Macleay River Floodplain Prioritisation Study: Appendix A – L

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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 Macleay 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, a watercourse or a 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., 2020a). 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 Macleay 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
Kempsey Shire Council Flood Council Drains	Shapefile	Yes	No	Local
Kempsey Shire Council Named Watercourse	Shapefile	Yes	No	Local
Kempsey Shire Council Flood Mitigation Line	Shapefile	Yes	No	Local
Kempsey Shire Council Flood Joint Owned Drains	Shapefile	Yes	No	Local

A3 Waterway classification

For this study, an updated waterways spatial dataset was developed for the Macleay 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., 2020a). 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.

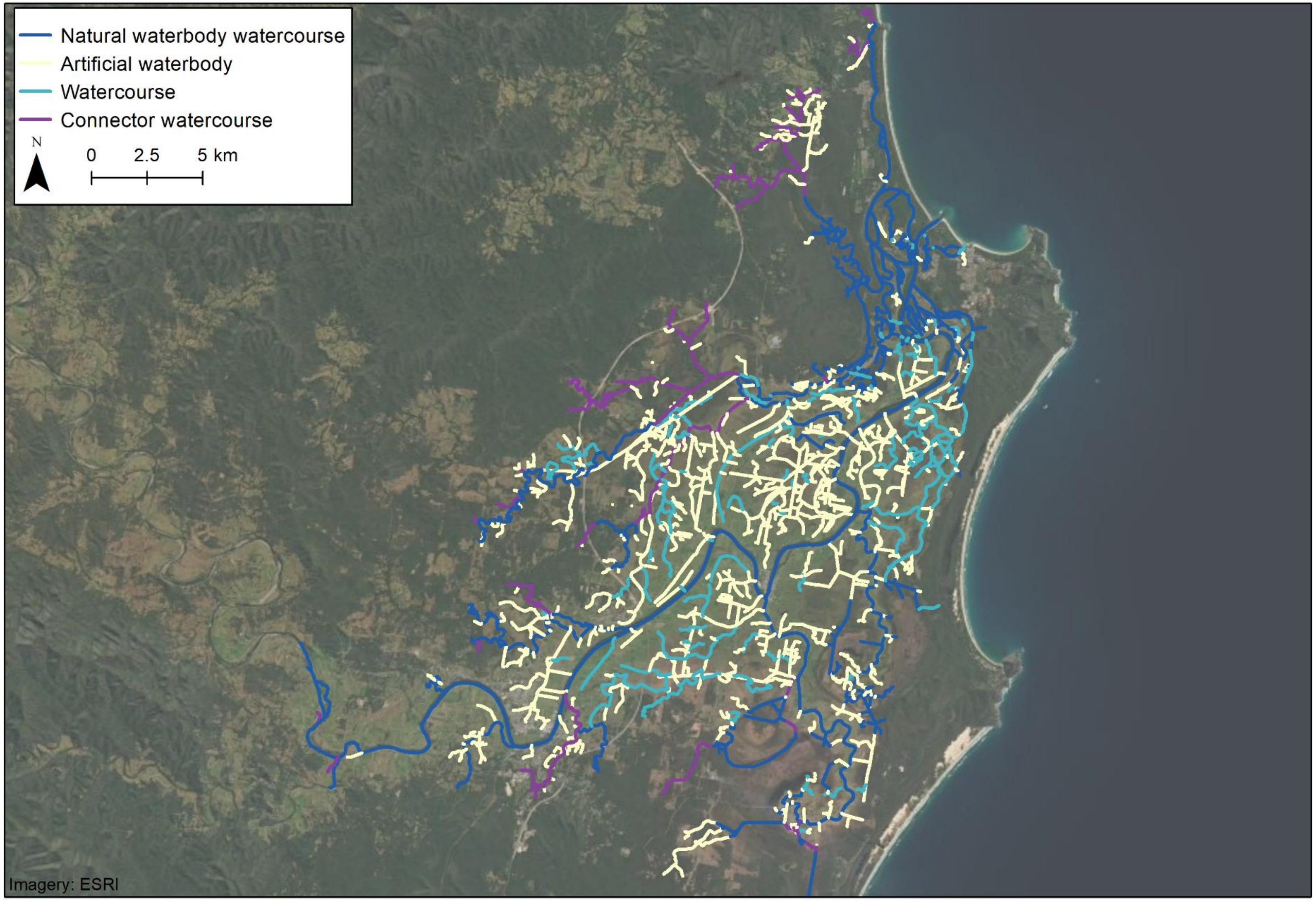

Figure A-1: Macleay River floodplain waterways

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., 2020a). 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 Macleay 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**
Belmore Swamp	44,060	47.63	925	11
Christmas Creek	41,560	12.48	3,330	3
Collombatti-Clybucca	197,580	74.28	2,660	5
Euroka Creek	9,380	1.95	4,804	1
Frogmore/Austral Eden/Verges Swamp	102,050	48.10	2,122	8
Kinchela Creek	77,210	58.14	1,328	9
Pola Creek	13,540	3.52	3,846	2
Raffertys/Saltwater Inlet	72,790	30.44	2,392	6
Rainbow Reach	41,820	19.02	2,199	7
Summer Island	79,970	28.10	2,846	4
Yarrahapinni	42,400	39.83	1,065	10

* 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.

