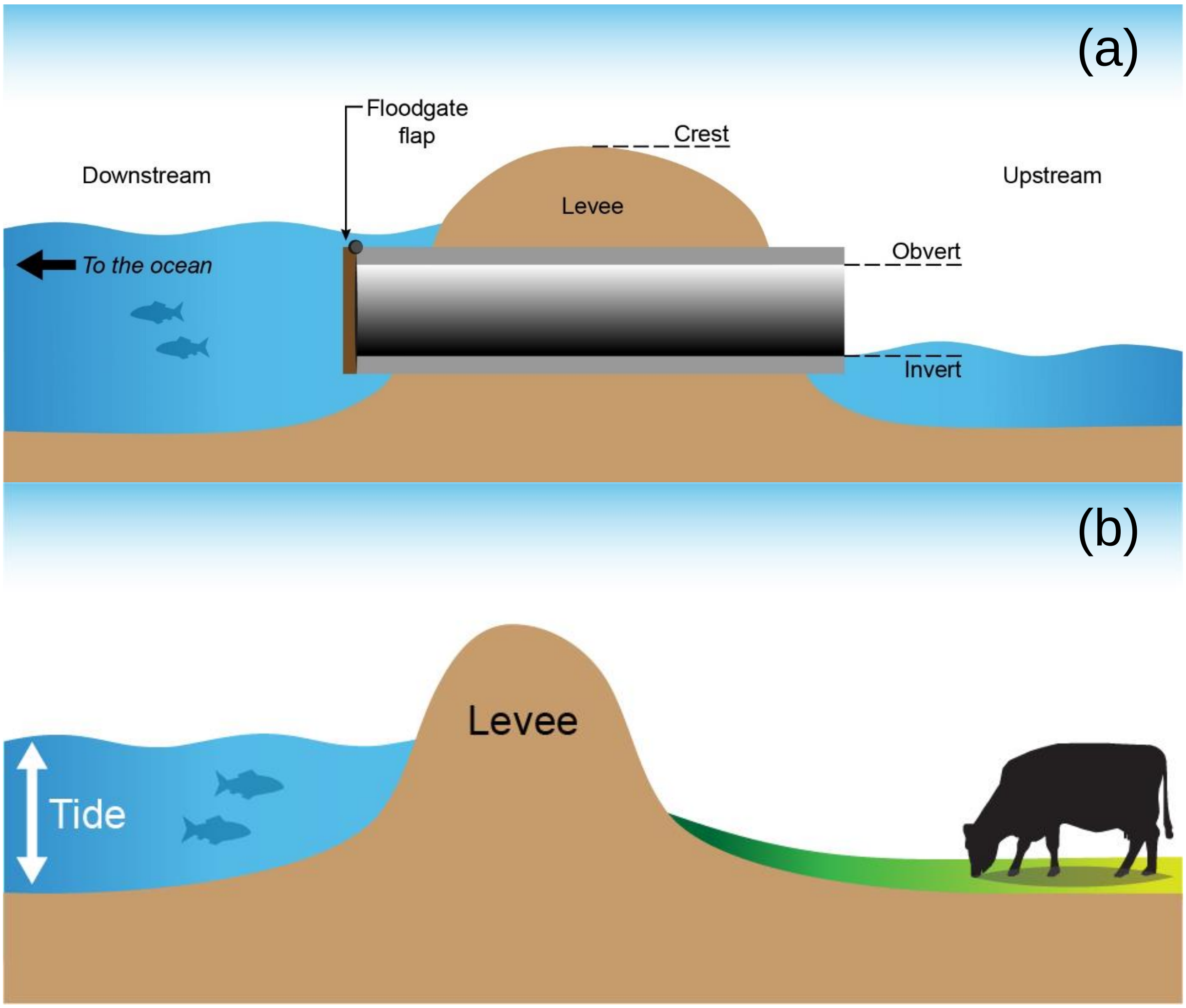

Figure F-4: Example of (a) a floodgate structure ensuring water levels upstream of a levee remain at the low tide level and (b) a levee preventing tidal inundation of the floodplain

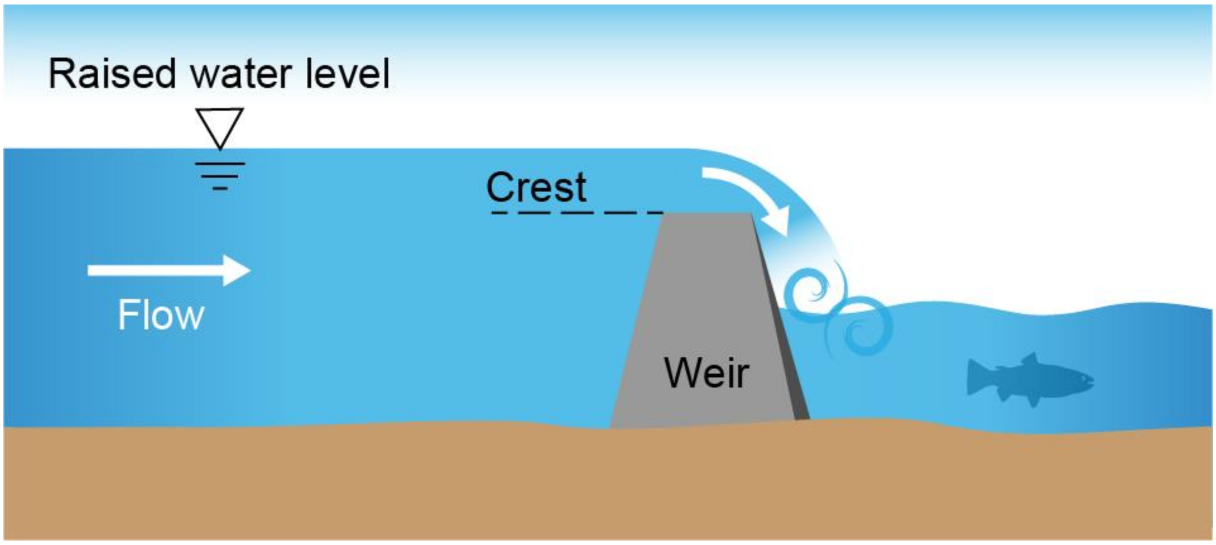

Figure F-5: Example of a weir ensuring a raised water level on the upstream side

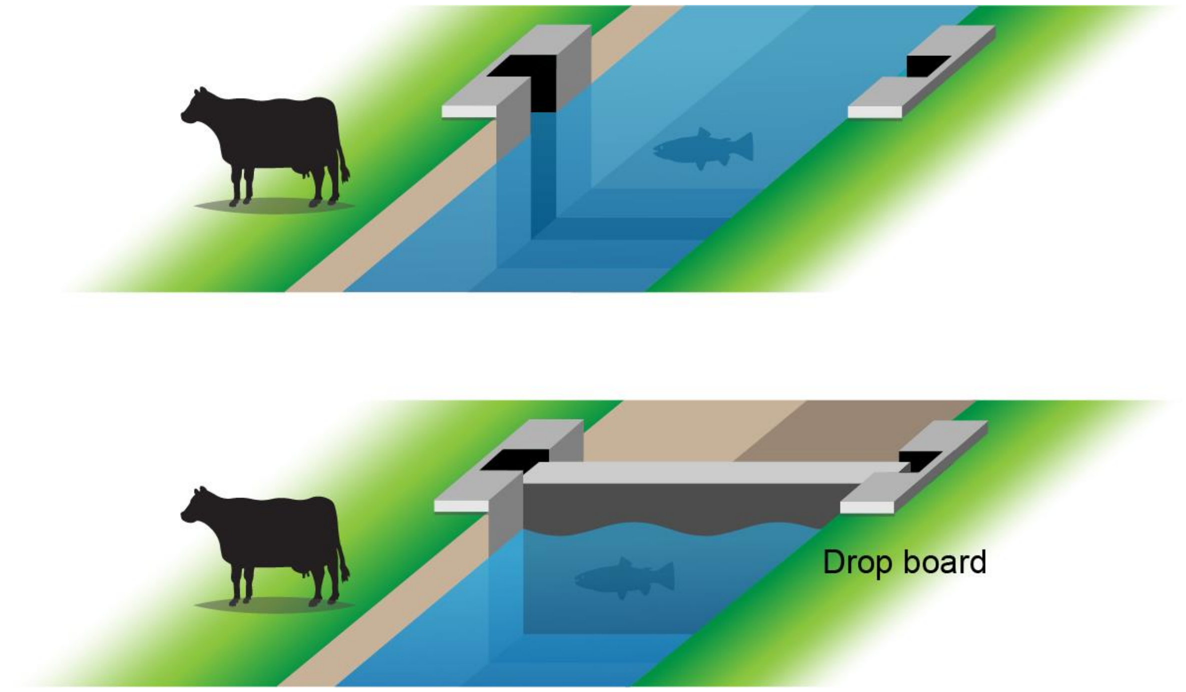

Figure F-6: Example of a drop board structure which can be used to control water levels and prevent inundation

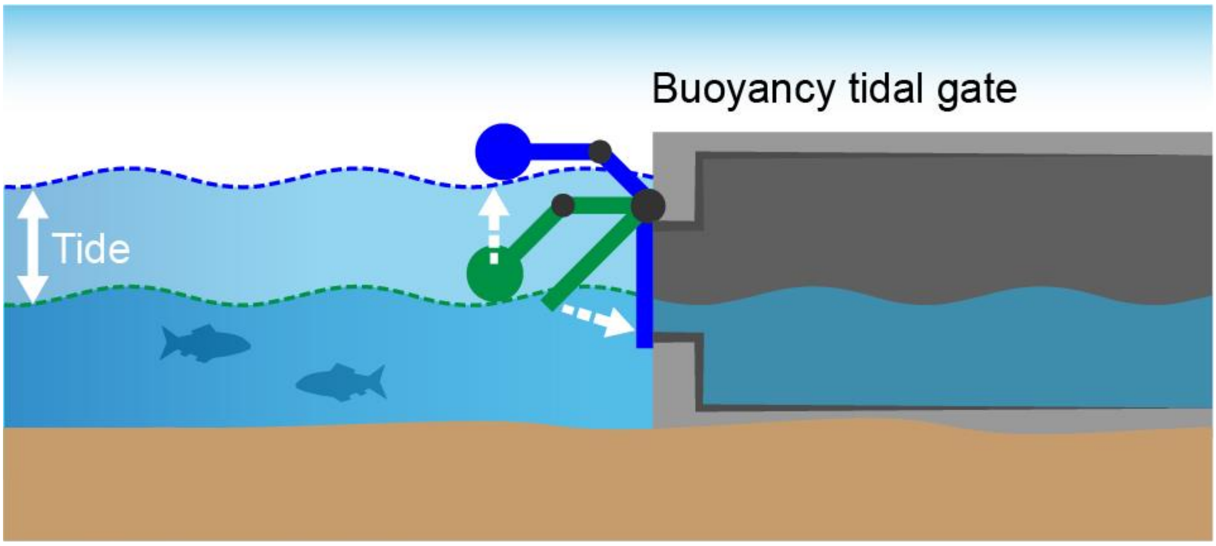

Figure F-7: Example of a buoyancy tidal gate that lets a controlled level of tidal water upstream of the structure (green) before closing due to a buoyancy mechanism and preventing further water ingress (blue)

F4 Data from Glamore et al. (2016)

Glamore et al. (2016) provided a summary of the data available of floodplain prior to the *Lower Manning River Remediation Action Plan*. At the time, the most recent survey of floodgates in the Manning River was completed by the NSW Department of Primary Industries (Fisheries) in 2006 and revealed that there were approximately 140 floodgates located within the MidCoast Council LGA. The majority of the floodgates are located in Pipeclay Canal-Cattai Creek, Dickensons Creek, Ghinni Ghinni Creek, Scotts

Creek, and the Lansdowne River. While some of the floodgates in the LGA are owned by MidCoast Council and the drainage unions of Moto and Oxley Island, the majority of the floodgates are owned by private land holders. The distribution of floodgates located within the study area is presented in Figure F-8 and a summary of the available floodgate data is provided in Table F-1.

Note that the survey completed by Fisheries in 2006 did not include any invert levels of the drainage structures across the LGA. Glamore et al. (2016) also completed a field survey on 26 November 2015 of key floodgates in Scotts Creek, Cattai Creek, and the Lansdowne River. The field survey was undertaken to assess the floodgate condition and to obtain drain invert levels. Where possible, floodgate structures and culvert inverts were surveyed to AHD using Trimble RTK-GPS survey gear. A summary of the field survey completed by Glamore et al. (2016) is provided in Table F-2.

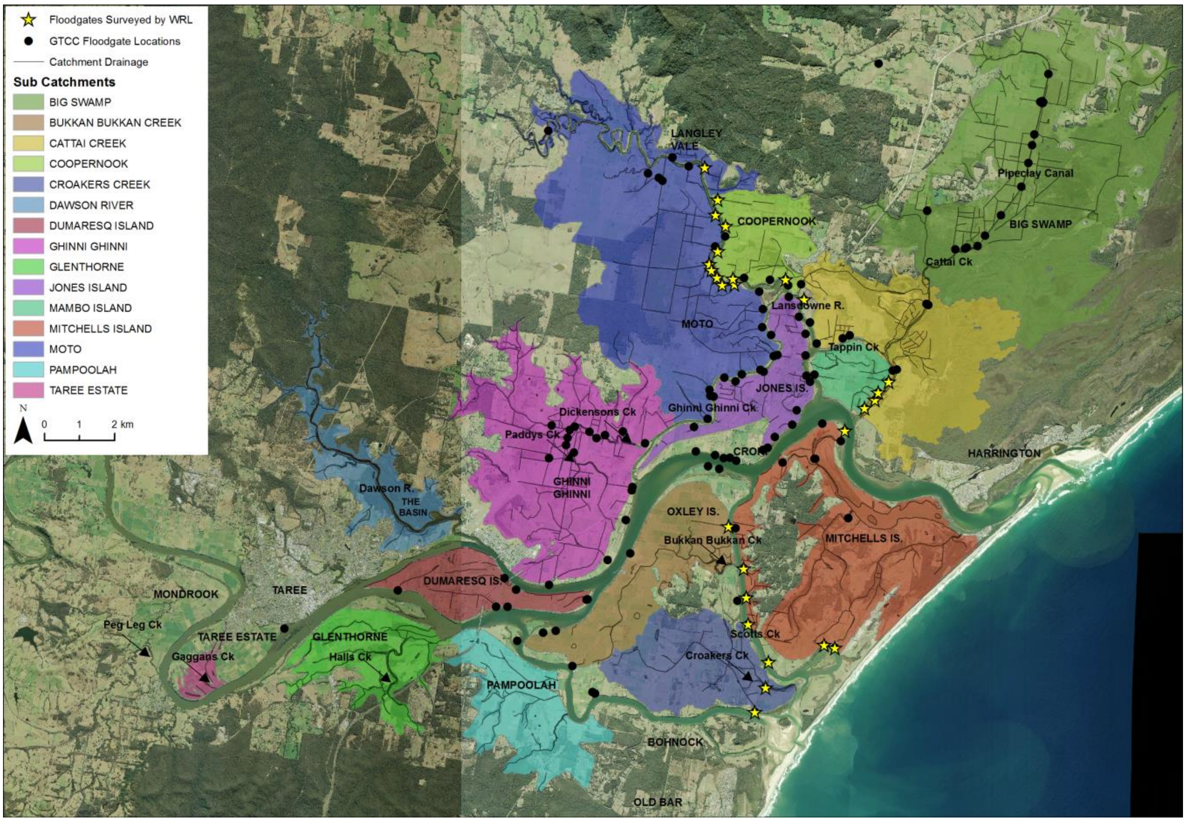

Figure F-8: Floodgates located within the study area

Table F-1: Summary of floodgate data provided by MidCoast Council

ID	Easting (m)	Northing (m)	Type	Details	Condition
MANN140F	463006.0	6478255.3	Floodgate	Steel concrete	
MANN141F	456522.5	6473451.2	Floodgate	Concrete	
MANN120F	470073.2	6484245.7	Floodgate	Concrete and timber	Fair
MANN121F	469889.8	6483474.9	Floodgate	Concrete and timber	Fair
MANN122F	469836.3	6483459.5	Floodgate	Concrete and timber	Fair
MANN123F	469917.4	6483444.5	Floodgate	Concrete and timber	Fair
MANN124F	469886.7	6483438.8	Floodgate	Concrete and timber	Fair
MANN125F	469880.1	6483430.2	Floodgate	Concrete and timber	Fair
MANN126F	469910.3	6483426.2	Floodgate	Concrete and timber	Poor
MANN127F	469669.9	6482521.6	Floodgate	Concrete and timber	Fair
MANN128F	469601.7	6482214.8	Floodgate	Concrete and timber	Poor
MANN059F	459342.4	6481869.9	Floodgate	Concrete and fibro	Poor
MANN129F	469493.4	6481715.3	Floodgate	Concrete and timber	Poor
MANN058F	459799.6	6481620.5	Floodgate	Timber and fibro	Poor
MANN057F	460262.7	6481585.4	Floodgate	Concrete and fibro	Poor
MANN060F	458634.6	6481411.2	Floodgate	Concrete and fibro	Good
MANN096F	458942.8	6481292.8	Floodgate	Concrete and fibro	Fair
MANN095F	459053.5	6481208.2	Floodgate	Concrete and fibro	Fair
MANN130F	469293.0	6481029.4	Floodgate	Concrete and timber	Fair
MANN004F	460628.1	6480667.8	Floodgate	Concrete and timber	Poor
MANN003F	460632.6	6480661.5	Floodgate	Timber	Poor
MANN119F	466605.1	6480346.0	Floodgate	Concrete and steel	Fair
MANN056F	460570.3	6480234.3	Floodgate	Concrete and fibro	Fair
MANN131F	468709.4	6480215.7	Floodgate	-	-
MANN001F	460848.7	6479910.6	Floodgate	Concrete and timber	Poor
MANN002F	460845.4	6479612.9	Floodgate	Concrete and fibro	Poor
MANN132F	468254.0	6479634.4	Floodgate	-	-
MANN033F	460551.3	6479330.7	Floodgate	Steel and fibro	Fair
MANN133F	468046.9	6479344.3	Floodgate	-	-
MANN134F	467742.9	6479301.9	Floodgate	Concrete and timber	Poor
MANN135F	467692.3	6479270.4	Floodgate	Concrete and timber	Poor
MANN136F	467417.4	6479240.9	Floodgate	Concrete and timber	Fair
MANN009F	460631.1	6479196.7	Floodgate	Concrete and timber	Poor
MANN032F	460382.2	6478822.2	Floodgate	Concrete and steel	Fair
MANN031F	460447.9	6478652.9	Floodgate	Concrete and timber	Poor
MANN030F	460609.8	6478442.5	Floodgate	Concrete and steel	Fair
MANN007F	461378.6	6478431.0	Floodgate	Concrete and timber	Poor
MANN008F	461074.1	6478403.3	Floodgate	Concrete and timber	Poor
MANN005F	462568.9	6478392.0	Floodgate	Concrete and fibro	Poor
MANN006F	462119.5	6478376.7	Floodgate	Concrete and timber	Poor
MANN028F	461109.5	6478250.6	Floodgate	Concrete and steel	Fair
MANN029F	460760.4	6478231.0	Floodgate	Concrete and steel	Fair
MANN010F	462638.4	6478216.8	Floodgate	Concrete and fibro	Poor

ID	Easting (m)	Northing (m)	Type	Details	Condition
MANN027F	461817.1	6478040.6	Floodgate	Concrete and steel	Poor
MANN098F	462660.2	6477890.3	Floodgate	Concrete and steel	Fair
MANN025F	463091.9	6477820.0	Floodgate	Steel	Good
MANN051F	466589.6	6477693.1	Floodgate	Timber	Fair
MANN050F	466637.1	6477653.2	Floodgate	Steel	Fair
MANN026F	461921.2	6477545.3	Floodgate	Concrete and steel	Good
MANN055F	462951.9	6477322.2	Floodgate	Concrete and steel	Fair
MANN054F	463260.3	6477155.4	Floodgate	Concrete and steel	Fair
MANN024F	461897.8	6477028.1	Floodgate	Concrete and timber	Poor
MANN037F	463133.8	6476832.5	Floodgate	Concrete and steel	Fair
MANN097F	462151.3	6476799.9	Floodgate	Concrete and fibro	Fair
MANN100F	464399.0	6476788.8	Floodgate	Concrete and fiberglass	Fair
MANN099F	464193.8	6476705.6	Floodgate	Concrete and fiberglass	Fair
MANN053F	463452.4	6476554.6	Floodgate	Concrete and fibro	Fair
MANN103F	462333.4	6476226.9	Floodgate	Concrete and timber	Fair
MANN036F	463134.1	6476222.9	Floodgate	Steel and fibro	Fair
MANN023F	462227.5	6476198.3	Floodgate	Concrete and steel	Fair
MANN022F	461845.6	6475801.5	Floodgate	Concrete and timber	Fair
MANN048F	465742.9	6475811.9	Floodgate	Concrete and fibro	Poor
MANN049F	465628.9	6475780.8	Floodgate	Concrete and fibro	Fair
MANN061F	461940.1	6475755.0	Floodgate	Concrete and fibro	Good
MANN021F	461320.8	6475683.4	Floodgate	Concrete and steel	Fair
MANN101F	463386.8	6475668.8	Floodgate	Concrete and fibro	Fair
MANN035F	463154.9	6475640.5	Floodgate	Concrete and fibro	Fair
MANN020F	460815.5	6475579.8	Floodgate	Concrete and fibro	Fair
MANN107F	461141.0	6475474.6	Floodgate	Concrete	Poor
MANN034F	463263.8	6475470.2	Floodgate	Concrete and steel	Fair
MANN047F	465507.3	6475467.8	Floodgate	Concrete and fibro	Fair
MANN019F	460398.4	6475235.4	Floodgate	Steel and fibro	Fair
MANN046F	465210.3	6475160.4	Floodgate	Concrete and steel	Poor
MANN018F	460412.5	6475062.0	Floodgate	Timber	Poor
MANN108F	460510.9	6475044.4	Floodgate	Concrete and timber	Fair
MANN045F	465116.7	6474944.5	Floodgate	Concrete and fibro	Poor
MANN052F	464815.3	6474712.3	Floodgate	Brick	Poor
MANN102F	462886.1	6474650.1	Floodgate	Concrete and fibro	Good
MANN094F	460346.1	6474404.9	Floodgate	Concrete and fibro	Fair
MANN080F	463615.8	6474273.6	Floodgate	Concrete	Poor
MANN012F	462759.7	6474244.4	Floodgate	Concrete and fibro	Poor
MANN089F	455885.8	6474214.5	Floodgate	Timber	Good
MANN017F	456541.6	6474185.8	Floodgate	Timber and fibro	Poor
MANN106F	459954.1	6474181.3	Floodgate	Concrete and timber	Fair
MANN090F	456401.7	6474087.2	Floodgate	Concrete and timber	Good
MANN014F	457921.0	6474053.9	Floodgate	Concrete and fibro	Fair
MANN081F	464254.6	6474073.8	Floodgate	Concrete and steel	Poor

ID	Easting (m)	Northing (m)	Type	Details	Condition
MANN016F	456967.7	6474036.1	Floodgate	Concrete and fibreglass	Fair
MANN015F	457414.6	6473941.0	Floodgate	Concrete and fibro	Fair
MANN013F	462257.1	6473895.6	Floodgate	Concrete	Poor
MANN093F	456345.1	6473871.8	Floodgate	Concrete	Poor
MANN063F	457169.5	6473858.8	Floodgate	Concrete and fibro	Fair
MANN079F	464145.2	6473771.9	Floodgate	Concrete and steel	Poor
MANN062F	458554.8	6473711.4	Floodgate	Concrete and fibro	Fair
MANN092F	456299.7	6473662.5	Floodgate	Concrete	Poor
MANN104F	462058.0	6473588.2	Floodgate	Concrete and timber	Good
MANN105F	461917.0	6473516.2	Floodgate	Concrete and timber	Fair
MANN067F	460001.6	6473481.7	Floodgate	Concrete and timber	Fair
MANN068F	460558.6	6473372.2	Floodgate	Concrete and fibro	Fair
MANN091F	455811.4	6473284.4	Floodgate	Concrete and timber	Fair
MANN070F	460976.4	6473300.1	Floodgate	Concrete and fibro	Fair
MANN069F	460796.4	6473288.1	Floodgate	Concrete	Good
MANN078F	463393.8	6473263.9	Floodgate	Concrete	Poor
MANN077F	463414.7	6473263.7	Floodgate	Concrete	Poor
MANN071F	461155.4	6473211.3	Floodgate	Concrete and fibro	Fair
MANN076F	462476.6	6473157.7	Floodgate	Concrete and steel	Fair
MANN039F	460350.0	6473059.1	Floodgate	Concrete and fibreglass	Fair
MANN038F	460675.0	6472981.6	Floodgate	Concrete and fibro	Fair
MANN115F	458196.3	6472460.7	Floodgate	Concrete and timber	Poor
MANN116F	458172.1	6472368.2	Floodgate	Concrete	Poor
MANN082F	464354.6	6471570.2	Floodgate	Concrete and timber	Fair
MANN064F	458003.0	6471522.1	Floodgate	Concrete and fibro	Fair
MANN040F	460941.9	6471334.1	Floodgate	Concrete and fibreglass	Fair
MANN075F	461141.3	6471284.6	Floodgate	Concrete and timber	Fair
MANN065F	458130.9	6470570.4	Floodgate	Concrete and fibro	Fair
MANN117F	457484.4	6470379.4	Floodgate	Concrete and timber	Poor
MANN084F	461366.6	6470140.8	Floodgate	Concrete and timber	Fair
MANN066F	454548.7	6469860.8	Floodgate	Concrete and fibro	Fair
MANN118F	455810.2	6469668.5	Floodgate	Concrete and steel	Fair
MANN111F	454869.0	6469533.0	Floodgate	Concrete	Poor
MANN114F	451495.1	6469504.3	Floodgate	Concrete and steel	Fair
MANN073F	461440.2	6469305.7	Floodgate	Concrete and steel	Fair
MANN109F	456915.8	6469253.9	Floodgate	Concrete and timber	Poor
MANN110F	456879.0	6469243.9	Floodgate	Concrete and timber	Fair
MANN085F	461185.8	6469212.7	Floodgate	Concrete and steel	Fair
MANN112F	454630.3	6469046.7	Floodgate	Concrete and fiberglass	Fair
MANN113F	454299.8	6469041.0	Floodgate	Concrete and fiberglass	Good
MANN138F	461494.1	6468547.7	Floodgate	Concrete	Poor
MANN139F	448258.8	6468422.9	Floodgate	Concrete and timber	Poor
MANN088F	456007.5	6468353.3	Floodgate	Concrete and timber	Poor
MANN087F	455649.0	6468298.2	Floodgate	Concrete	Poor

ID	Easting (m)	Northing (m)	Type	Details	Condition
MANN137F	454906.7	6468066.4	Floodgate	Concrete	Poor
MANN083F	463661.4	6467954.0	Floodgate	Concrete and timber	Fair
MANN074F	463971.3	6467879.3	Floodgate	Concrete	Poor
MANN072F	462076.1	6467466.1	Floodgate	Concrete and fibro	Fair
MANN086F	456482.8	6467349.7	Floodgate	Concrete and timber	Fair
MANN043F	461988.5	6466738.4	Floodgate	Concrete and fibro	Good
MANN042F	457048.0	6466614.0	Floodgate	Concrete and steel	Fair
MANN041F	457125.4	6466567.0	Floodgate	Concrete and fibro	Fair
MANN044F	461687.0	6466038.4	Floodgate	Concrete and timber	Poor

Table F-2: Summary of floodgates assessed by Glamore et al. (2016)

ID	Easting (m)	Northing (m)	Invert (m AHD)	Headwall Elevation (m AHD)	Condition
MANN044	461689.1	6466042.1	0.062	2.048	Good
MANN043	461990.3	6466739.1	-0.423	1.888	Good
MANN074	463968.8	6467873.6	0.199	1.622	None
MANN083	463661.4	6467954.0	-	-	None
MANN072	462076.1	6467466.1	-	-	Unknown
MANN138	461494.1	6468547.7	-	-	Unknown
MANN073	461440.2	6469305.7	-	-	Unknown
MANN084	461372.3	6470137.1	-0.196	1.312	Good
MANN040	460938.1	6471341.8	0.561	1.606	Good
MANN081	464254.6	6474073.8	-	-	None
MANN052	464819.6	6474718.4	0.037	1.537	Good
MANN045	465116.7	6474944.5	-	-	Good
MANN046	465210.3	6475160.4	-	-	Good
MANN047	465507.5	6475466.5	0.51	1.71	Good
MANN057	460262.7	6481585.4	-	-	None
MANN004	460628.1	6480667.8	-	-	Good
MANN056	460570.3	6480234.3	-	-	Good
MANN001	460852.2	6479914.4	0.186	1.486	Fair
MANN009	460631.1	6479196.7	-	-	Good
MANN032	460380.6	6478823.6	-0.86	1.323	Good
MANN031	460447.3	6478647.6	-0.528	1.485	Good
MANN030	460609.8	6478442.5	-	-	Good
MANN029	460760.4	6478231.0	-	-	Good
MANN028	461109.5	6478250.6	-	-	Good
MANN008	461066.7	6478406.5	-0.1	1.659	Good
MANN005	462568.9	6478392.0	-0.557	1.348	Poor
MANN025	463091.9	6477820.0	-0.75	0.154	Good

F5 Additional data

For this updated study, a more comprehensive assessment of the vulnerability of floodplain infrastructure has been completed. This required additional data of dimensions and inverts of floodplain infrastructure across the Manning River floodplain. Table F-3 provides a summary of the additional data collected on floodplain infrastructure during the 2019 and 2020 field campaigns. In 2021, additional floodgate surveys were collected by Abbott & Macro to fill remaining data gaps. This data, along with other data from literature, or provided by MidCoast Council, is summarised in Table F-4. Structures that still lack good quality survey data are presented in Table F-5.

Table F-3: Summary of structures where data was collected during this current project

Structure ID*	Date/time surveyed	Type	Number of Culverts	Diameter (m)	Width (m)	Height (m)	Easting (m) GDA94	Northing (m) GDA94	Upstream Invert (m AHD)	Downstream Invert (m AHD)	Condition	Category	Tenure	Comment
MANN_002	5/03/2020 11:07	Floodgate	1		1	2	460845	6479613		0.58	Poor	Secondary	Private	Floodgates cannot open due to sediment build up in front of the gates. Height taken from Tony Townsend survey.
MANN_006	5/03/2020 12:17	Floodgate	2		1.05	1.6	462123	6478367		-0.43	Fair	Secondary	Private	
MANN_007	5/03/2020 11:50	Floodgate	2		1.4	1.6	461381	6478430		-0.53	Good	Primary	Private	
MANN_009	5/03/2020 11:23	Floodgate	1		1.4	1.45	460637	6479193		-0.26	Fair	Secondary	Private	
MANN_018	12/09/2019	Floodgate	1				460412	6475067		0.30	Fair	Secondary	Private	Invert measured from water level (approximately 0.15 m below water level).
MANN_020_ Centre	12/09/2019	Floodgate	1	0.9			460819	6475593	0.28		Good	Secondary	Private	One of three floodgates. Large gate located in the centre of the three.
MANN_020_ Outside	12/09/2019	Floodgate	2	0.6			460819	6475593	0.47		Good	Secondary	Private	Two of three floodgates. Two smaller floodgates on the outside.
MANN_021_ Centre	12/09/2019	Floodgate	1	0.9			461314	6475692	0.14		Good	Primary	Private	One of three floodgates. Large gate located in the centre of the three. Mangroves growing in front of floodgate. Does not easily open.
MANN_021_ Outside	12/09/2019	Floodgate	2	0.6			461314	6475692	0.30		Good	Primary	Private	Two of three floodgates. Two smaller floodgates on the outside. Upstream is dry with no flow.
MANN_022_ centre	12/09/2019	Floodgate	1	1			461839	6475807	-0.08		Good	Secondary	Private	One of three floodgates. Large gate located in the centre of the three. Gate leaking.
MANN_022_ Outside	12/09/2019	Floodgate	2	0.6			461839	6475806	0.35		Good	Secondary	Private	Two of three floodgates. Two smaller floodgates on the outside.
MANN_023_ Centre	12/09/2019	Floodgate	1	1.5			462222	6476204	-0.17		Good	Primary	Private	One of three floodgates. Large gate located in the centre of the three. Gate leaking.
MANN_023_ Outside	12/09/2019	Floodgate	2	0.6			462222	6476204	0.42		Good	Primary	Private	Two of three floodgates. Two smaller floodgates on the outside.
MANN_024_ Centre	12/09/2019	Floodgate	1	1.8			461941	6477049	-0.47		Good	Secondary	Private	One of three floodgates. Large gate located in the centre of the three.
MANN_024_ Outside	12/09/2019	Floodgate	2	0.6			461942	6477048	0.10		Good	Secondary	Private	Two of three floodgates. Two smaller floodgates on the outside.
MANN_026	12/09/2019	Floodgate	2	1.5			461915	6477541	-0.60		Good	Primary	Private	Right hand gate partially winched open.
MANN_027	5/03/2020 12:00	Floodgate	4	0.6			461812	6478040		0.08	Good	Primary	Private	
MANN_028	5/03/2020 11:40	Floodgate	2		1.55	1.6	461109	6478250		-0.43	Fair	Primary	Private	
MANN_029	12/09/2019	Floodgate	2		1.76	1.5	460759	6478222	0.07		Good	Secondary	Private	
MANN_030_ Left	12/09/2019	Floodgate	2	0.6			460603	6478440	0.34		Good	Secondary	Private	Two left gates, in good condition. Higher invert level.
MANN_030_ Right	12/09/2019	Floodgate	1	0.9			460604	6478439	-0.36		Good	Secondary	Private	One gate on right side, slightly wedged open. Lower invert level.
MANN_035	5/03/2020 14:47	Floodgate	1		1.8	1.05	463151	6475640		0.04	Fair	Primary	Private	
MANN_036	5/03/2020 14:35	Floodgate	1		1.4	1.1	463136	6476231		-0.36	Fair	Secondary	Private	
MANN_045	5/03/2020 15:14	Floodgate	1		1	1.3	465135	6474917		-0.21	Poor	Secondary	Private	Very poor condition. Flap open permanently.
MANN_048	5/03/2020 16:05	Floodgate	1		0.9	0.9	465743	6475812		0.01	Poor	Secondary	Private	
MANN_049	5/03/2020 15:56	Floodgate	1		3.3	1.65	465629	6475781		-0.49	Good	Primary	Private	