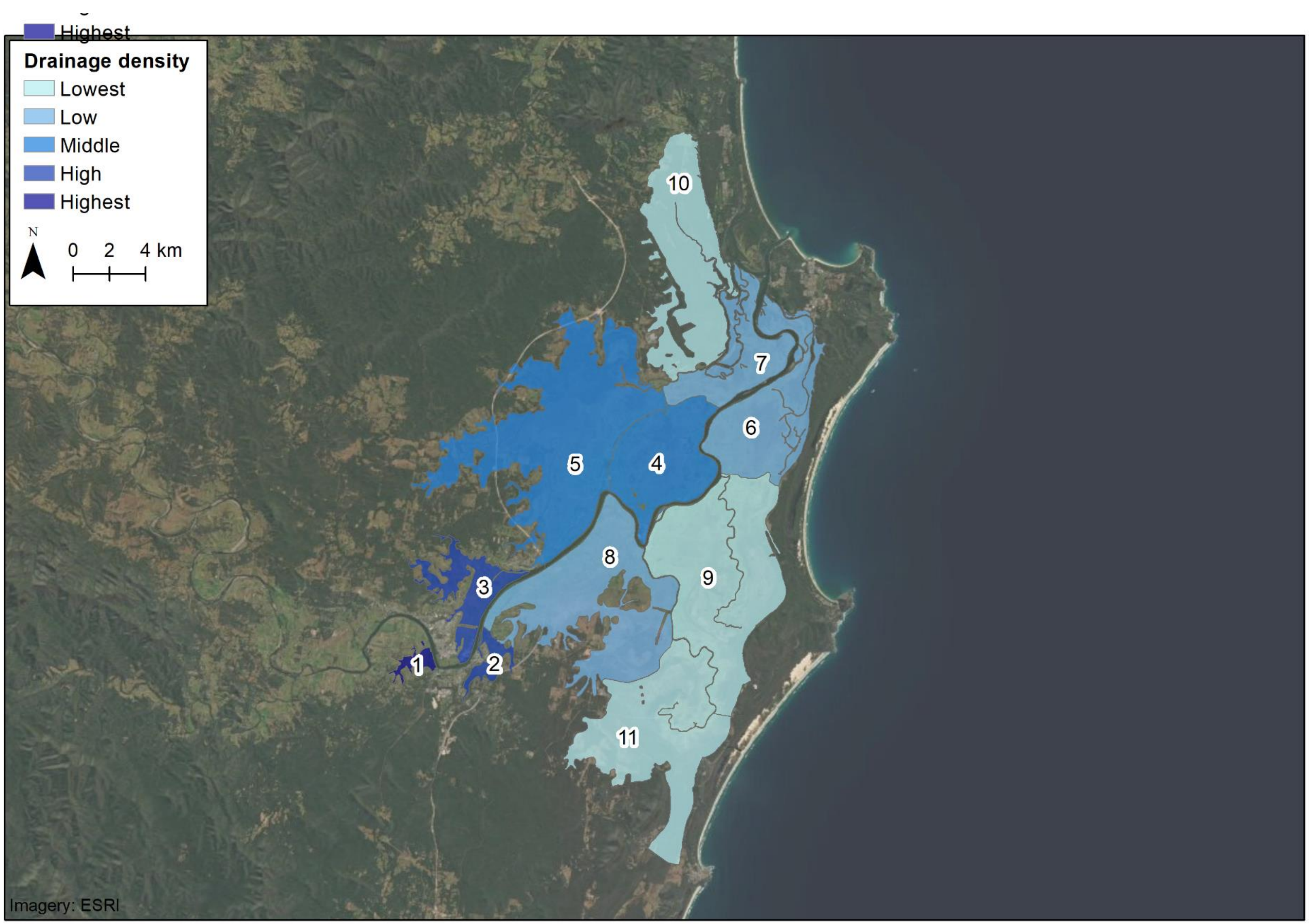

Figure A-2: Floodplain drainage density ranking

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., 2020a). This includes the calculation of a runoff coefficient (Section B2) and a catchment size factor (Section B2), to determine an inflow factor (Section B4).

B2 Runoff coefficient

The catchment runoff assessment for the Macleay 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., 2020a). The WaterNSW network of river flow gauges the available daily rainfall data from the Bureau of Meteorology (BOM) for the Macleay River floodplain are shown in Figure B-1.

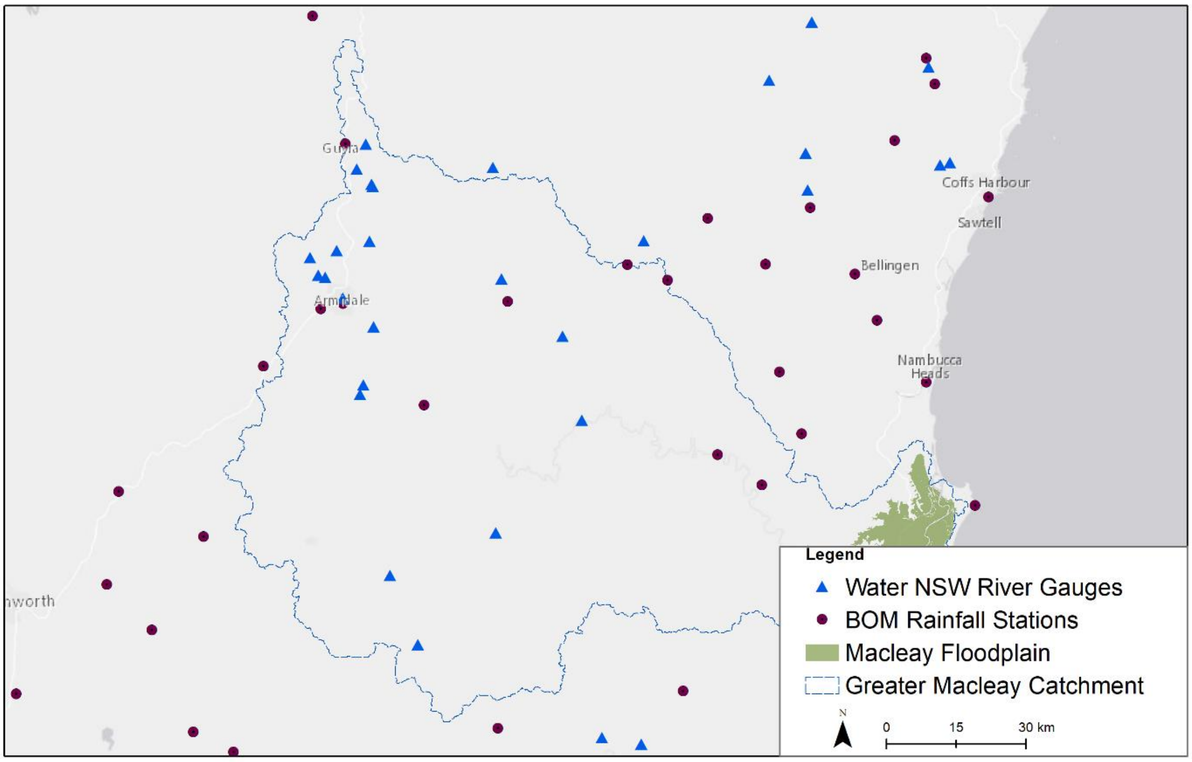

Figure B-1: Macleay River floodplain location of rainfall and runoff stations

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 206011 was selected for assessment of the Macleay River floodplain. The upstream contributing area for this site was delineated using standard GIS techniques based on a digital elevation model (DEM) of the catchment. Daily rainfall data relative to each river gauging station was sourced from the BOM database and a Thiessen polygon approach was applied to weight the total rainfall to upstream areas. The location of the gauging site, upstream catchment area of the gauging site, and the BOM rainfall contribution used in the analysis is summarised in Figure B-2.