Structure ID*	Date/time surveyed	Type	Number of Culverts	Diameter (m)	Width (m)	Height (m)	Easting (m) GDA94	Northing (m) GDA94	Upstream Invert (m AHD)	Downstream Invert (m AHD)	Condition	Category	Tenure	Comment
MANN_053	5/03/2020 14:26	Floodgate	1		2.6	1.1	463457	6476556		-0.47	Fair	Secondary	Private	
MANN_056	5/03/2020 10:52	Floodgate	2		1.45	1.45	460584	6480241		-0.34	Poor	Secondary	Private	Concrete cancer. Gates do not completely block culvert.
MANN_059	5/03/2020 10:13	Floodgate	1		2.4	1.5	459342	6481870		-0.12	Good	Secondary	Private	
MANN_060	12/09/2019	Floodgate	2	1.2			458631	6481406	-0.04		Poor	Secondary	Private	Old floodgates - in poor condition. Owner says they intentionally let the gates leak.
MANN_062	6/03/2020 9:40	Floodgate	1		1.8	1.2	458555	6473710		-0.34	Fair	Secondary	Private	
MANN_065	6/03/2020 10:25	Floodgate	1		1.2	1.55	458131	6470568		0.03	Good	Secondary	Private	
MANN_066	6/03/2020 16:09	Floodgate	2		1	1	454564	6469861		-0.60	Poor	Secondary	Private	Floodgates blocked by log preventing them from opening properly.
MANN_068	6/03/2020 15:32	Floodgate	1		1.3	1.25	460568	6473361		0.01	Fair	Secondary	Private	
MANN_069	6/03/2020 15:14	Floodgate	1		2.5	1.4	460781	6473296		0.05	Good	Secondary	Private	
MANN_070	6/03/2020 14:54	Floodgate	1	1			460980	6473299		-0.12	Good	Secondary	Private	Good condition. Photo not taken.
MANN_071	6/03/2020 14:45	Floodgate	1	0.9			461168	6473167		-0.25	Fair	Secondary	Private	Square flap on circular culvert.
MANN_073	6/03/2020 14:11	Floodgate	1	0.375			461446	6469301	0.31		Good	Secondary	Private	Good condition.
MANN_082	6/03/2020	Floodgate	4	1.2			464345	6471567	-0.13		Poor	Primary	MidCoast Council	Very old flaps.
MANN_085	6/03/2020 14:00	Floodgate	1	0.9			461181	6469213	0.06		Good	Secondary	Private	
MANN_088	6/03/2020 0:00	Culvert	1	0.75			456007	6468353			Other	Secondary	Private	Structure with floodgate removed. Foliage too dense to obtain GPS position. No water level available for alternate GPS position. No longer end of system structure.
MANN_095	12/09/2019	Floodgate	2	0.9			459054	6481203	0.35		Poor	Secondary	Private	Left gate almost fallen off. Both gates are in a poor condition.
MANN_096	12/09/2019	Floodgate	3	0.8			458935	6481290	0.57		Poor	Primary	Private	Old floodgates - in poor condition. Farmer says he purposely lets leak.
MANN_097	5/03/2020 13:01	Floodgate	1	0.7			462151	6476800		-0.18	Fair	Secondary	Private	
MANN_10	5/03/2020 12:35	Floodgate	1		1.2	2.1	462637	6478215		-0.23	Fair	Secondary	Private	
MANN_108	6/03/2020 9:10	Floodgate	1	1.2			460511	6475044		0.14	Good	Secondary	Private	
MANN_112	6/03/2020 0:00	N/A					454630	6469047			Other		Private	No floodgate observed. Found some pipe and rubble. Floodgate appears to have been covered with rock bank protection or removed.
MANN_114	6/03/2020 11:58	Floodgate	1	1.2			451495	6469504		0.33	Good	Secondary	Private	Gate covered in dense vegetation (lantana).
MANN_19	12/09/2019	Floodgate	1	1.85			460393	6475242	-0.28		Good	Secondary	Private	
MANN_25	5/03/2020 13:59	Floodgate	1	0.55			463092	6477820		-0.43	Fair	Secondary	Private	
MANN_54	5/03/2020 14:17	Floodgate	2	0.9			463266	6477154		-0.21	Good	Secondary	Private	
MANN_55	5/03/2020 14:08	Culvert	1		1.8	1.2	462947	6477318		-0.29	Other	Primary	Private	Culvert completely blocked on upstream side. Culvert in very bad condition/partly demolished. Flap on downstream side has been removed.

Structure ID*	Date/time surveyed	Type	Number of Culverts	Diameter (m)	Width (m)	Height (m)	Easting (m) GDA94	Northing (m) GDA94	Upstream Invert (m AHD)	Downstream Invert (m AHD)	Condition	Category	Tenure	Comment
MANN_72	6/03/2020 13:44	Floodgate	1	0.3			462076	6467466		-0.36	Good	Secondary	Private	Gate has been jammed shut with piece of wood wedged against it.
MANN_98	5/03/2020 13:41	Floodgate	1	1.2			462660	6477890		-0.05	Fair	Secondary	Private	Disused structure that has been filled in immediately upstream on the Lansdowne River.
WRL_MAN_01	6/03/2020	Floodgate	3	0.6			467406	6470929	0.13		Good	Secondary	Private	
WRL_MAN_02	5/03/2020 15:36	Floodgate	1		2.5	2	465591	6475609		-0.04	Good	Secondary	Private	
WRL_MAN_03	6/03/2020 10:13	Floodgate	1		1.8	1.2	457955	6471141		-0.32	Fair	Primary	Private	
WRL_MAN_04	6/03/2020 12:38	Culvert	1		0.95	0.6	455576	6467532		0.52	Poor	Secondary	Private	No evidence of floodgates ever existing.
WRL_MAN_05	12/09/2019	Culvert	2		2.4	1.62	460497	6478649		-1.05	Good	Secondary	Private	

* Structure ID's have been provided by MidCoast Council. If a structure was identified that did not have a MidCoast Council ID it has been given a WRL ID (WRL_MAN_##).

Table F-4: Summary of data in Abbott & Macro (2021), other literature and provided by MidCoast Council

Structure ID	Type	# Culverts	Diameter (m)	Width (m)	Height (m)	Easting (m)	Northing (m)	Invert (m AHD)	Category	Tenure	Condition	Comment	Dimension data source	Invert data source
MANN 031	Floodgate	1				460447	6478648	-0.528	Primary	Private			Glamore et al. (2014)	Glamore et al. (2014)
UNK01	Culvert	1	0.9			469613	6482109	-0.13	Secondary	Private			Glamore et al. (2014)	Glamore et al. (2014)
UNK02	Culvert	1	0.7			469396	6481211	0.02	Secondary	Private			Glamore et al. (2014)	Glamore et al. (2014)
MANN 120	Floodgate	1		1.5	0.9	470073	6484246	0.18	Secondary	Private			Glamore et al. (2014)	Glamore et al. (2014)
MANN 130	Floodgate	1	0.9			469291	6481033	-0.26	Primary	Private			Glamore et al. (2014)	Glamore et al. (2014)
MANN 129	Floodgate	1	0.9			469493	6481715	-0.19	Secondary	Private			Glamore et al. (2014)	Glamore et al. (2014)
MANN 128	Floodgate	1	1.2			469602	6482215	-0.79	Secondary	Private			Glamore et al. (2014)	Glamore et al. (2014)
MANN 127	Floodgate	1		0.5	0.9	469670	6482522	-0.05	Secondary	Private			Glamore et al. (2014)	Glamore et al. (2014)
MANN 121	Floodgate	1		1	0.9	469890	6483475	0.034	Primary	Private			Glamore et al. (2014)	Glamore et al. (2014)
MANN 123	Floodgate	1		1.5	1.85	469917	6483445	-0.738	Primary	Private			Glamore et al. (2014)	Glamore et al. (2014)
MANN 126	Culvert	1		0.6	0.9	469914	6483426	0.07	Primary	Private			Glamore et al. (2014)	Glamore et al. (2014)
MANN 125	Culvert	1		0.5	0.9	469878	6483431	0.08	Primary	Private			Glamore et al. (2014)	Glamore et al. (2014)
MANN 124	Culvert	1		1	0.6	469881	6483443	0.08	Primary	Private			Glamore et al. (2014)	Glamore et al. (2014)
UNK05	Culvert	1	0.9			469458	6481447	0.02	Secondary	Private			Glamore et al. (2014)	Glamore et al. (2014)
UNK06	Culvert	1	0.9			469516	6481712	-0.1	Secondary	Private			Glamore et al. (2014)	Glamore et al. (2014)
UNK07	Culvert	1	0.9			469572	6481917	-0.01	Secondary	Private			Glamore et al. (2014)	Glamore et al. (2014)
UNK08	Culvert	1	0.9			469701	6482521	-0.08	Secondary	Private			Glamore et al. (2014)	Glamore et al. (2014)
UNK09	Culvert	1	1.5			469818	6483024	0.07	Secondary	Private			Glamore et al. (2014)	Glamore et al. (2014)
UNK12	Culvert	1	0.9			469917	6483438	0.29	Secondary	Private			Glamore et al. (2014)	Glamore et al. (2014)
UNK13	Floodgate	1	1.5			469932	6483498	-0.39	Secondary	Private			Glamore et al. (2014)	Glamore et al. (2014)
UNK14	Floodgate	1			1.5	469291	6481033	-0.47	Primary	Private			Glamore et al. (2014)	Glamore et al. (2014)
UNK15	Culvert	1	0.9			469322	6481021	-0.26	Secondary	Private			Glamore et al. (2014)	Glamore et al. (2014)
UNK16	Culvert	1	1.5			469324	6481025	-0.47	Secondary	Private			Glamore et al. (2014)	Glamore et al. (2014)
MANN 137	Culvert	1	0.35			454960	6468176	-0.034	Secondary	Private			Ruprecht et al. (2020b)	Ruprecht et al. (2020b)
UNK03	Floodgate	2	1.2			454872	6467717	0.135	Secondary	Private			Ruprecht et al. (2020b)	Ruprecht et al. (2020b)
MANN 003	Floodgate	1		1.8	1.3	460633	6480664	-0.284	Primary	Private	Poor	Very old wooden floodgates not working properly	Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 004	Culvert	1	0.6			460627	6480671	1.083	Primary	Private	Fair	No floodgate just pipe	Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 012	Floodgate	1		1.1	1.1	462760	6474243	0.043	Secondary	Private	Good		Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 013		1				462325	6473882	2.228	Secondary	Private		No floodgate or pipe, ground level given	Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 014	Floodgate	1 of 2		1.8	1.2	457918	6474050	-0.677	Secondary	Private	Good	1 of 2 floodgates	Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 014	Culvert	1 of 2		1.8	1.2	457916	6474051	-0.72	Secondary	Private	Poor	Floodgate broken fallen off, 1 of 2 floodgates	Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 015	Floodgate	1		1.5	1.2	457413	6473944	-0.527	Secondary	Private	Good		Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 016	Floodgate	1		3	1.8	456962	6474047	0.133	Secondary	Private	Good		Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 017	Floodgate	1		3	1.8	456535	6474193	0.093	Primary	Private	Good		Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 033	Culvert	1	0.9			460546	6479331	-0.128	Secondary	Private	Fair	Pipe blocked with mud no floodgate	Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 034	Floodgate	1	0.9			463284	6475494	-0.26	Secondary	Private	Poor	Pipe blocked with mud no floodgate	Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 037	Floodgate	1	1.2			463139	6476835	-0.001	Secondary	Private	Good		Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 038	Floodgate	1 of 2		1.5	0.8	460678	6472987	-0.099	Secondary	Private	Good	1 of 2 floodgates	Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 038	Floodgate	1 of 2		1.5	0.8	460680	6472986	-0.071	Secondary	Private	Good	Custom headwall, 1 of 2 floodgates	Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 039	Floodgate	1		1	1.2	460347	6473062	-0.237	Secondary	Private	Good		Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 042	Floodgate	1 of 2	0.9			457051	6466614	0.534	Secondary	Private	Good	1 of 2 floodgates	Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 042	Floodgate	1 of 2	0.6			457127	6466560	0.576	Secondary	Private	Good	1 of 2 floodgates	Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 046	Floodgate	1		4	1.5	465207	6475168	0.045	Secondary	Private	Good	Large custom floodgate 4m wide	Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 050	Floodgate	1	0.75			466636	6477645	-0.277	Secondary	Private	Fair	Pipe on lean may be broken	Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 051	Floodgate	1	0.6			466580	6477704	-0.477	Secondary	Private	Fair	Wooden flap part broken	Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 058		1				459812	6481633	-0.381	Secondary	Private		No floodgate just open drain, invert of drain given	Abbott & Macro (2021)	Abbott & Macro (2021)

Structure ID	Type	# Culverts	Diameter (m)	Width (m)	Height (m)	Easting (m)	Northing (m)	Invert (m AHD)	Category	Tenure	Condition	Comment	Dimension data source	Invert data source
MANN 061	Floodgate	1 of 2	0.9			461941	6475757	-0.763	Secondary	Private	Good	Structure has 2 pipes, this one has a floodgate	Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 061	Culvert	1 of 2	0.9			461943	6475757	-0.763	Secondary	Private	Good	Structure has 2 pipes, this one does not have a floodgate	Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 063	Floodgate	1	1.2			457167	6473861	-0.109	Secondary	Private	Good		Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 064	Floodgate	1	0.45			458002	6471528	0.015	Secondary	Private	Good	Clear trees on banks	Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 067	Floodgate	1		1	1.2	459998	6473485	0.263	Secondary	Private	Good		Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 075	Floodgate	1	0.45			461145	6471291	0.479	Secondary	Private	Good	Small rubber wooden custom floodgate	Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 076	Floodgate	1 of 2	1.2			462471	6473164	0.499	Secondary	Private	Good	1 of 2 floodgates	Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 076	Floodgate	1 of 2	1.2			462471	6473164	0.501	Secondary	Private	Good	1 of 2 floodgates	Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 079	Floodgate	1	0.6			464149	6473771	-0.049	Primary	Private	Poor	Floodgate fallen off laying nearby	Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 080	Floodgate	1	0.45			463617	6474282	0.035	Secondary	Private	Poor	Pipe blocked with mud no floodgate	Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 081	Floodgate	1	0.6			464259	6474078	0.38	Secondary	Private	Poor	Floodgate fallen off bad erosion around pipe	Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 083	Floodgate	1	0.9			463667	6467954	0.069	Secondary	Private	Good	Thick trees upstream	Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 086	Floodgate	1 of 2	0.9			456480	6467356	-0.452	Secondary	Private	Good	One floodgate with chain for pulling open, 1 of 2 floodgates	Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 086	Floodgate	1 of 2	0.9			456480	6467357	-0.431	Secondary	Private	Good	1 of 2 floodgates	Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 087	Floodgate	1	1.5			455649	6468300	0.441	Secondary	Private	Good		Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 088	Culvert	1	0.75			456009	6468355	0.368	Secondary	Private	Good	Sheets of tin used to close pipe in high water	Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 089	Floodgate	1		2.2	1	455886	6474217	0.162	Primary	Private	Good		Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 090	Floodgate	1 of 2		1.5	1.5	456407	6474096	-0.494	Primary	Private	Good	Removable flaps upstream to reduce flow in dry periods, 1 of 2 floodgates	Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 090	Floodgate	1 of 2		1.5	1.5	456409	6474096	-0.494	Primary	Private	Good	Removable flaps upstream to reduce flow in dry periods, 1 of 2 floodgates	Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 091	Culvert	1	2.1			455808	6473288	-0.604	Secondary	Private	Fair	Pipe completely blocked with plywood	Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 092	Floodgate	1 of 2	0.6			456296	6473659	-0.374	Secondary	Private	Fair	1 of 2 floodgates	Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 092	Floodgate	1 o f2	0.6			456296	6473658	-0.374	Secondary	Private	Fair	1 of 2 floodgates	Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 093	Culvert	1 of 2	0.6			456349	6473873	-0.043	Secondary	Private	Fair	1 of 2 floodgates	Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 093	Culvert	1 of 2	0.6			456349	6473872	-0.037	Secondary	Private	Fair	1 of 2 floodgates	Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 094	Floodgate	1	1.8			460331	6474384	0.03	Secondary	Private	Good		Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 102	Floodgate	1 of 4	0.9			462888	6474658	-0.458	Secondary	Private	Good	1 of 4 floodgates	Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 102	Floodgate	1 of 4	0.9			462888	6474657	-0.458	Secondary	Private	Good	1 of 4 floodgates	Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 102	Floodgate	1 of 4	0.9			462887	6474655	-0.458	Secondary	Private	Good	1 of 4 floodgates	Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 102	Floodgate	1 of 4	0.9			462887	6474654	-0.458	Secondary	Private	Good	1 of 4 floodgates	Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 103	Floodgate	1		1	1	462338	6476229	-0.266	Secondary	Private	Good		Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 104		1		2.1	1.8	462058	6473584	-0.415	Secondary	Private	Good	Auto tidal gate working	Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 105	Floodgate	1	1.2			461917	6473516	-0.202	Secondary	Private	Good		Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 111	Floodgate	1		0.6	0.6	454868	6469534	0.726	Secondary	Private	Poor	No floodgate small headwall tide goes around	Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 113	Floodgate	1 of 3	0.9			454307	6469045	-0.037	Secondary	Private	Good	1 of 3 floodgates	Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 113	Floodgate	1 of 3	0.9			454305	6469044	-0.058	Secondary	Private	Good	1 of 3 floodgates	Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 113	Floodgate	1 of 3	0.9			454303	6469043	0.173	Secondary	Private	Good	One pipe a little higher than others, 1 of 3 floodgates	Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 118	Floodgate	1 of 2		1.2	2.1	455805	6469668	-0.186	Secondary	Private	Good	Auto tidal gate working, 1 of 2 floodgates	Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 118	Floodgate	1 of 2		1.2	2.1	455803	6469668	-0.187	Secondary	Private	Good	1 of 2 floodgates	Abbott & Macro (2021)	Abbott & Macro (2021)
MANN 052	Floodgate	1	0.4			464815	6474712	0.037	Secondary	Private			MidCoast Council (2014)	Glamore et al. (2014)