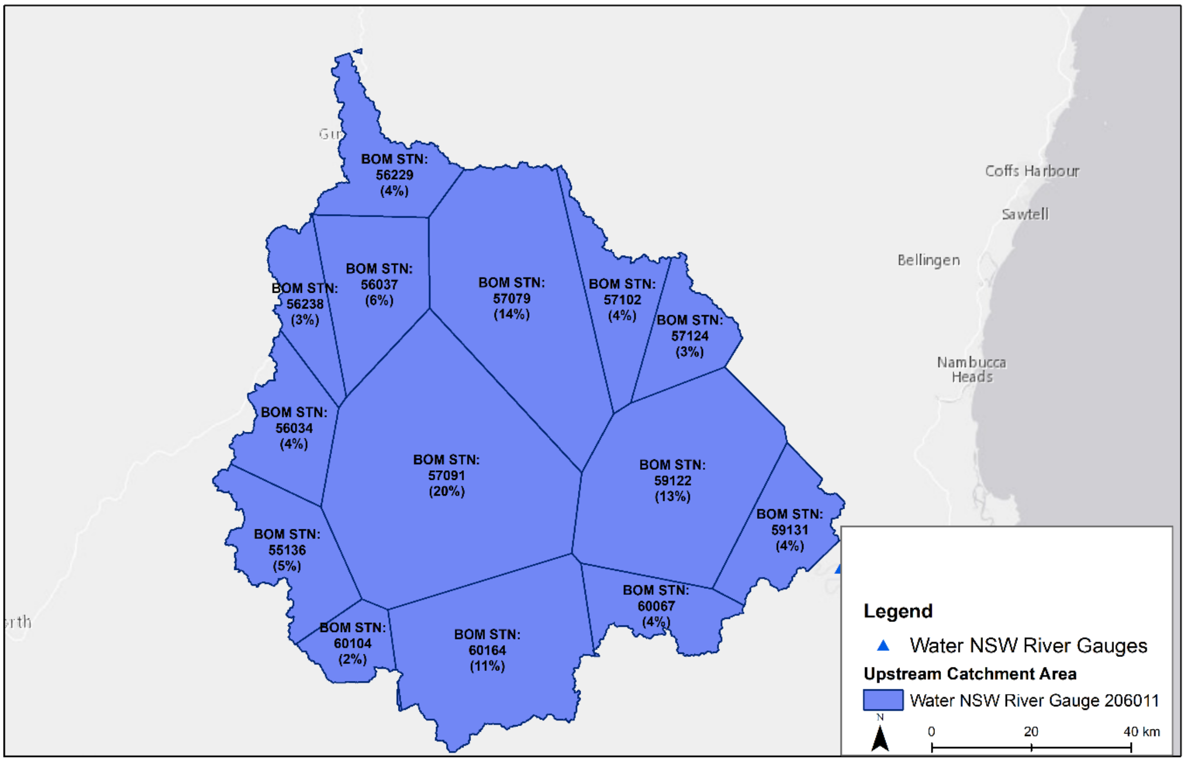

Figure B-2: Upstream catchment of selected flow sites including rainfall contribution (shown in parenthesis)

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 stations. Figure B-3 shows an example time-series of predicted and observed runoff for 2017. This analysis yielded an estimated runoff coefficient of 0.3, which was applied to Macleay River floodplain subcatchments for the acid prioritisation assessment.

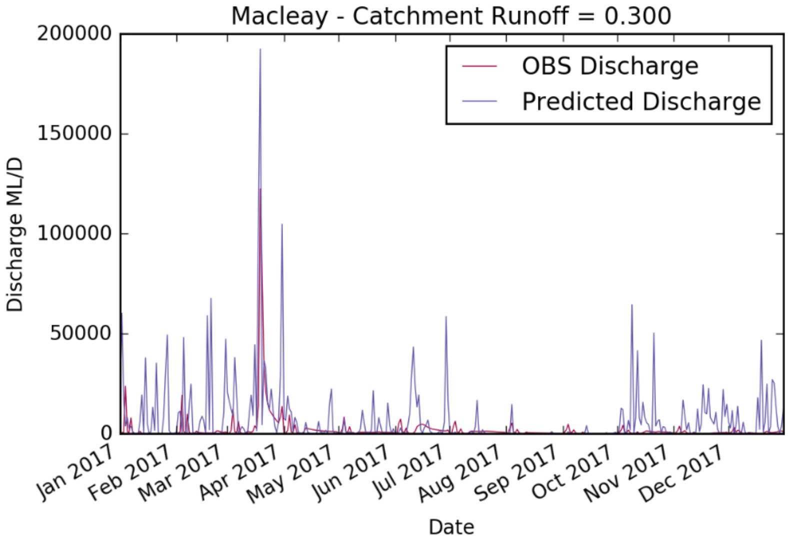

Figure B-3: Predicted and observed runoff for the catchment area upstream of river gauging station 206011 for 2017

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 normalised against the subcatchment with the largest total area (i.e. catchment size factor = 1.0) for comparison.

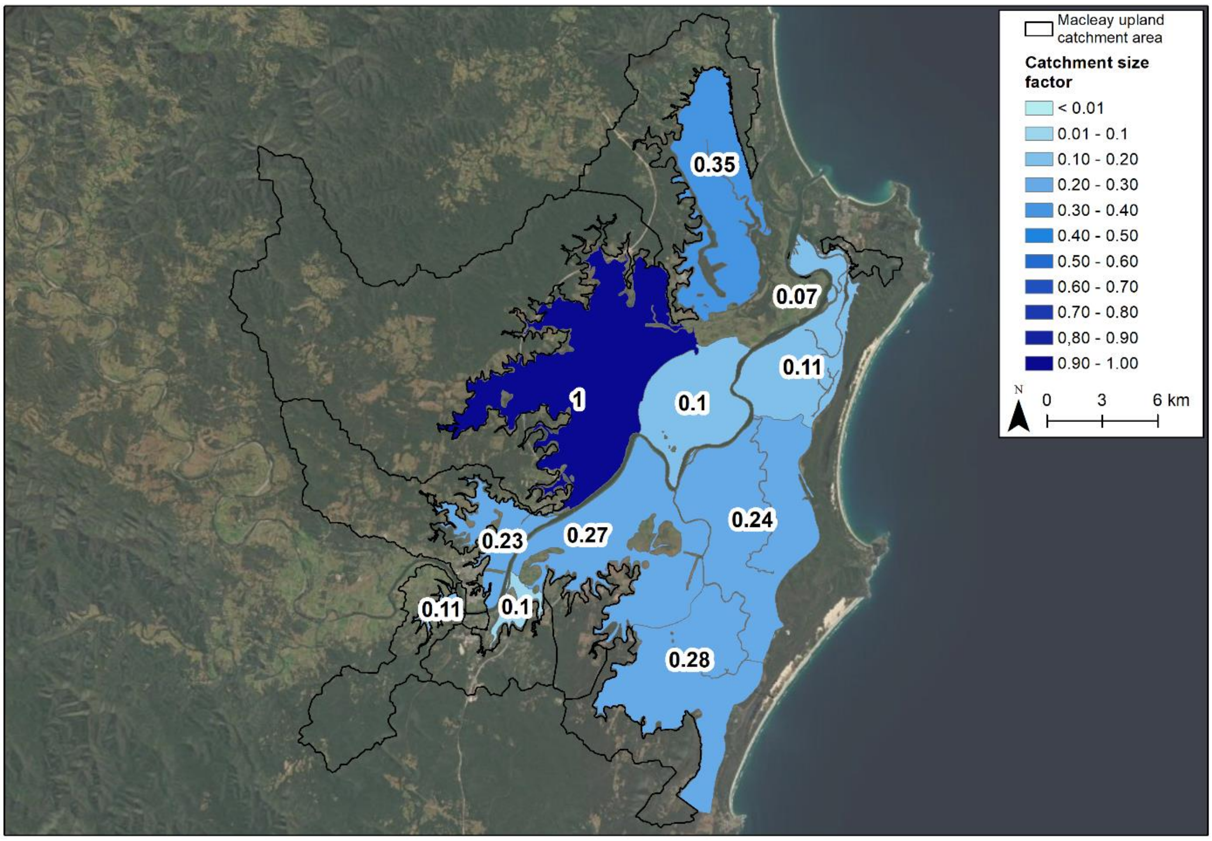

Figure B-4: Catchment size factor for each subcatchment in the Macleay River estuary