Structure ID	Type	# Culverts	Diameter (m)	Width (m)	Height (m)	Easting (m)	Northing (m)	Invert (m AHD)	Category	Tenure	Condition	Comment	Dimension data source	Invert data source
MANN 047	Floodgate	1		0.5		465507	6475468	0.51	Secondary	Private			MidCoast Council (2014)	Glamore et al. (2014)
MANN 119	Floodgate	2	0.5			466605	6480346		Secondary	Private			MidCoast Council (2014)	
MANN 101	Floodgate	2	0.5			463387	6475669		Secondary	Private			MidCoast Council (2014)	
MANN 099	Floodgate	1		0.3		464194	6476706		Secondary	Private			MidCoast Council (2014)	
MANN 100	Floodgate	1		0.3		464399	6476789		Secondary	Private			MidCoast Council (2014)	
MANN 005	Floodgate	3		1.5		462569	6478392	-0.557	Secondary	Private			MidCoast Council (2014)	Glamore et al. (2014)
MANN 008	Floodgate	1		0.5		461074	6478403	-0.1	Secondary	Private			MidCoast Council (2014)	Glamore et al. (2014)
MANN 107	Floodgate	1	1.8			461141	6475475		Primary	Private			MidCoast Council (2014)	
MANN 106	Floodgate	2		0.5		459954	6474181		Secondary	Private			MidCoast Council (2014)	
MANN 115	Floodgate	1	1			458196	6472461		Secondary	Private			MidCoast Council (2014)	
MANN 117	Floodgate	2		1		457484	6470379		Primary	Private			MidCoast Council (2014)	
MANN 139	Floodgate	1	1.5			448259	6468423		Secondary	Private			MidCoast Council (2014)	
MANN 110	Floodgate	1		0.5		456916	6469254		Secondary	Private			MidCoast Council (2014)	
MANN 044	Floodgate	1		0.5		461687	6466038	0.062	Primary	Oxley Island Drainage Union			MidCoast Council (2014)	Glamore et al. (2014)
MANN 043	Floodgate	5	1.5			461990	6466739	-0.432	Primary	Oxley Island Drainage Union			MidCoast Council (2014)	Glamore et al. (2014)
MANN 074	Culvert	1		1		463971	6467879	0.199	Primary	Private			MidCoast Council (2014)	Glamore et al. (2014)
MANN 084	Floodgate	1	0.5			461367	6470141	-0.196	Secondary	Private			MidCoast Council (2014)	Glamore et al. (2014)
MANN 001	Floodgate	2		1.3	0.9	460849	6479911	0.186	Secondary	Private			Glamore et al. (2014)	Glamore et al. (2014)
MANN 040	Floodgate	4		1.8	1.5	460942	6471334	0.561	Secondary	Private			Glamore et al. (2014)	Glamore et al. (2014)

Table F-5 Summary of unsurveyed structures

Structure ID	Easting	Northing	Sub-catchment	Comment
MANN 119	466605.128	6480345.96	Big Swamp	Inspected not surveyed
MANN 101	463386.7638	6475668.78	Mambo Island	Inspected not surveyed
MANN 099	464193.8349	6476705.561	Cattai Creek	Inspected not surveyed
MANN 100	464398.958	6476788.852	Cattai Creek	Inspected not surveyed
MANN 107	461140.9621	6475474.645	Jones Island	Inspected not surveyed
MANN 106	459954.0731	6474181.313	Jones Island	Inspected not surveyed
MANN 115	458196.342	6472460.663	Ghinni Ghinni	Inspected not surveyed
MANN 117	457484.3806	6470379.413	Ghinni Ghinni	Inspected not surveyed
MANN 139	448258.7891	6468422.913	Taree Estate	Inspected not surveyed
MANN 110	456915.8009	6469253.853	Dumaresq Island	Inspected not surveyed
MANN 112	454630.3367	6469046.686	Dumaresq Island	Inspected, structure destroyed

Appendix G Water Quality

G1 Preamble

Historically, the Manning River estuary and backswamp drainage areas have been extensively monitored. Water quality monitoring has typically focused on spot checks of dry weather pH and salinity, or a range of other water quality indicators as part of the NSW Food Authority Shellfish Quality Assurance Program following freshwater inflows from the catchment. Extensive monitoring of the Cattai Creek-Pipeclay Canal area was undertaken as part of the Big Swamp Hydrologic Study (Glamore et al., 2014). This study included dry weather drain pH and wet weather sampling events of acid flux (concentration x discharge) from the Big Swamp floodplain. Overall, low pH water (pH < 4.0) was measured across the site in drains before the rain event and in Cattai Creek-Pipeclay Canal post-flood. Following Big Swamp Hydrologic Study and subsequent on-ground remediation works, MidCoast Council commissioned a continuous monitoring program of the Cattai Creek-Pipeclay Canal drainage area, the first of its kind in the Manning River estuary targeting acid drainage, which has now been going for approximately six (6) years Ruprecht et al. (2020a).

Other key water quality studies of the Manning River estuary, include:

- Sonter (1999);
- Smith et al. (1999);
- Dove (2003); and
- Johnston (2007).

However, the majority of water quality information measured during these investigations cannot be used to assign typical pH values to individual drains or drainage areas, and as such, the data from these studies has not been reproduced in this report. Nonetheless, the information provided in these studies is useful in understanding the extent of the ASS drainage issue across the Manning River estuary.

This section provides an overview of prominent water quality objectives for the Manning River estuary, as well as a summary of the water quality monitoring program at Big Swamp since its inception in early 2014. It also provides a summary of statistics on salinity in the lower estuary based on data provided by the NSW Food Authority.

G2 Manning River Water Quality Objectives

Surface water quality objectives for the Manning River are based on recommendations from the ANZECC guidelines for marine and/or estuarine waters. Table G-1 outlines default trigger values for stressors applicable to south-east Australia for slightly disturbed ecosystems. Trigger values are used to assess the risk of adverse effects to sensitive receivers due to water quality parameters in various ecosystem types.

Table G-1: ANZECC guidelines for estuaries and wetlands in NSW ANZECC and ARMCANZ (2000)

Ecosystem type	DO (% saturation)		pH	
	Lower limit	Upper limit	Lower limit	Upper limit
Estuaries	80	110	7.0	8.5
Wetlands	No data	No data	No data	No data

G3 Big Swamp Water Quality Monitoring Program

WRL commenced a monitoring program at Big Swamp in April 2014 (Ruprecht et al., 2020a) following the recent Big Swamp hydrological study (Glamore et al., 2014) and subsequent on-ground remediation works to improve onsite ASS drainage issues. As part of the monitoring program, MidCoast Council initially purchased three (3) water quality monitoring units that measure pH, temperature, electrical conductivity (EC), dissolved oxygen (DO) and water levels. This equipment was installed in August 2014 and strategically placed in key areas of the remediation zones including the Eastern Swale Drain, Angelina Swamp and Angelina Mouth, as shown in Figure G-1. Additional water quality units were purchased in September 2014 and stationed at Cockatoo Island and Cattai Creek (Figure G-1) to improve and quantify understanding of the acid contribution from other areas of the site following the remediation works.

All monitoring stations record pH, electrical conductivity (EC), temperature, and pressure (i.e. water levels). Note that all water levels are reported relative to AHD. In addition, monitoring sites located at Angelina Mouth, Angelina Swamp, and the Eastern Swale Drain also record Dissolved Oxygen (DO), which is reported as a % saturation in the water column as per the ANZECC and ARMCANZ (2000).

A summary of three (3) years of the water quality data at the monitoring locations, including the median, and 10th percentile and 90th percentile values, is provided in Table G-2 (from Ruprecht et al. (2017)). Note that by definition, a percentile indicates the value below which a given percentage of observations in a time series of observations fall. For example, the 10th percentile is the value below which 10 percent of the observations may be found.

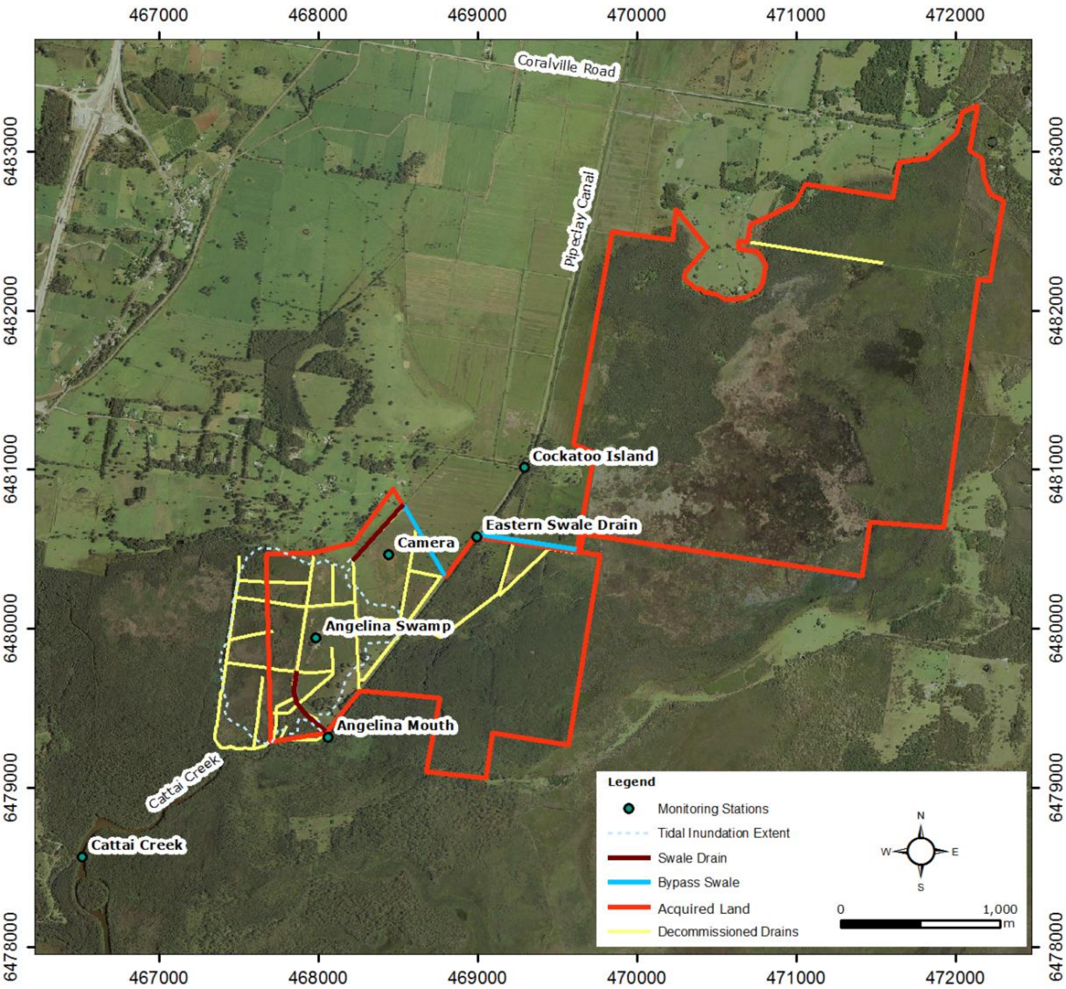

Figure G-1: Water quality monitoring sites at Big Swamp

Table G-2: Summary of statistics for three (3) years of the monitoring program (Ruprecht et al., 2017)

Location	Percentile	EC (µS/cm)	pH	Dissolved Oxygen (% saturation)
Cockatoo Island	10th Percentile	303	4.6	Not Recorded
	Median	3,510	6.0	Not Recorded
	90th Percentile	36,334	7.9	Not Recorded
Eastern Swale Drain	10th Percentile	521	3.7	1.7
	Median	6,521	5.8	52.7
	90th Percentile	38,470	7.1	78.4
Angelina Swamp	10th Percentile	21,850	3.9	-0.3
	Median	33,770	5.2	0.2
	90th Percentile	49,149	6.3	0.9
Angelina Mouth	10th Percentile	1,499	4.8	9.2
	Median	23,731	6.6	54.1
	90th Percentile	40,137	7.3	80.5
Cattai Creek	10th Percentile	2,212	6.0	Not Recorded
	Median	33,467	7.3	Not Recorded
	90th Percentile	45,498	9.2	Not Recorded

G4 Manning River Shellfish Quality Assurance Program

The Sydney rock oyster (Saccostrea glomerata) is produced in areas of the Manning River estuary that are at times impacted by acid discharges from ASS-affected floodplain drainage areas. Acidification of waterways severely degrades estuarine ecosystems – it can cause fish and oyster kills, fish disease, and impact oysters.

Oyster farmers on the Manning River hold a food safety licence which is regulated by the Food Standards Code in accordance with Australian Shellfish Quality Assurance Program (ASQAP). As part of ASQAP, the NSW Food Authority is responsible for implementing the Shellfish Quality Assurance Program on the Manning River. The program includes water quality sampling each year in search of poor water quality risks. A growing area can be closed for harvesting if there is any potential risk from known triggers such as high rainfall or algal blooms.

The water quality sampling sites on Manning River monitored by the NSW Food Authority are shown in Figure G-2. A summary of all records of water quality data at the monitoring locations, including the median, and 10th percentile and 90th percentile values, are provided in Table G-3. Note that the salinity of seawater is approximately 35.0 ppt (or 56,000 µS/cm). Also note that water pH is not regularly sampled at these locations by the NSW Food Authority.

Table G-3: Summary of statistics from the Manning River Shellfish Quality Assurance Program sampling sites

Station	Period	Statistic	Salinity (ppt)
Pelican Point	2003 - Present	10th Percentile	18.58
		Median	23.50
		90th Percentile	30.04
Mangrove Island	2003 - Present	10th Percentile	13.90
		Median	21.00
		90th Percentile	27.90
Mitchells Island	2003 - Present	10th Percentile	15.26
		Median	20.05
		90th Percentile	27.20
Scotts Creek	2003 - Present	10th Percentile	14.36
		Median	20.80
		90th Percentile	27.24
South Channel	2005 - Present	10th Percentile	14.76
		Median	22.40
		90th Percentile	29.88

Figure G-2: Manning River Shellfish Quality Assurance Program sampling sites

Source: NSW Food Authority 2016

Appendix H Hydrodynamic Modelling

H1 Preamble

The following section provides a summary of the hydrodynamic numerical model adopted for the Manning 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 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 Manning 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-1:

$$\varepsilon_{xy} = \alpha(x,y,t) \cdot V(x,y,t) \cdot \Delta_{elt}(x,y)$$ **Equation H-1**

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 Manning River Floodplain was adopted from Miller and Tarrade (2010) 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 Manning River is a complex estuarine system which includes a number of tributary creeks, branch channels and two ocean entrances, the main entrance being at Harrington and the secondary entrance, Farquhar Inlet, which is often entirely closed by littoral sand (Miller and Tarrade, 2010)[1]. The model domain extended across the major tidal regions of the Manning River and its tributaries including Lansdowne River and Dawson River up to the tidal limit about 60 km upstream from the river mouth near Abbott's Falls at Killawarra. For this study, the hydrodynamic model was further extended through Cattai Creek using bathymetry used in the most recent numerical model for the flood study of the Manning River Flood floodplain developed by BMT WBM (2016). This was done to ensure the model extent covered all areas of interest where there were surveyed floodgate structures. The updated model area is shown in Figure H-1.

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

[1] In this particular hydrodynamic model Farquhar Inlet 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 tidal model developed for the Manning River Estuary by Miller and Tarrade (2010) and updated using bathymetry data from the Manning River Flood Study (BMT WBM, 2016). The model was also refined near the Harrington entrance using single beam bathymetry data sourced from NSW Office of Heritage (OEH).

Catchment inflows were based on observed river flow data from WaterNSW gauging stations in the upper Manning River catchment as shown in Figure H-2. 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 Harrington (Station Number 208425).

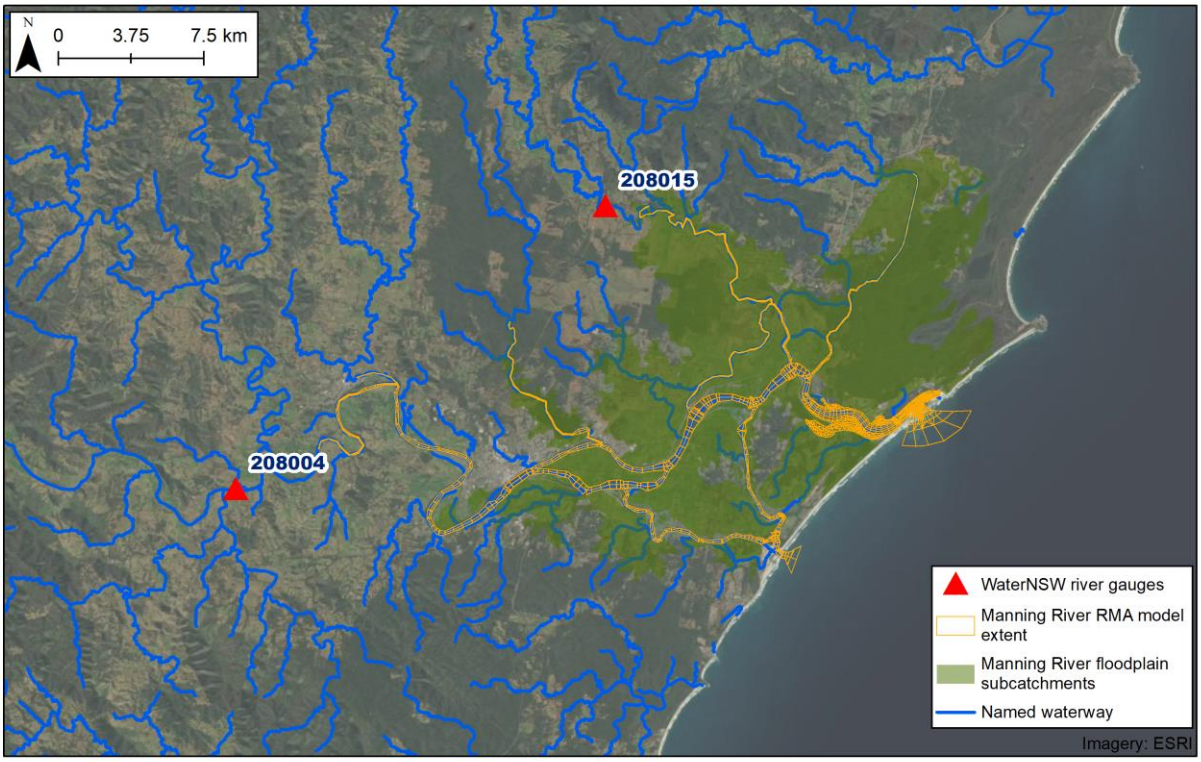

Figure H-2: Location of WaterNSW river flow gauges with relation to the hydrodynamic model extent

Table H-1: Summary of model boundary conditions

Gauging Station Name	Data Source	Station Number	Scale Factor
Manning River at Killawarra	WaterNSW	208004	1
Lansdowne River at Lansdowne	WaterNSW	208015	1
Harrington	MHL	208425	NA

H2.4 Model calibration

The hydrodynamic model for the Manning River estuary was calibrated to selected water level and tidal flow gauging stations for 1998. The year 1998 was selected based on short-term tidal flow gauging of the Manning Estuary which was recorded at various locations within the estuary on 3 November 1998 (MHL, 1999). 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-10. The water level calibration results for an 8-day window during this period are shown in Figure H-11 and Figure H-15. The model was calibrated (for dry weather periods) to less than 0.2 m for the entire estuary.