B4 Inflow Factor

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

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

The inflow factors for each Macleay 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 (m^2)	Total catchment area (m^2)	Catchment size factor	Inflow factor
Frogmore/Austral Eden/Verges Swamp	0.3	28,211,000	76,313,950	0.274	0.082
Summer Island	0.3	102,600	28,205,600	0.101	0.030
Rainbow Reach	0.3	0	19,018,400	0.068	0.021
Kinchela Creek	0.3	7,826,750	65,963,350	0.237	0.071
Belmore Swamp	0.3	29,104,550	76,736,250	0.276	0.083
Raffertys/Saltwater Inlet	0.3	1,259,450	31,694,600	0.114	0.034
Pola Creek	0.3	24,065,450	27,586,850	0.099	0.030
Euroka Creek	0.3	29,202,800	31,155,250	0.112	0.034
Yarrahapinni	0.3	57,962,950	97,789,300	0.352	0.106
Collombatti-Clybucca	0.3	203,793,050	278,068,650	1.000	0.300
Christmas Creek	0.3	52,718,400	65,201,150	0.234	0.070

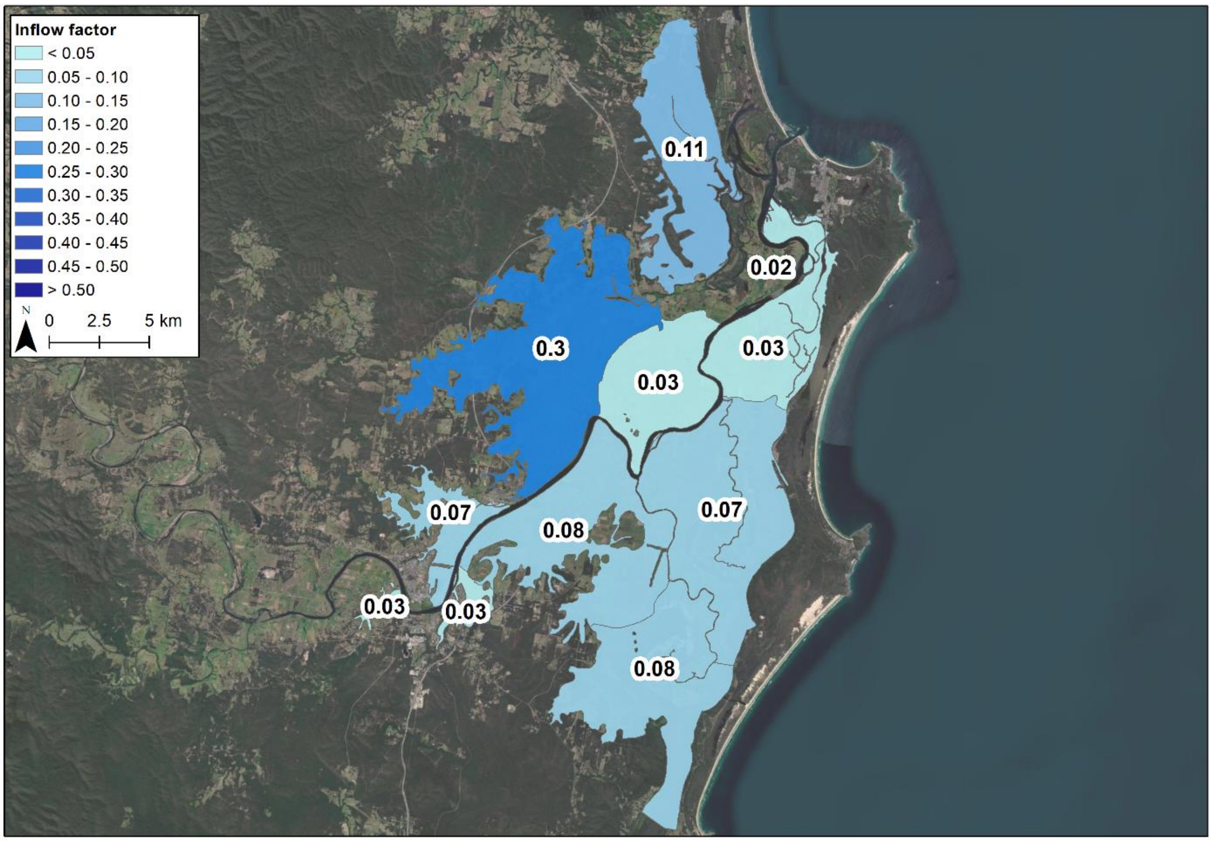

Figure B-5: Subcatchment inflow factors

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 Macleay River floodplain. A detailed discussion of the principles relating to hydraulic conductivity and data collection can be found in Appendix B of the Methods report (Rayner et al., 2020a). Details on the techniques and methods used to collect the field data presented in this section can be found in Appendix A of the Methods report (Rayner et al., 2020a).

C2 Existing saturated hydraulic conductivity data

A data gaps analysis was completed to identify existing hydraulic conductivity data within the Macleay River floodplain. The data identified was limited to certain areas of the floodplain as listed in Table C-1 and spatially presented in Figure C-1. Data was available from the following sources:

- Johnston (2004) presented previously unpublished hydraulic conductivity data for the Collombatti-Clybucca subcatchment calculating discrete values using the Bouwer and Rice (1983) pit bailing method. There was no specific location information provided with this data to determine its exact location within the subcatchment. Close inspection indicated that this was the same data later published by Kempsey Shire Council (2004a).

- Kempsey Shire Council (2004a) presented hydraulic conductivity results from two (2) pit bailing tests completed in the Collombatti-Clybucca subcatchment. Discrete hydraulic conductivity values have been calculated using the Boast and Langebartel (1984) method.

- Smith (2005) installed a number of piezometers in the Yarrahapinni and Rainbow Reach subcatchments, completing auger hole slug tests using the Hvorslev (1951) method to determine the hydraulic conductivity.

- Hirst et al. (2009) collected hydraulic conductivity data for ASS across six (6) different NSW North Coast floodplains (Tweed, Richmond, Clarence, Hastings, Macleay, and Manning), using the pit bailing method. On the Macleay River floodplain, data was collected in the Frogmore/Austral Eden/Verges Swamp, Raffertys/Saltwater Inlet and Summer Island subcatchments. The hydraulic conductivity values were calculated using the Bouwer and Rice (1983) and Boast and Langebartel (1984) techniques.

- Johnston et al. (2009) presented hydraulic conductivity data collected using the pit bailing method for the Collombatti-Clybucca, Frogmore/Austral Eden/Verges Swamp, Kinchela Creek and Raffertys/Saltwater Inlet subcatchments. Close inspection indicated that the majority of this data is the same as was presented by Hirst et al. (2009) and Kempsey Shire Council (2004a). Furthermore, there was no specific location information provided with this data to determine its exact location within subcatchments. For these reasons this data has not been included in the analysis.

- Rayner et al. (2020b) collected hydraulic conductivity at one location in the Collombatti-Clybucca subcatchment using the pit bailing method and in two locations using the auger hole method. Discrete hydraulic conductivity values for the data collected using the pit bailing method have been calculated as outlined by Boast and Langebartel (1984).