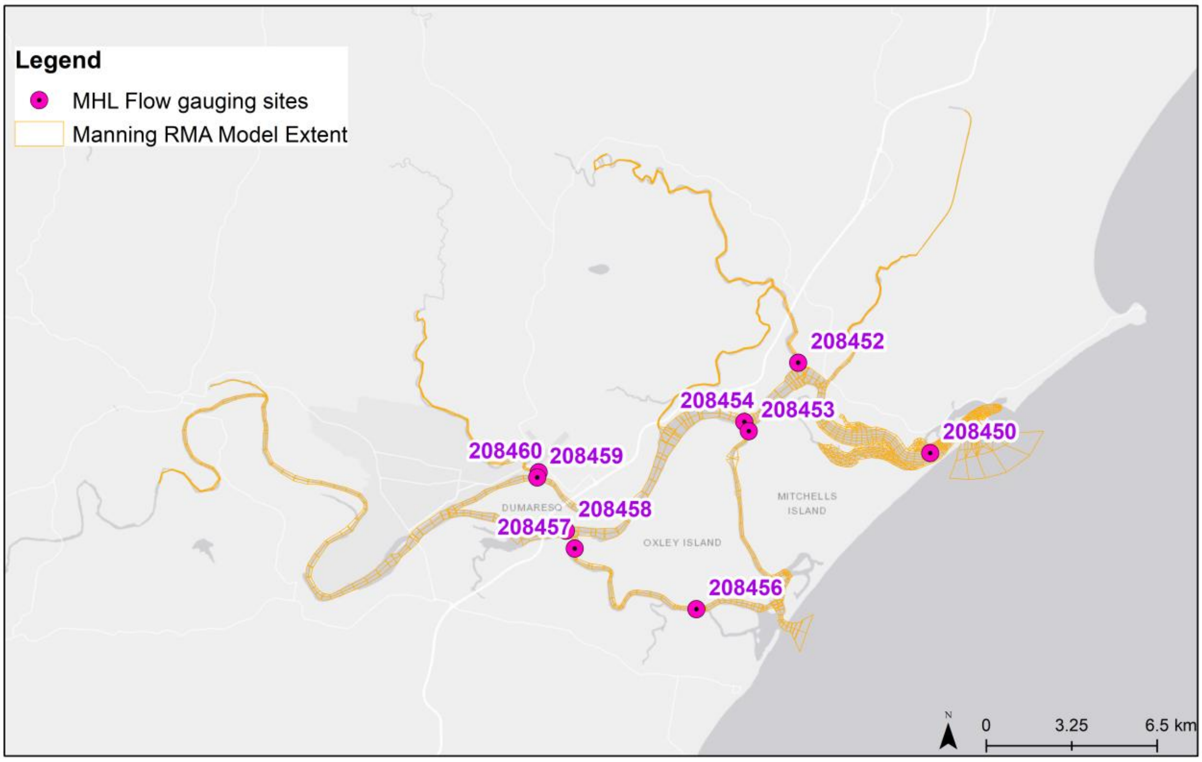

Figure H-3: Location of selected tidal flow gauging stations used for calibration of the Manning River estuary hydrodynamic model

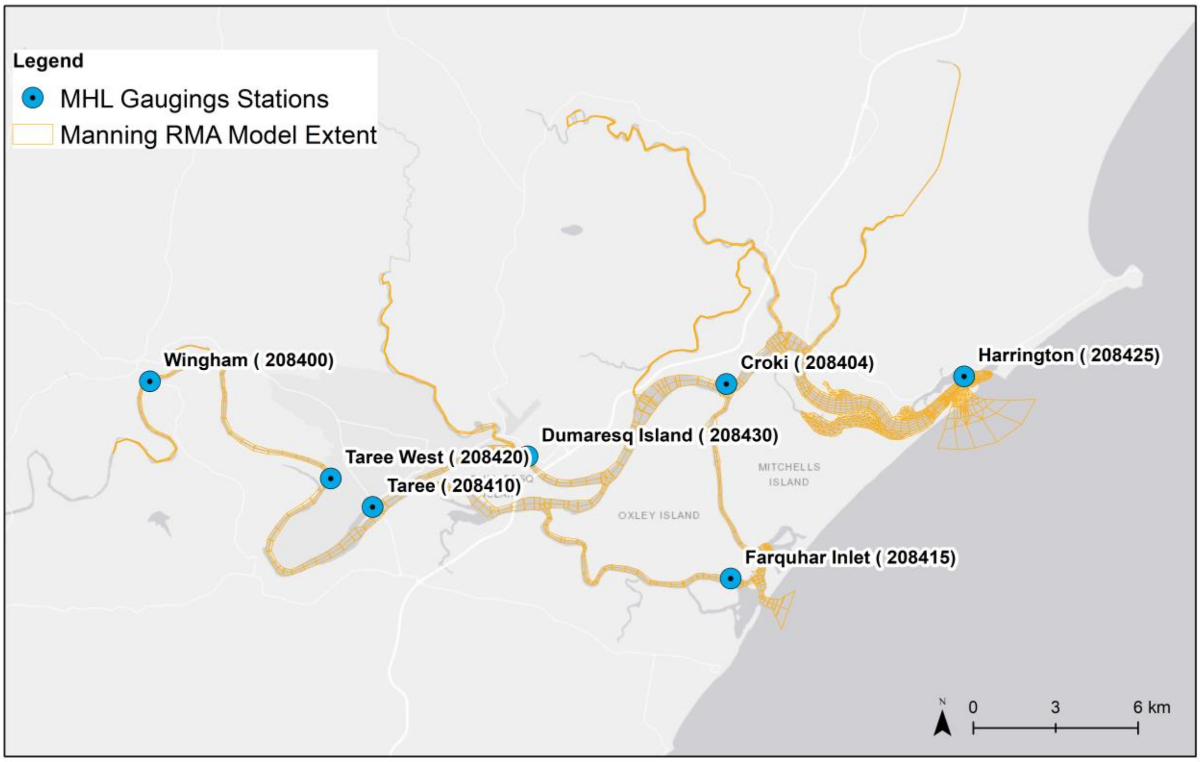

Figure H-4: Location of selected water level stations used for calibration of the Manning River estuary hydrodynamic model

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 Manning Estuary for 2013 and 2019 are provided in Figure H-16 and Figure H-22.

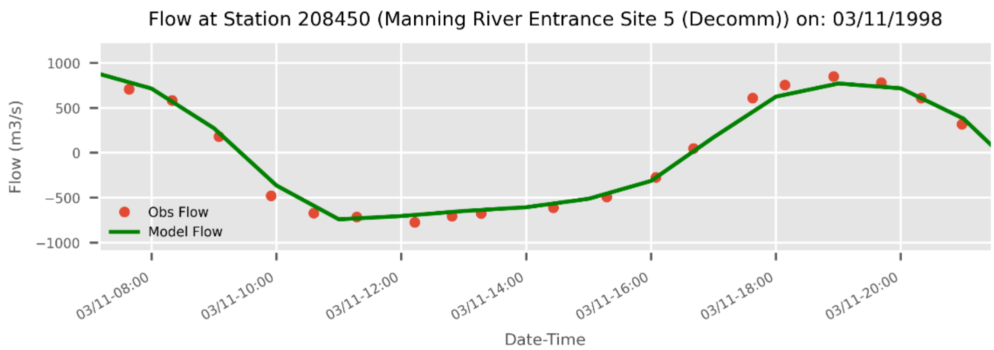

Figure H-5: Manning hydrodynamic model flow calibrations at Station 208450

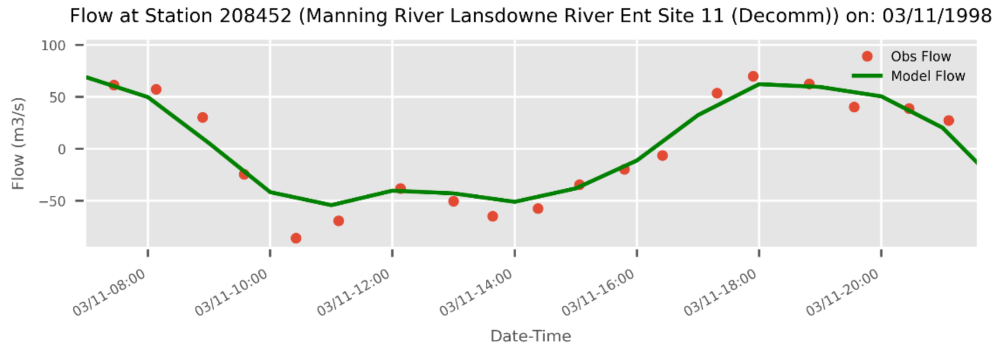

Figure H-6: Manning hydrodynamic model flow calibrations at Station 208452

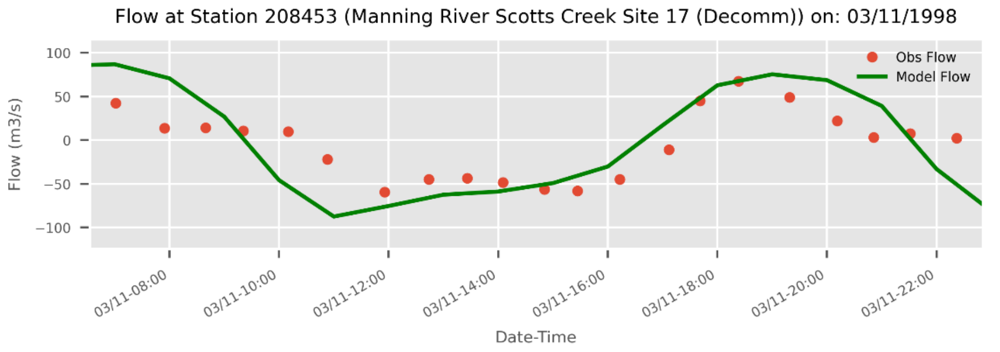

Figure H-7: Manning hydrodynamic model flow calibrations at Station 208453

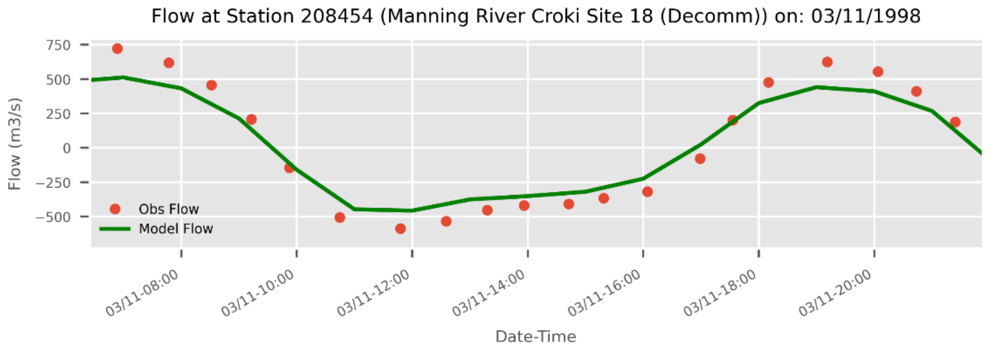

Figure H-8: Manning hydrodynamic model flow calibrations at Station 208454

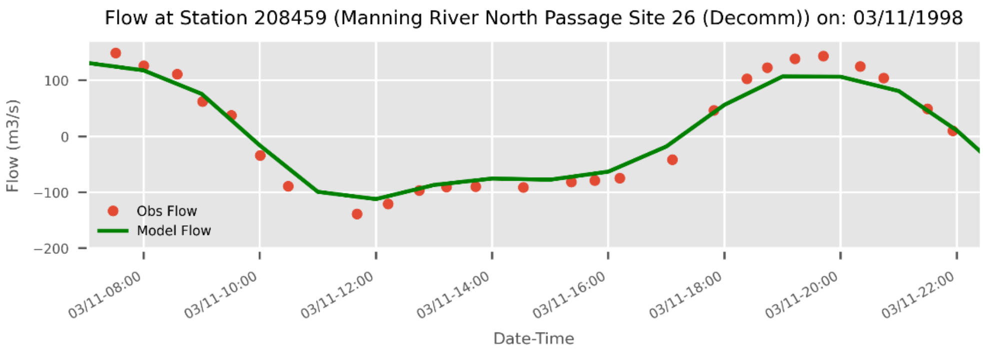

Figure H-9: Manning hydrodynamic model flow calibrations at Station 208459

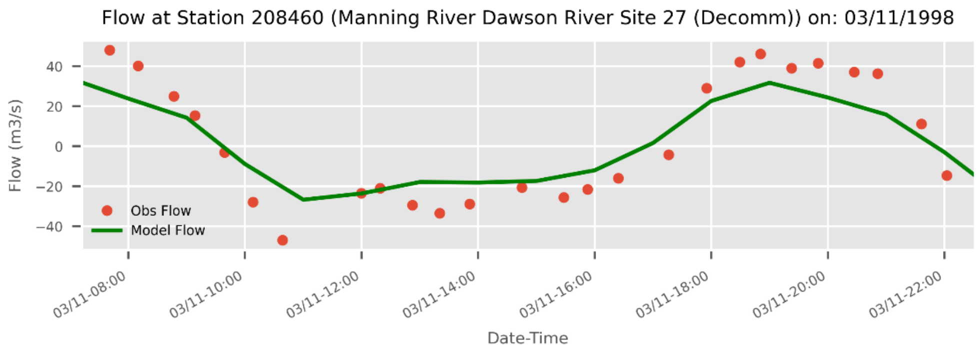

Figure H-10: Manning hydrodynamic model flow calibrations at Station 208460

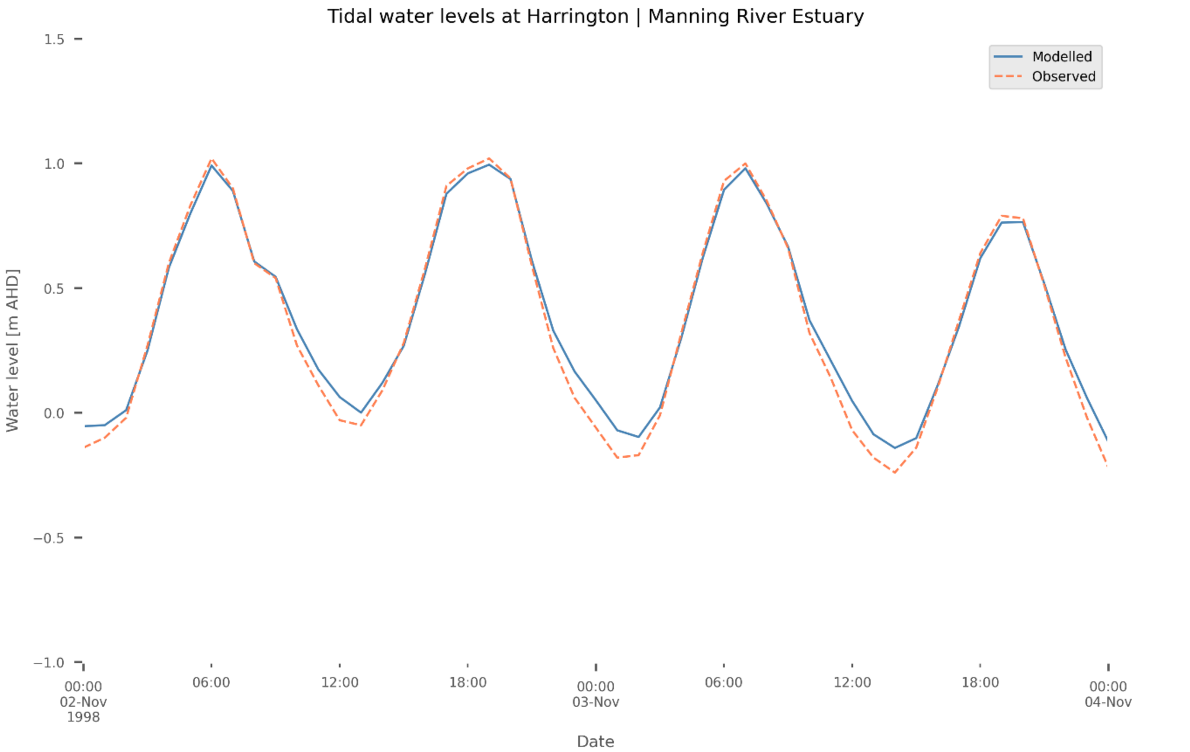

Figure H-11: Manning hydrodynamic model water level calibration results (1998) at Harrington (208425)

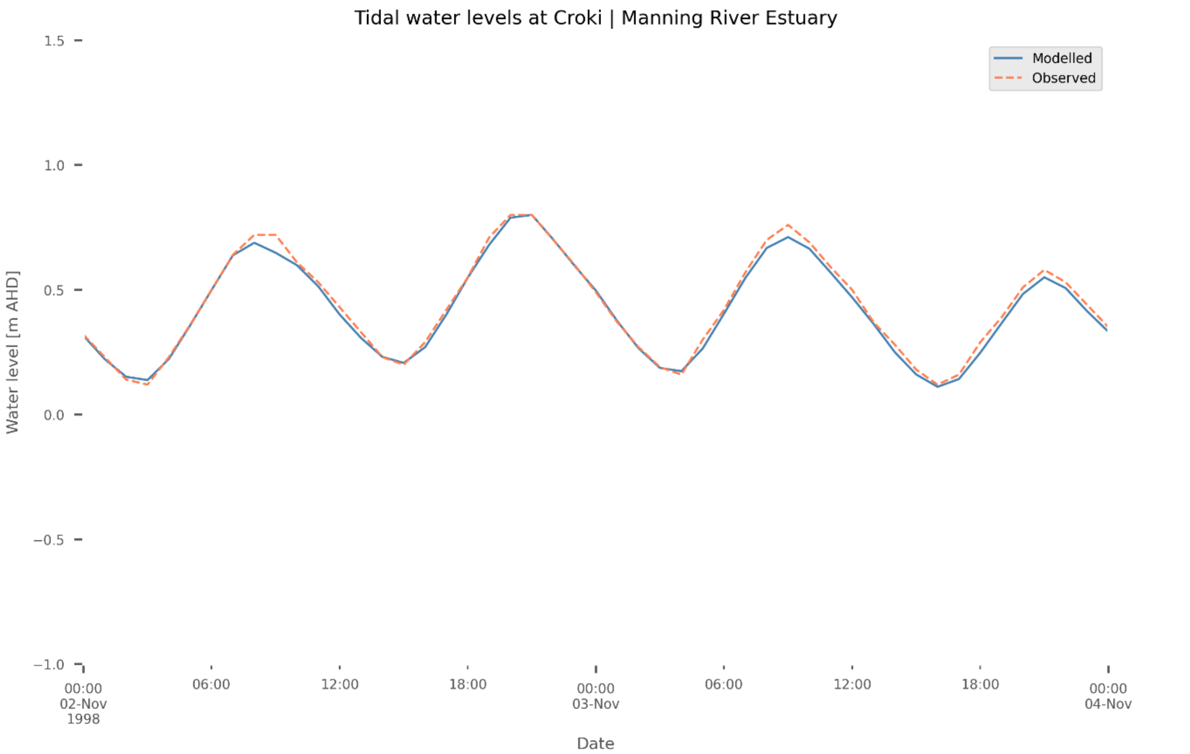

Figure H-12: Manning hydrodynamic model water level calibration results (1998) at Croki (209404)

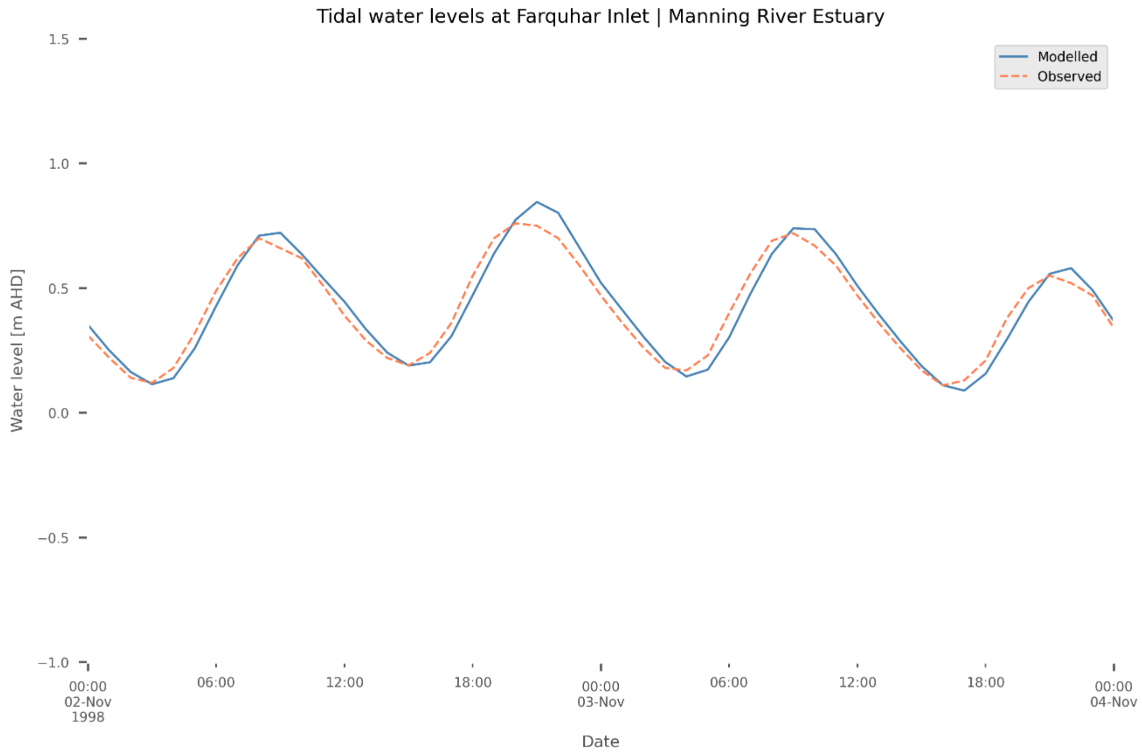

Figure H-13: Manning hydrodynamic model water level calibration results (1998) at Farquhar Inlet (208415)

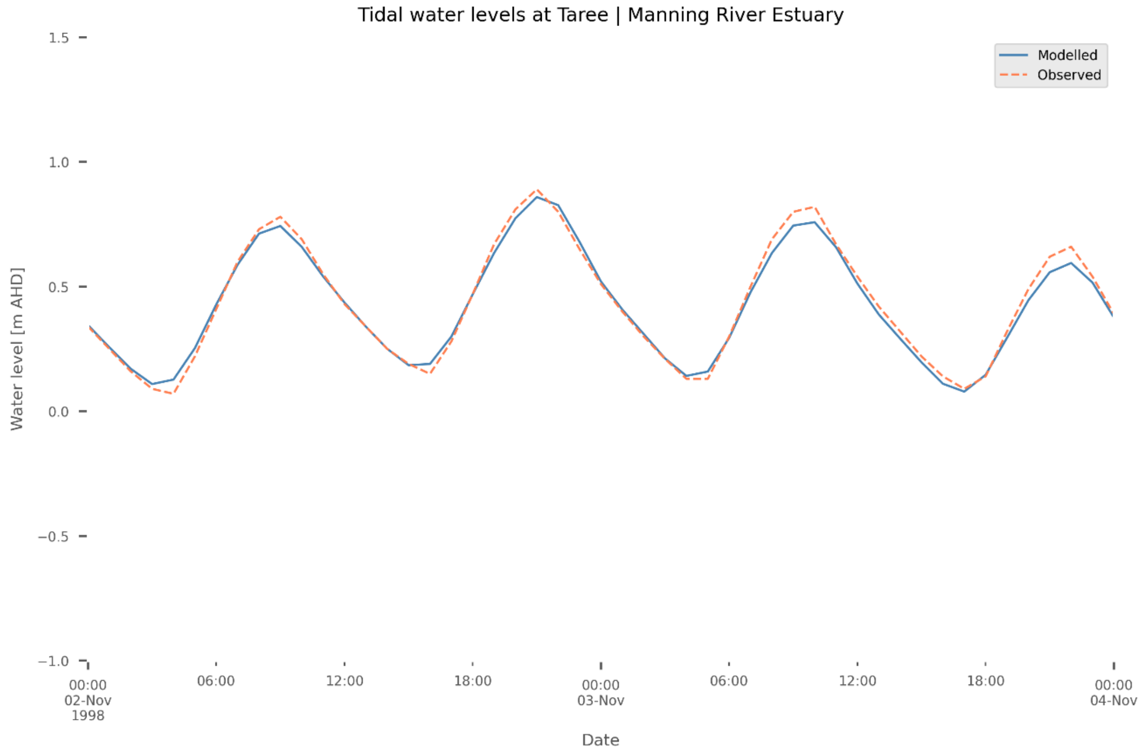

Figure H-14: Manning hydrodynamic model water level calibration results (1998) at Taree (208410)

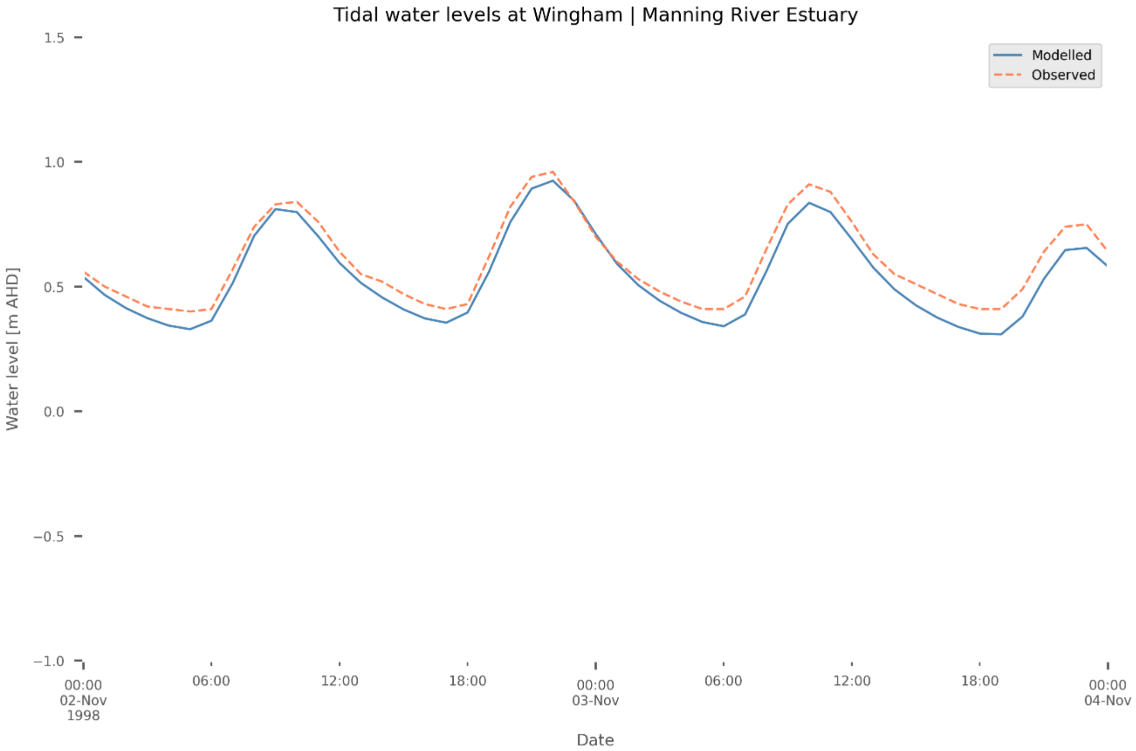

Figure H-15: Manning hydrodynamic model water level calibration results (1998) at Wingham (208400)

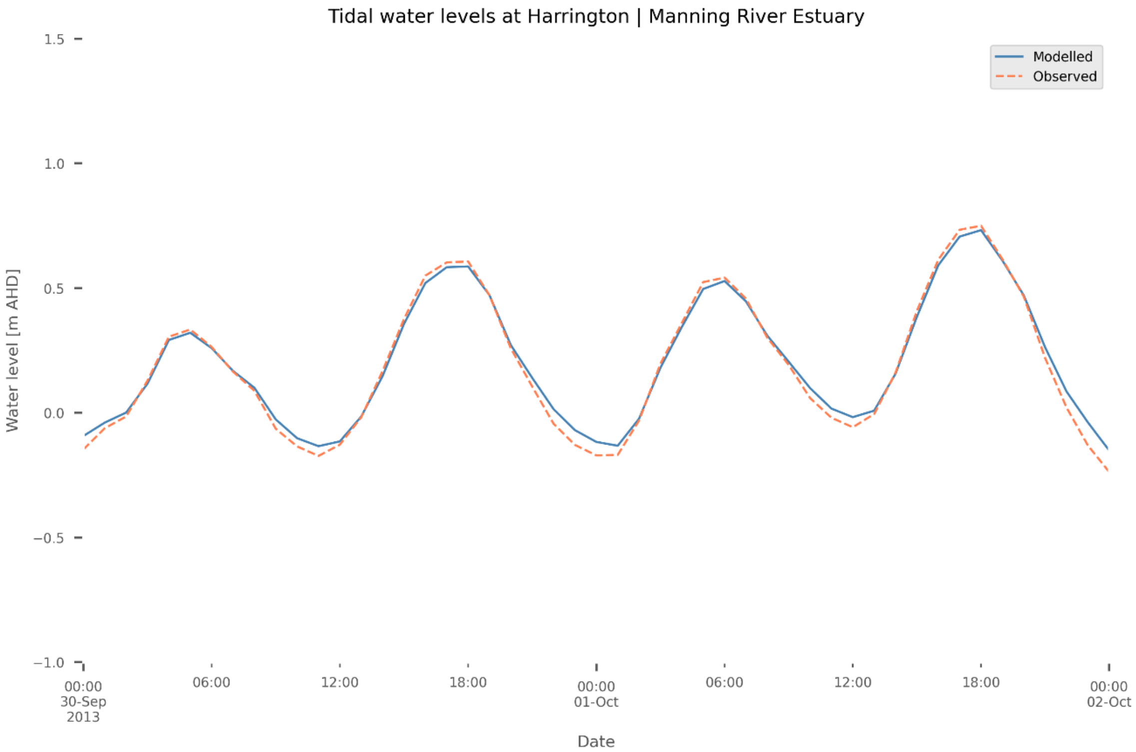

Figure H-16: Manning hydrodynamic model water level verification results (2013) at Harrington (208425)

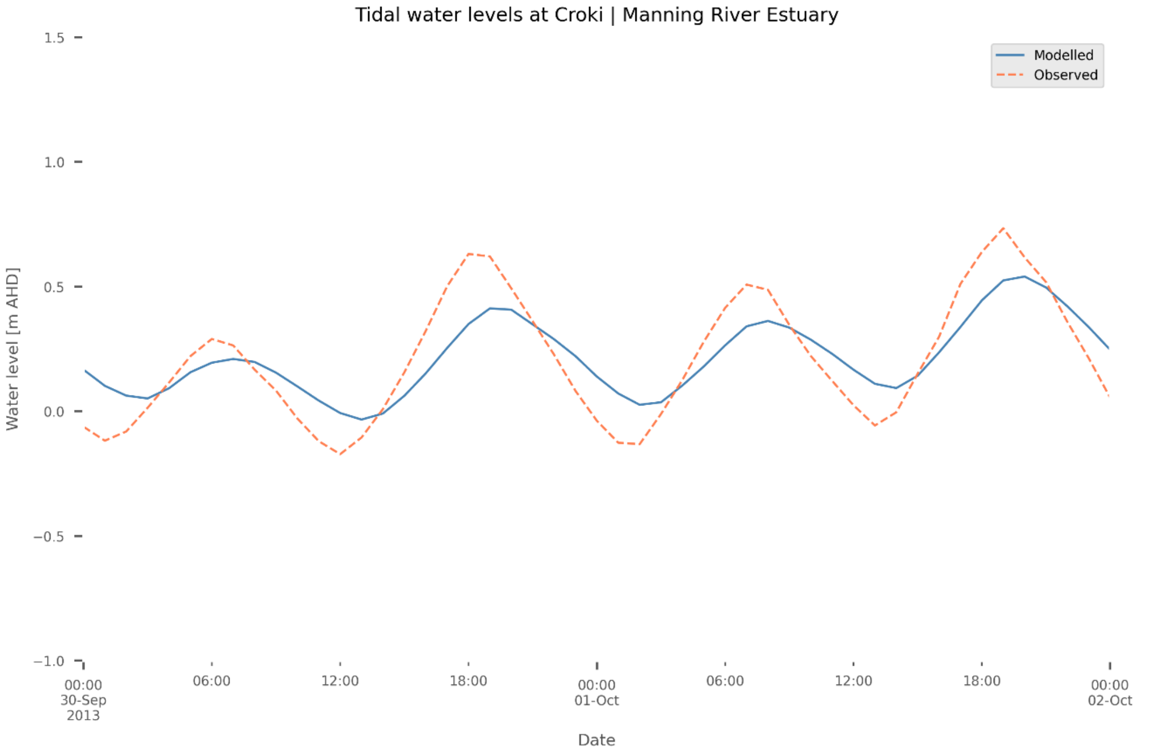

Figure H-17: Manning hydrodynamic model water level verification results (2013) at Croki (209404)