Table C-1 Summary of existing hydraulic conductivity data in the Macleay River floodplain

Point ID	Saturated hydraulic conductivity (m/day)			Risk classification	Reference	Method
	Bouwer and Rice (1983) method	Boast and Langebartel (1984) method	Other method			
1			2.7	Moderate	Smith (2005)	Auger hole
2			5.8	Moderate	Smith (2005)	Auger hole
3			18.0	High	Smith (2005)	Auger hole
4			17.0	High	Smith (2005)	Auger hole
5			2.1	Moderate	Smith (2005)	Auger hole
6			7.0	Moderate	Smith (2005)	Auger hole
7			14.4	Moderate	Smith (2005)	Auger hole
8			14.2	Moderate	Smith (2005)	Auger hole
9			18.8	High	Smith (2005)	Auger hole
10			19.9	High	Smith (2005)	Auger hole
11			15.8	High	Smith (2005)	Auger hole
12			0.7	Low	Smith (2005)	Auger hole
13			5.1	Moderate	Smith (2005)	Auger hole
14			22.7	High	Smith (2005)	Auger hole
15			0.5	Low	Smith (2005)	Auger hole
16			9.8	Moderate	Smith (2005)	Auger hole
17			5.1	Moderate	Smith (2005)	Auger hole
18			0.6	Low	Smith (2005)	Auger hole
19			0.4	Low	Smith (2005)	Auger hole
20			0.05	Low	Smith (2005)	Auger hole
21			0.1	Low	Smith (2005)	Auger hole
22			3.9	Moderate	Smith (2005)	Auger hole
23			10.8	Moderate	Smith (2005)	Auger hole
24	19.6	28.3		High	Hirst et al. (2009)	Pit bailing
25	17.1	19.6		High	Hirst et al. (2009)	Pit bailing
26	18.4	28.1		High	Hirst et al. (2009)	Pit bailing
27	12.3	15.1		Moderate - High	Hirst et al. (2009)	Pit bailing
28	21.1	32.8		High	Hirst et al. (2009)	Pit bailing
29	157.0	154.8		Extremely high	Hirst et al. (2009)	Pit bailing
30	216.9	222.8		Extremely high	Hirst et al. (2009)	Pit bailing
31	143.1	148.1		Extremely high	Hirst et al. (2009)	Pit bailing
32	111.5	127.4		Extremely high	Hirst et al. (2009)	Pit bailing
33	196.5	216.1		Extremely high	Hirst et al. (2009)	Pit bailing
34	11.8	15.3		Moderate - High	Hirst et al. (2009)	Pit bailing
35	18.9	26.0		High	Hirst et al. (2009)	Pit bailing

Point ID	Saturated hydraulic conductivity (m/day)			Risk classification	Reference	Method
	Bouwer and Rice (1983) method	Boast and Langebartel (1984) method	Other method			
36	11.2	15.3		Moderate - High	Hirst et al. (2009)	Pit bailing
37	41.9	58.6		High	Hirst et al. (2009)	Pit bailing
38	42.2	53.8		High	Hirst et al. (2009)	Pit bailing
39		300.9		Extremely high	Rayner et al. (2020b)	Pit bailing
40		6.8		Moderate	Kempsey Shire Council (2004a)	Pit bailing
41		19.3		High	Kempsey Shire Council (2004a)	Pit bailing
42			0.8	Low	Rayner et al. (2020b)	Auger hole
43			0.3	Low	Rayner et al. (2020b)	Auger hole

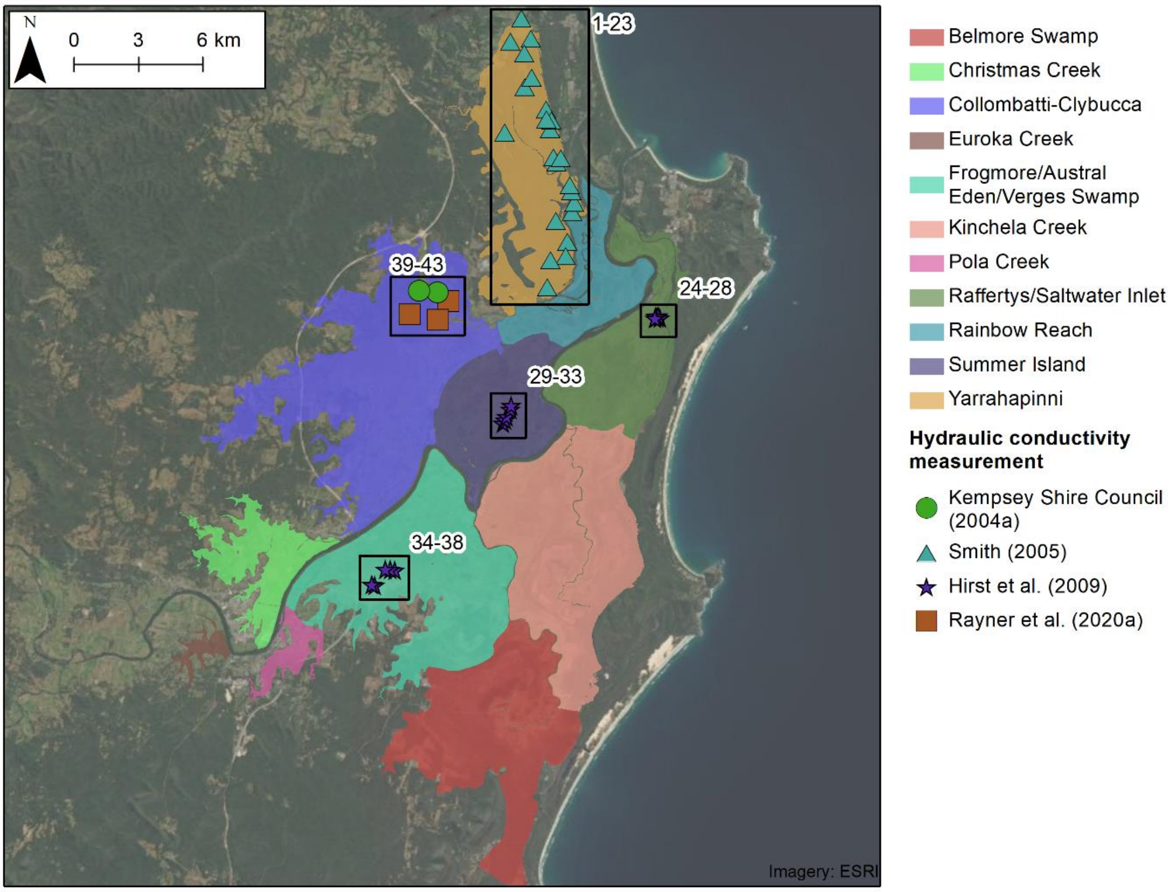

Figure C-1: Existing saturated hydraulic conductivity data available on the Macleay River floodplain

C3 Data collection

Following the data gaps analysis, a data collection program was completed to further supplement existing data. The auger hole slug test method was used as the primary way to determine the hydraulic conductivity across the coastal floodplains. This method was chosen:

- Due to drought conditions occurring at the time of field investigations, and the water table depth was too low to determine hydraulic conductivity using the standard pit bailing method at many sites;
- As it was easily implemented using the existing soil sampling equipment and did not require additional large machinery to be transported on-site; and
- As it allowed for hydraulic conductivity measurements to be taken at most soil sample locations.

In addition to the auger hole slug test method, the pit bailing and inverse auger methods were also used. Wherever the water table was high enough, a pit bailing test was completed as well as an auger hole slug test allowing for comparison of the two methodologies. In some circumstances, the water table was sufficiently deep below the ground surface that the auger hole created by the soil sampling equipment could not reach the water table. In these instances, the inverse auger method was used to obtain a hydraulic conductivity measurement. A detailed description of the sampling procedure and data analysis techniques used to calculate the hydraulic conductivity can be found in Appendix B of the Methods report (Rayner et al., 2020a). The hydraulic conductivity measurements obtained across the Macleay River floodplain are summarised in Table C-2 and the measurement location shown in Figure C-2.

During the data collection field campaign, it was observed that the water table within the sample hole used to measure hydraulic conductivity was below the mean low water spring (MLWS) tide level of nearby waterways. This was due to the ongoing drought conditions that were prevalent at the time of data collection (August 2019 – March 2020). The result of this was that the hydraulic conductivity measured using the slug test method is of a soil layer that is unlikely to contribute to export of acid via horizontal water movement. For this reason, it was decided that only hydraulic conductivity measurements where the water table was above the MLWS tide level would be used. This meant that only a selection of measurements in Table C-2 are representative of groundwater flow potential within acidic soil layers and are therefore applicable in the prioritisation methodology. Hydraulic conductivity data that has been used for the Macleay River floodplain to supplement existing data for the calculation of the groundwater factor and subsequently the risk ratings of the subcatchments within the floodplain, are identified in Table C-2 and shown in Figure C-2.

Table C-2: Summary of saturated hydraulic conductivity data collected by WRL and data used during the subcatchment prioritisation

Location ID	Easting (m) GDA94	Northing (m) GDA94	Hydraulic conductivity (m/day)	Risk classification	Measurement method	Data used for prioritisation?*
MA_02_PA	497314.3	6561083.3	0.1	Low	Auger hole	Below MLWS
MA_08_P	487335.6	6561201.8	88.6	High	Auger hole	Below MLWS
MA_11_A	481495.4	6561379.9	5.4	Moderate	Auger hole	Below MLWS
MA_11_P	481738.0	6560677.9	0.7	Low	Auger hole	Below MLWS
MA_13_P	484877.5	6566953.5	3.7	Moderate	Auger hole	Below MLWS
MA_16_A	501161.6	6577247.4	0.4	Low	Auger hole	Below MLWS
MA_16_PA	500487.5	6577535.9	1.4	Low	Auger hole	Below MLWS
MA_22_P	500839.7	6571885.9	152.8	Extremely high	Auger hole	Yes
MA_23_A	489837.1	6562910.8	105.7	Extremely high	Inverse auger	Yes
MA_23_PA	500194.3	6575287.3	0.3	Low	Auger hole	Below MLWS
MA_26_P	499196.8	6558683.5	>100	Extremely high	Auger hole	Yes
MA_31_A	498294.4	6566463.1	1.4	Low	Auger hole	Below MLWS
MA_33_P	485307.0	6565076.5	0.9	Low	Auger hole	Yes
MA_34_A	493372.5	6561523.9	1.2	Low	Auger hole	Yes
MA_36_A	499549.9	6564149.5	22.5	High	Pit bailing	Yes
MA_36_A	499549.9	6564149.5	0.7	Low	Auger hole	Yes
MA_36_P	492761.3	6563912.7	26.8	High	Auger hole	Below MLWS
MA_37_A	499608.3	6569673.2	0.2	Low	Auger hole	Yes
MA_38_A	498958.0	6574451.7	9.5	Moderate	Inverse auger	Yes
MA_39_A	502951.1	6579962.2	1.1	Low	Auger hole	Below MLWS
MA_41_A	484178.9	6566135.2	0.2	Low	Auger hole	Below MLWS

*Note: Only hydraulic conductivity values where the water table was above the MLWS level were used for subcatchment prioritisation.

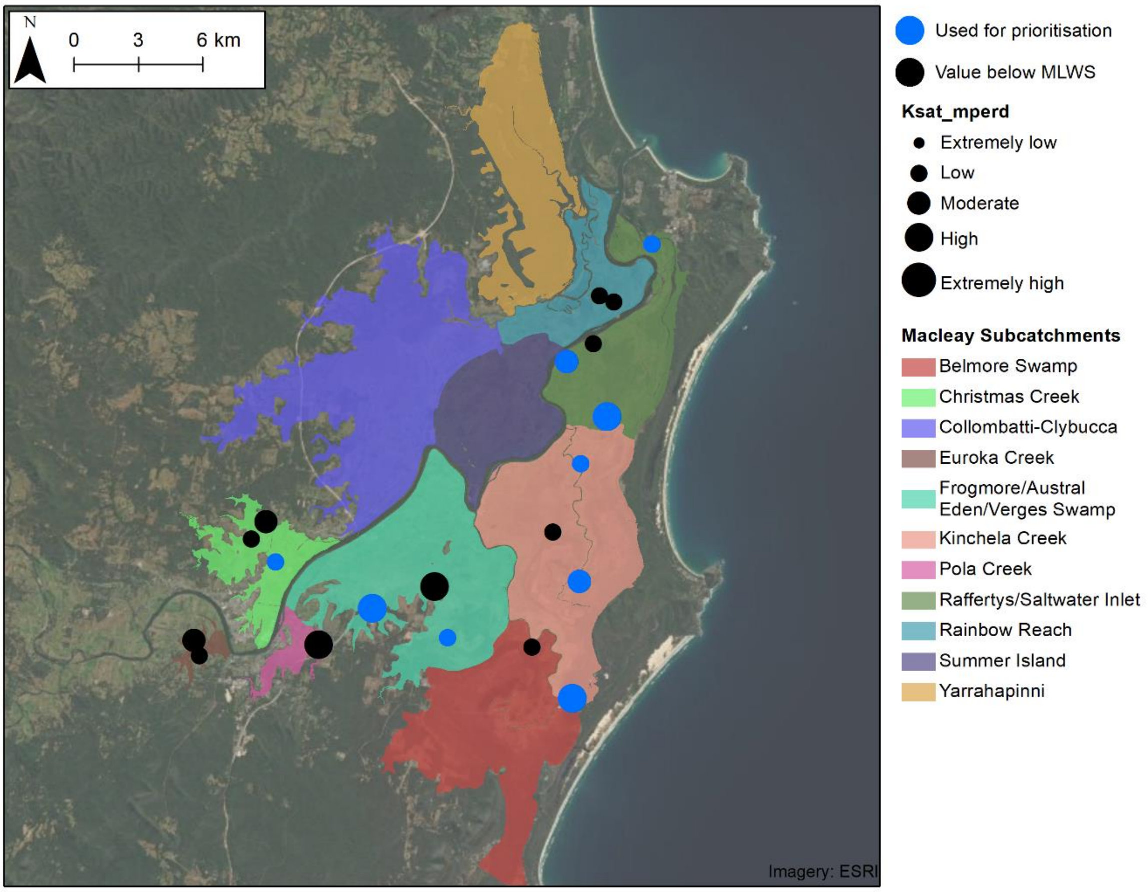

Figure C-2: Location of saturated hydraulic conductivity data collected by WRL and data used during the subcatchment prioritisation

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 Appendix B of the Methods report (Rayner et al., 2020a). The risk rating applies on a scale of one (1) to five (5) corresponding to the risk classifications with extremely low equating to a risk rating of one (1) and extremely high equating to a risk rating or five (5). This results in subcatchments with larger hydraulic conductivities having an increased risk as they are able to transport larger volumes of acidic groundwater to the estuary.