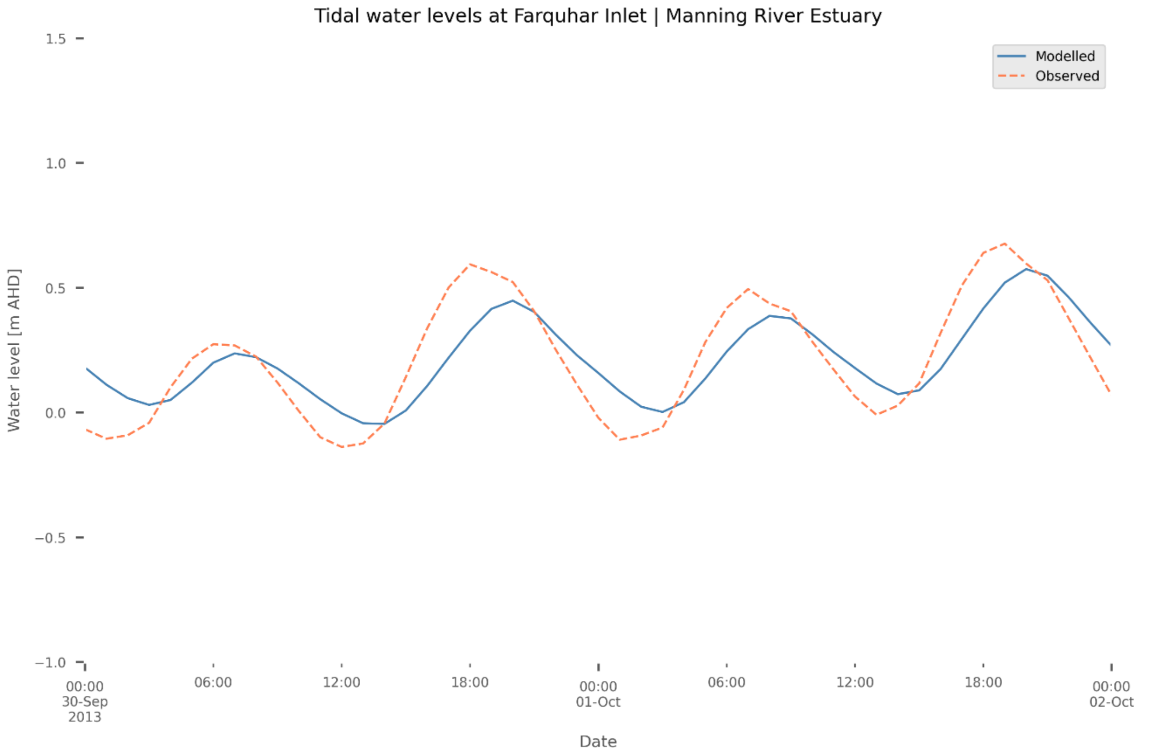

Figure H-18: Manning hydrodynamic model water level verification results (2013) at Farquhar Inlet (208415)

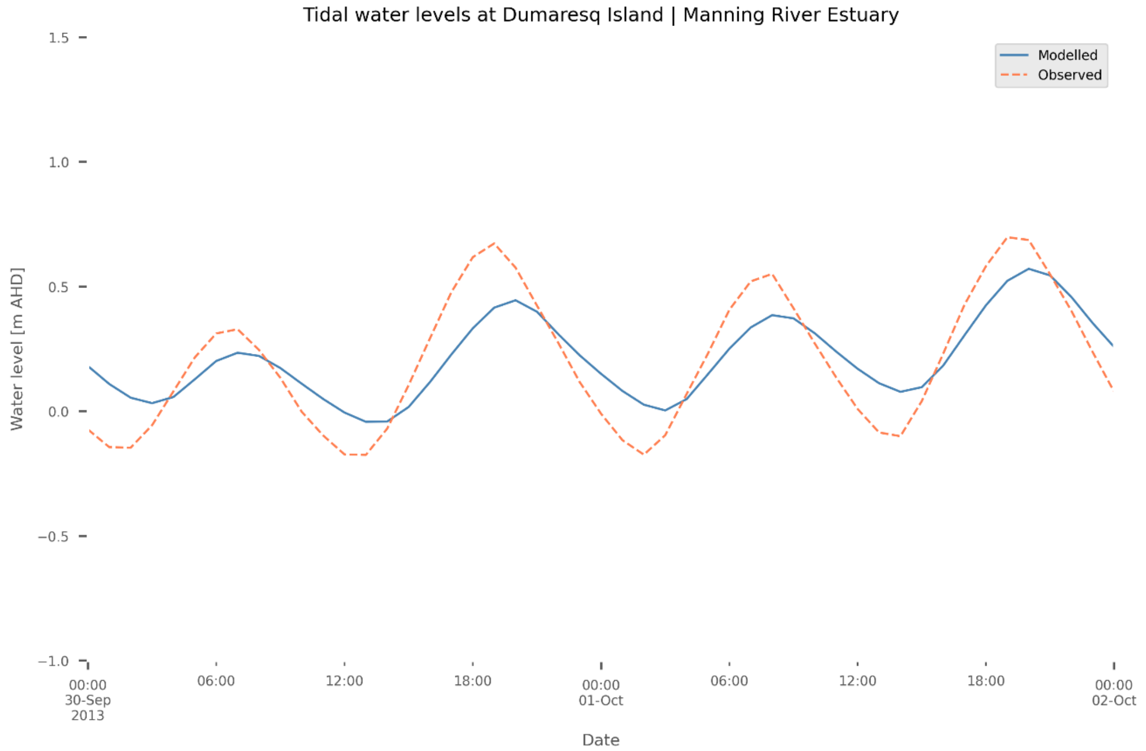

Figure H-19: Manning hydrodynamic model water level verification results (2013) at Dumaresq Island (208430)

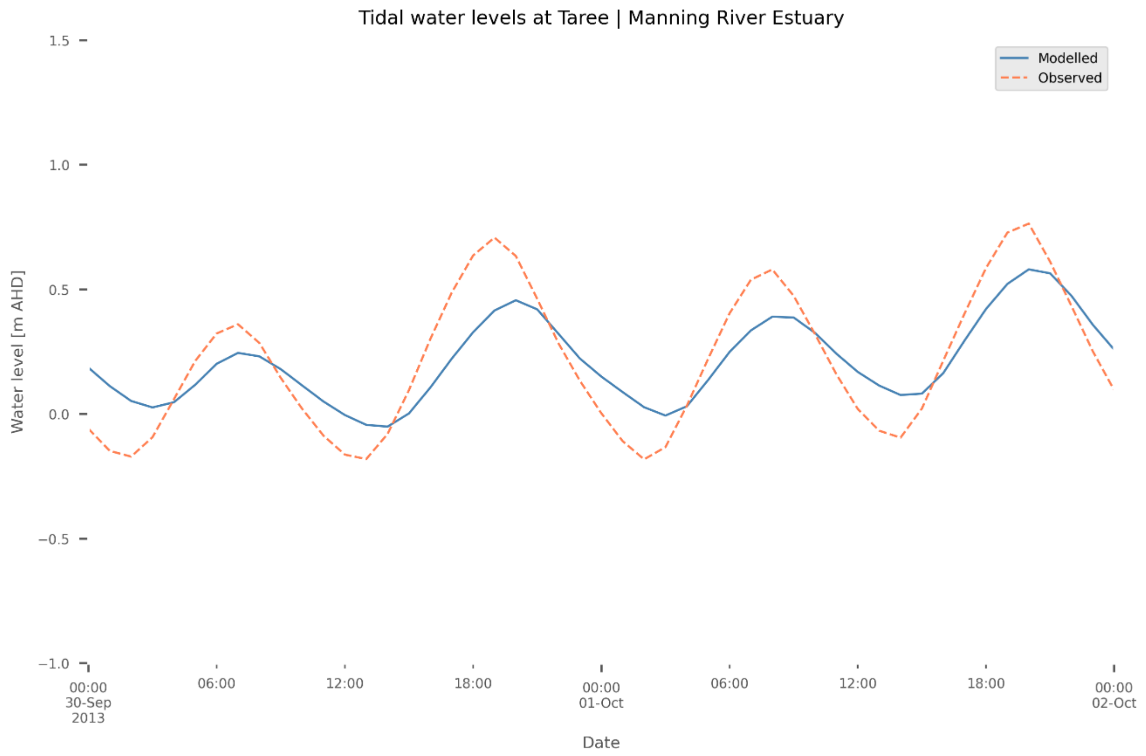

Figure H-20: Manning hydrodynamic model water level verification results (2013) at Taree (208410)

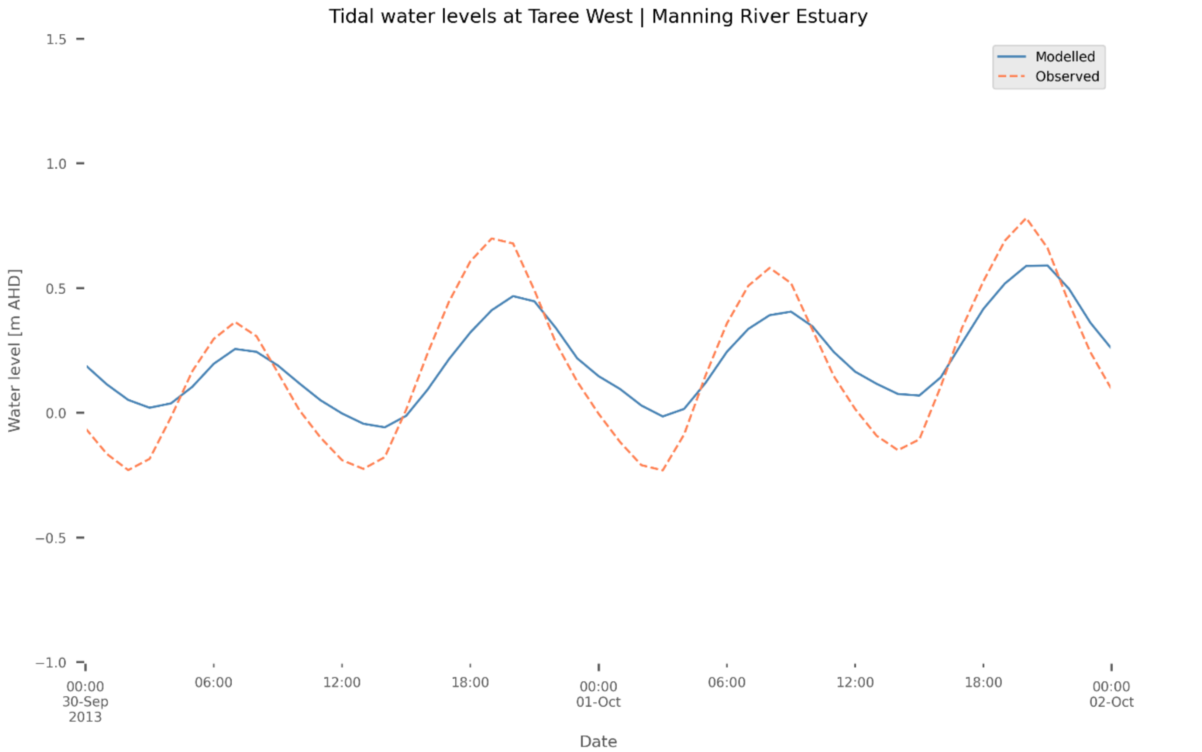

Figure H-21: Manning hydrodynamic model water level verification results (2013) at Taree West (208420)

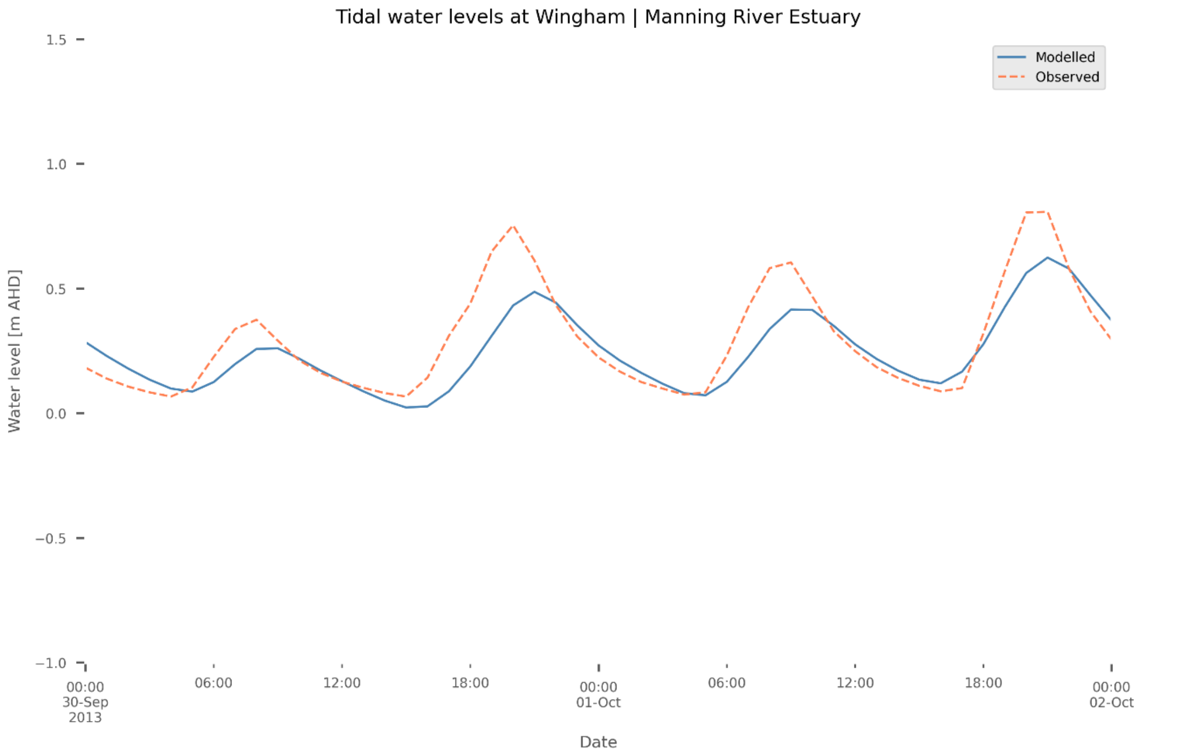

Figure H-22: Manning hydrodynamic model water level verification results (2013) at Wingham (208400)

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 Manning 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 Manning 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 Figure I-1 to Figure 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 sub-catchment within the study area

Subcatchment	Oyster leases	Estuarine Macrophytes			Coastal Management SEPP coastal wetlands	SER within sub-catchment
		Saltmarsh	Seagrass	Mangroves		
Big Swamp	4,200	0	3,600	0	0	Coastal wetlands, key fish habitat
Bukkan Bukkan Creek	0	0	0	0	0	Coastal wetlands, saltmarsh, mangroves, key fish habitat
Cattai Creek	0	0	0	0	0	Coastal wetlands, saltmarsh, mangroves, key fish habitat
Coopernook	2,400	0	3,300	0	0	Key fish habitat
Croakers Creek	0	0	0	0	0	Coastal wetlands, saltmarsh, mangroves, key fish habitat
Dawson River	8,400	800	0	0	0	Coastal wetlands
Dumaresq Island	5,900	500	0	0	0	Coastal wetlands, saltmarsh, key fish habitat
Ghinni Ghinni	4,200	0	0	0	0	Coastal wetlands, key fish habitat
Glenthorne	10,400	0	0	0	0	Coastal wetlands, saltmarsh, mangroves, key fish habitat
Harrington	0	0	0	0	0	Coastal wetlands, saltmarsh, mangroves, key fish habitat
Jones Island	0	0	0	0	0	Coastal wetlands, saltmarsh, mangroves, key fish habitat
Mambo Island	0	0	0	0	0	Key fish habitat
Mitchells Island	0	0	0	0	0	Coastal wetlands, seagrass, saltmarsh, mangroves, key fish habitat
Moto	2,700	0	2,200	0	0	Key fish habitat
Old Bar	0	0	0	0	0	Coastal wetlands, key fish habitat
Pampoolah	0	0	0	0	0	Coastal wetlands, saltmarsh, mangroves, key fish habitat
Taree Estate	17,000	2,400	0	0	0	Coastal wetlands, key fish habitat