Note that the spatial coverage of hydraulic conductivity data across certain subcatchments of the Macleay River floodplain is poor. This is due to limitations experienced in the field investigations including situations whereby the groundwater table was sufficiently deep that no hydraulic conductivity measurements within contributing acidic soil layers could be taken. For subcatchments where there was no available data, it has been interpolated from adjacent subcatchments:

- Belmore Swamp has been assumed to have the same hydraulic conductivity as Frogmore/Austral Eden/Verges Swamp and Kinchela Creek;
- Pola Creek has been assumed to have the same hydraulic conductivity as Christmas Creek; and
- Euroka Creek has been assumed to have the same hydraulic conductivity as Christmas Creek.

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-3 and Figure C-3.

Table C-3: Summary of saturated hydraulic conductivity for each subcatchment in the Macleay River floodplain

Subcatchment	Hydraulic conductivity classification	Hydraulic conductivity risk rating	Number of data points per area*
Frogmore/Austral Eden/Verges Swamp	High	4	7
Summer Island	Extremely high	5	5
Rainbow Reach	Moderate	3	1
Kinchela Creek	High	4	4
Belmore Swamp*	High	4	0
Raffertys/Saltwater Inlet	High	4	8
Pola Creek*	low	2	0
Euroka Creek*	low	2	0
Yarrahapinni	Moderate	3	22
Collombatti-Clybucca	Extremely high	5	3
Christmas Creek	low	2	1

* Where no data was available risk classifications were interpolated from adjacent subcatchments.

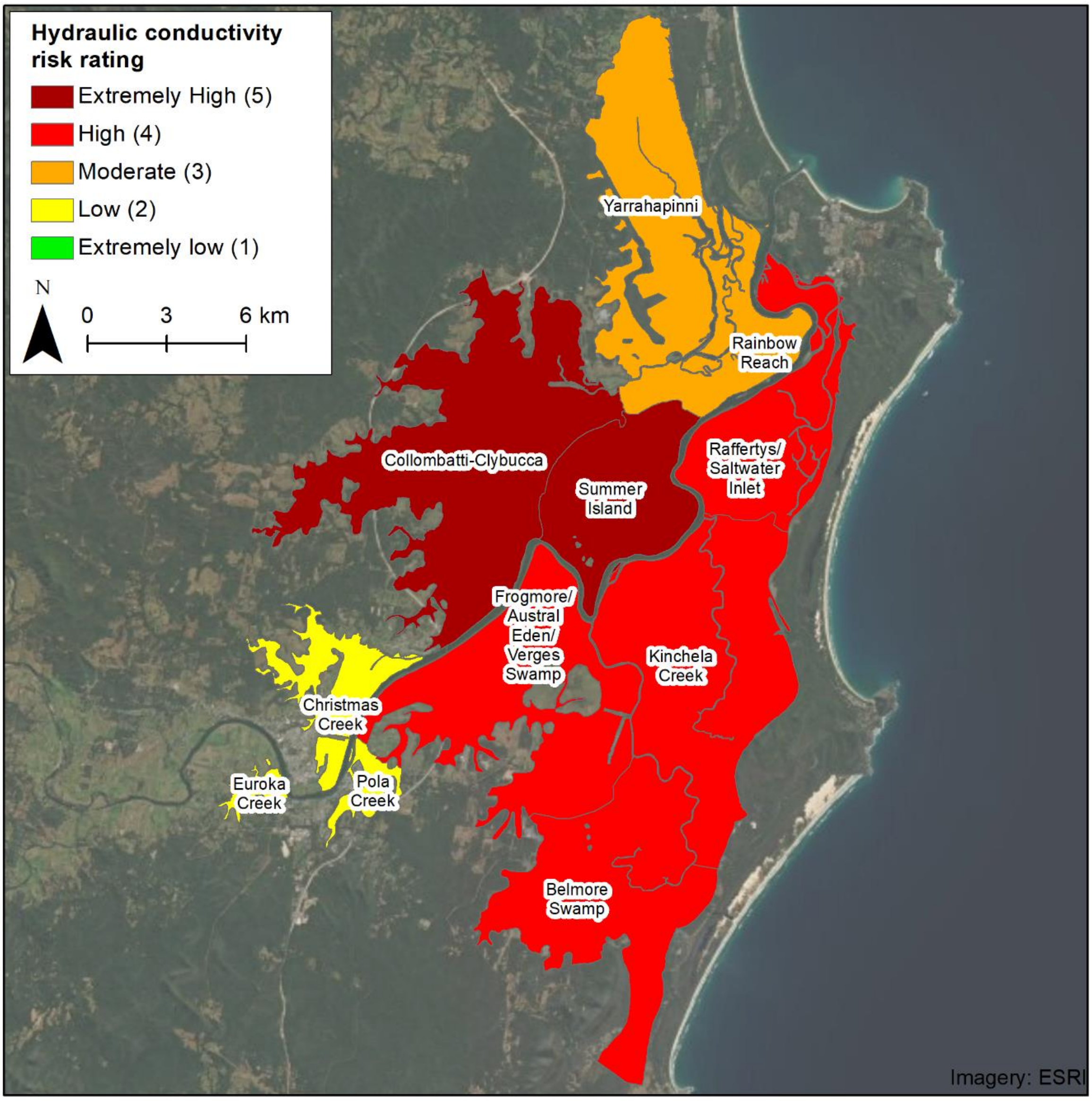

Figure C-3: Risk ratings for saturated hydraulic conductivity for each subcatchment in the Macleay River floodplain

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 Macleay River floodplain. This includes existing data available on the NSW Government eSPADE database and data in published literature where applicable (Section D2). In areas with limited existing soil profile information, a targeted field campaign was undertaken to address data gaps. Information on the data collected (including soil profiles) is summarised in Section D3.

D2 Existing soil profile data

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

- eSPADE Database (DPIE, 2020);
- Smith (2005);
- Edeson et al. (2004); and
- Rayner et al. (2020b)

D2.1 eSPADE database

eSPADE provides a database of information collected by earth scientists and other technical experts. eSPADE contains descriptions of soils, landscapes and other geographic features, and is used by the NSW Government, other organisations, and individuals, to improve planning and decision-making for land management. eSPADE contains extensive soil profile data for the Macleay 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 Macleay River 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 near neutral pH (pH 7 to 8) below an acidic layer indicates a potential acidic layer, 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.