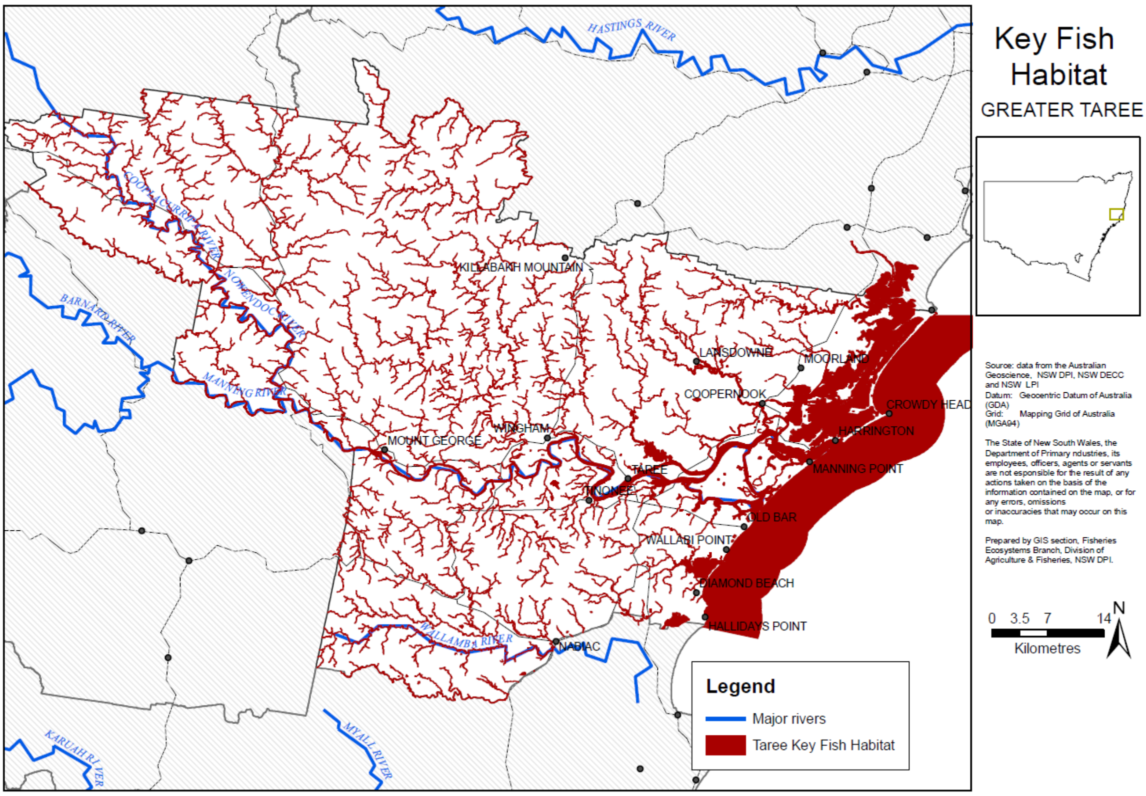

Figure I-1: Key fisheries habitat (Source: NSW DPI Fisheries)

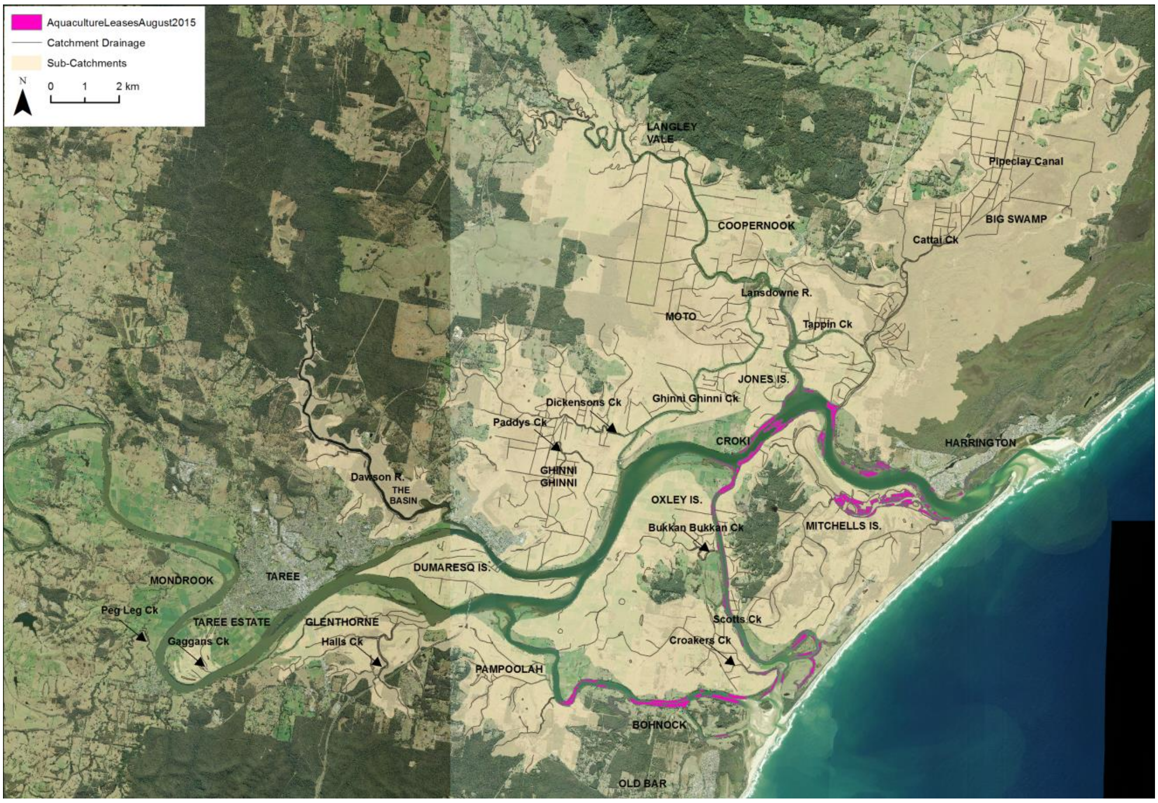

Figure I-2: Priority oyster leases (Source: NSW DPI Fisheries)

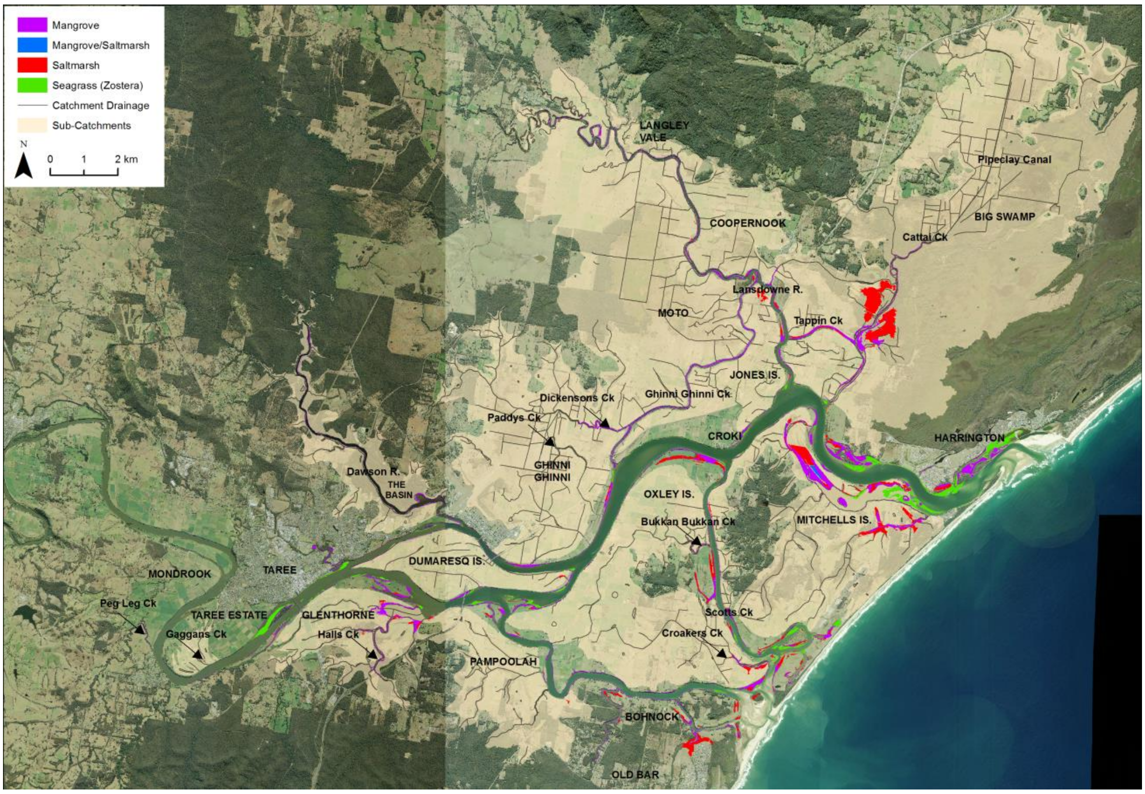

Figure I-3: Estuarine macrophytes (Source: NSW DPI Fisheries)

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 need 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 Manning 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, 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.

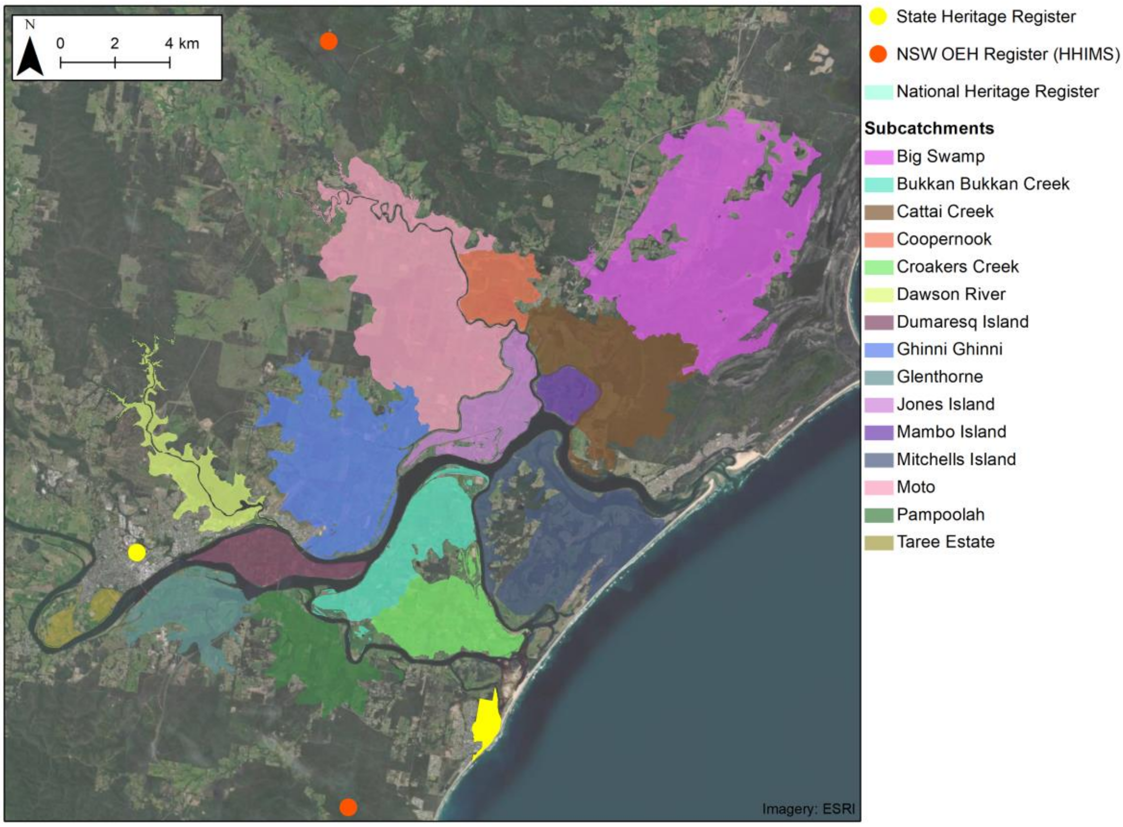

Figure J-1: Heritage items listed on Australian and NSW registers with location information

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.

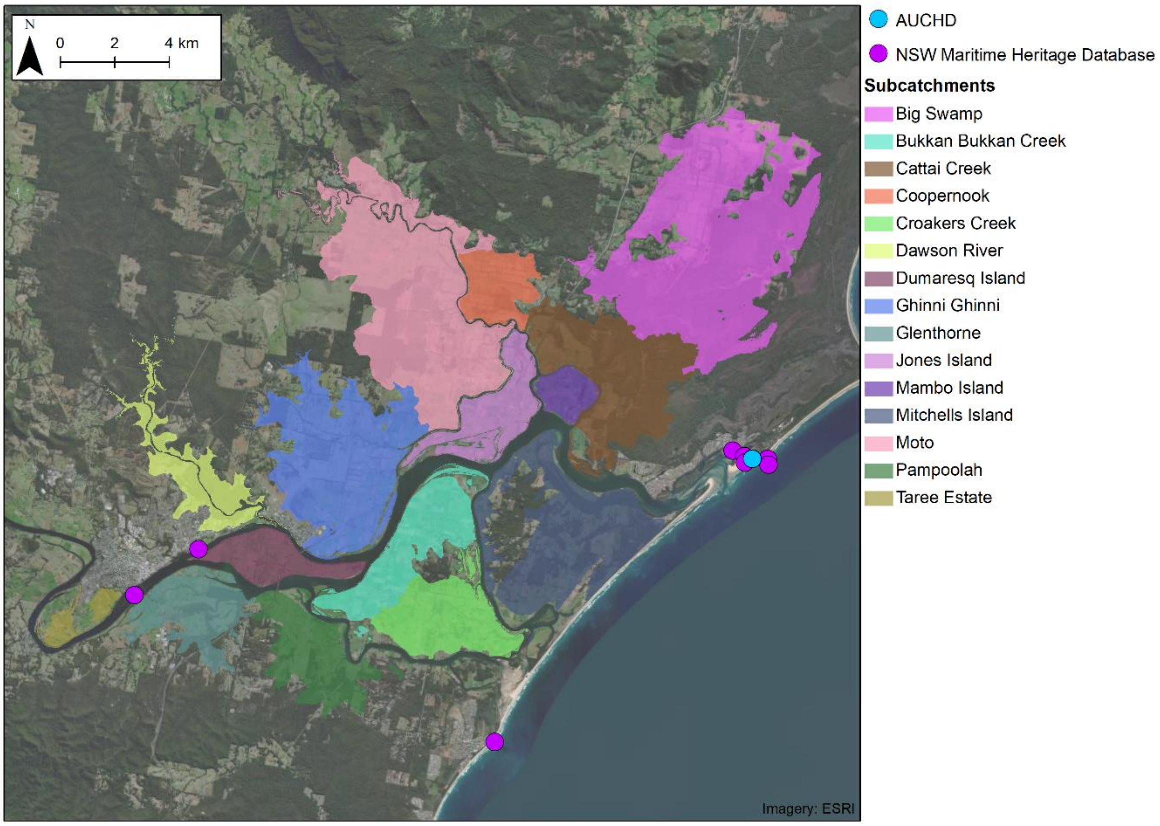

Figure J-2: Maritime heritage items listed on Australian and NSW registers.

Appendix References

ANZECC and ARMCANZ 2000. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Governments and Australian state and territory governments, Canberra ACT, Australia. Available at www.waterquality.gov.au/anz-guidelines.

BMT WBM 2016. Review and Update Manning River Flood Study.

Dove, M. C. 2003. *Effects of Estuarine Acidification on Survival and Growth of the Sydney Rock Oyster Saccostrea Glomerata.* PhD Thesis, The University of New South Wales.

DPIE. 2020. *eSpade NSW Soil and Land Information* [Online]. Available: https://www.environment.nsw.gov.au/eSpade2WebApp [Accessed 2019].

Glamore, W. 2003. *Evaluation and Analysis of Acid Sulfate Soil Impacts via Tidal Restoration.* PhD Thesis, Faculty of Engineering, University of Wollongong.

Glamore, W., Ruprecht, J., Rayner, D. & Smith, G. 2014. Big Swamp Rehabilitation Project: Hydrological Study, Water Research Laboratory, WRL Technical Report No. 2012/23.

Glamore, W., Ruprecht, J. E. & Rayner, D. 2016. Lower Manning River Drainage Remediation Action Plan. Manly Vale, NSW: Water Research Laboratory, University of New South Wales.

Hirst, P., Slavich, P., Johnston, S. & Walsh, S. 2009. Assessment of Hydraulic Conductivity in Coastal Floodplain Acid Sulphate Soils on the North Coast of NSW. Orange, Australia: Industry & Investment NSW.

Johnston, S. 2007. Cattai Creek – Preliminary Acid Sulfate Soil Assessment.

Johnston, S. G. & Slavich, P. G. 2003. Hydraulic conductivity – a simple field test for shallow coastal acid sulfate soils. Bruxner Highway, NSW: NSW Agriculture, Wollongbar Agricultural Institute.

King, I. P. 2015. Documentation RMA2 – A Two Dimensional Finite Element Model for Flow in Estuaries and Streams. Sydney Australia.

MHL 1999. Manning River Estuary Tidal Data Collection November-December 1998.

Miller, B. M. & Tarrade, L. 2010. Manning River Saline Dynamic Modelling.

Rayner, D. 2010. Understanding the Transport and Buffering Dynamics of Acid Plumes within Estuaries. Water Research Laboratory, WRL Research Report 238.

Rayner, D. S., Harrison, A. J., Tucker, T. A., Lumiatti, G., Rahman, P. F., Waddington, K., Juma, D. & Glamore, W. 2023. Coastal Floodplain Prioritisation Study – Background and Methodology WRL TR2020/32. Water Research Laboratory, University of New South Wales.

Ruprecht, J. E., Glamore, W., Harrison, A. J. & Chan, J. 2020a. Big Swamp Rehabilitation Project 2019 Annual Monitoring Report.

Ruprecht, J. E., Glamore, W., Harrison, A. J. & Gawlik, E. 2017. Big Swamp Wetland: Monitoring Review.

Ruprecht, J. E., Tucker, T. A., Coghlan, I. R. & Glamore, W. C. 2020b. Pampoolah Floodplain Remediation Investigation and Riverbank Vulnerability Assessment.

Sammut, J., White, I. & Melville, M. D. 1996. Acidification of an estuarine tributary in eastern Australia due to drainage of acid sulfate soils. *Marine & Freshwater Research*, 669-684.

Smith, R. J., Sammut, J. & Dove, M. C. 1999. Impacts of Acid Water Drainage on the Manning Oyster Industry.

Sonter, L. 1999. Spatial Characteristics of Acid Sulfate Soil – Induced Estuarine Acidification within Cattai Creek.

Winberg, P. & Heath, T. 2010. Ecological Impacts of Floodgates on Estuarine Tributary Fish Assemblages. Report to the Southern Rivers Catchment Management Authority.

WRL 2019. 226 Bakers Lane, Coralville: Acid Sulfate Soil and Hydraulic Conductivity Assessment.