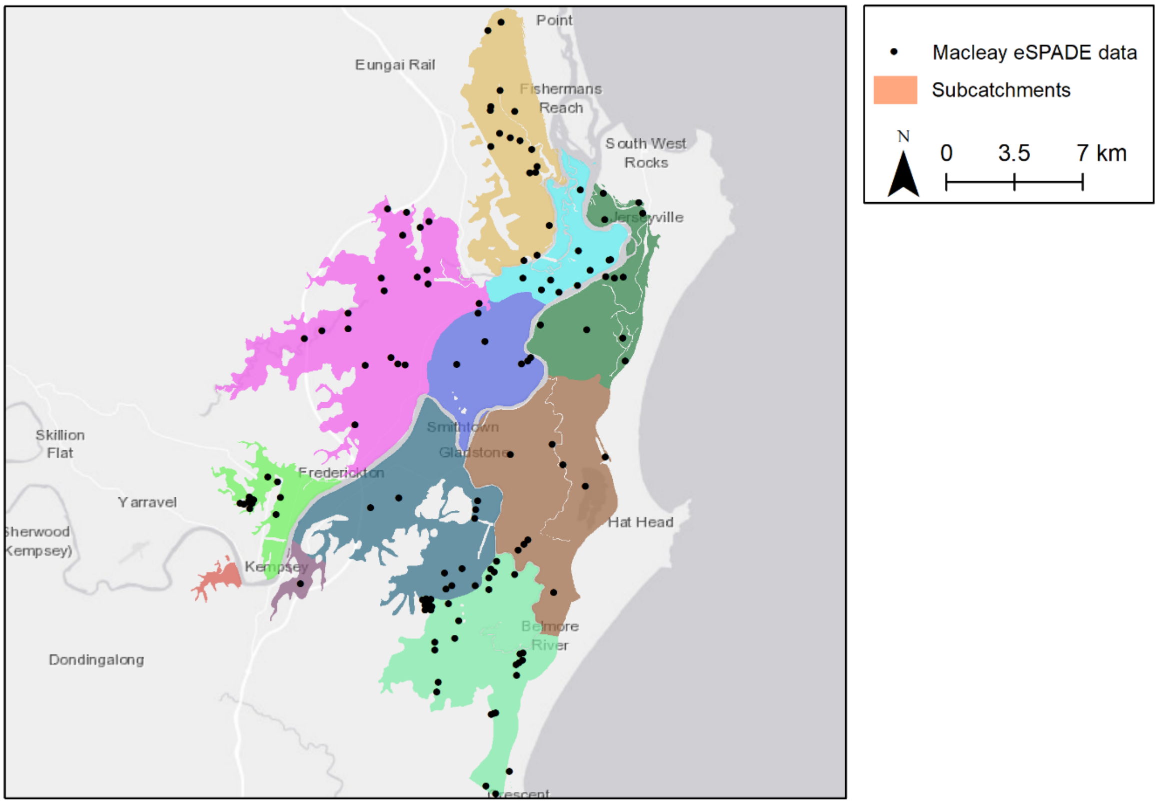

Figure D-1: Location of applicable eSPADE soil profiles in the study region

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**
15746	Belmore Swamp	496244	6550008	0.7	2	5
15753	Belmore Swamp	494144	6557988	0.9	1.5	4.5
15754	Belmore Swamp	497624	6556858	0.5	2	3.5
15755	Belmore Swamp	497654	6557238	0.9	2.5	4.5
15757	Belmore Swamp	496164	6561388	0.4	2	3.5
14055	Belmore Swamp	492604	6559438	0.9	2.7	4.5
14056	Belmore Swamp	492604	6559688	1.3	0.65	5
14057	Belmore Swamp	492804	6559563	0.4	2.9	4.5
14058	Belmore Swamp	492954	6559613	0.5	2.9	4
14059	Belmore Swamp	492904	6559438	0.3	2.9	4
14060	Belmore Swamp	492804	6559738	0.2	2.7	6
14061	Belmore Swamp	492479	6559963	0.3	1	5.5
14062	Belmore Swamp	492654	6560013	0.1	2	6.5
14063	Belmore Swamp	492904	6559988	0.3	2.8	6
4851	Belmore Swamp	495754	6550388	0.1	1.1	3.5

eSPADE profile ID	Subcatchment	Easting	Northing	Surface elevation (m AHD)*	Total profile depth (m)	Minimum pH**
4852	Belmore Swamp	496944	6551138	7.4	8	5.5
4869	Belmore Swamp	496304	6561938	1.8	1.2	6
4870	Belmore Swamp	496004	6561538	0.3	0.8	4.5
4871	Belmore Swamp	495904	6560488	1.3	1	6
4873	Belmore Swamp	495904	6561088	0.3	1	4.5
4879	Belmore Swamp	497504	6557178	0.6	1	4.5
4880	Belmore Swamp	497444	6556728	0.2	0.9	4.5
4881	Belmore Swamp	497304	6556628	0.2	0.9	4.5
4882	Belmore Swamp	497324	6556088	0.2	0.8	4.5
4883	Belmore Swamp	497224	6561268	1.5	0.9	6
5067	Belmore Swamp	493824	6559758	0.5	2	4.5
5068	Belmore Swamp	494354	6558898	1.2	2.5	5
5069	Belmore Swamp	493124	6557788	0.6	2.1	4.5
5070	Belmore Swamp	493124	6557378	0.6	1.9	4.5
5071	Belmore Swamp	493304	6555728	1.1	2.3	5.5
5072	Belmore Swamp	493214	6555238	1.9	2.3	4.5
5084	Belmore Swamp	496024	6554078	0.5	0.75	4.5
5085	Belmore Swamp	496144	6554118	0.4	0.7	4.5
5086	Belmore Swamp	496244	6554148	0.7	2	4.5
4795	Christmas Creek	484944	6564338	1.7	1.2	4.5
4797	Christmas Creek	485174	6565228	1.7	1.2	5
4798	Christmas Creek	484534	6566278	1.6	0.9	4.5
4799	Christmas Creek	485024	6566018	1.1	1.3	5
5076	Christmas Creek	483094	6564928	1.5	1.5	4.5
5077	Christmas Creek	483304	6564858	1.2	1.5	4.5
5078	Christmas Creek	483554	6565048	1.3	1.5	4.5
5079	Christmas Creek	483569	6565238	1.4	1.5	4.5
5080	Christmas Creek	483614	6564938	0.9	1.5	4.5
5081	Christmas Creek	483724	6564928	1.1	1.5	4.5
5082	Christmas Creek	483804	6565088	1.4	1.4	4.5
5083	Christmas Creek	483604	6564638	0.9	1.5	4.5
15764	Collombatti-Clybucca	489004	6568938	1.3	2	4
17880	Collombatti-Clybucca	491588	6572041	1.9	2.1	7
17881	Collombatti-Clybucca	489529	6572002	1.1	3	3.5
17882	Collombatti-Clybucca	488663	6573878	1.1	2.7	4
17883	Collombatti-Clybucca	490510	6575826	0.7	2.05	4
17885	Collombatti-Clybucca	486404	6573388	1.3	2.05	5
17886	Collombatti-Clybucca	487304	6573788	1.0	2.8	3.5

eSPADE profile ID	Subcatchment	Easting	Northing	Surface elevation (m AHD)*	Total profile depth (m)	Minimum pH**
17887	Collombatti-Clybucca	488654	6574688	0.6	2.6	5
17901	Collombatti-Clybucca	490682	6580048	0.8	3.1	4
17902	Collombatti-Clybucca	491674	6579859	1.2	1.7	5
17903	Collombatti-Clybucca	491458	6578700	0.3	3.1	3.5
17906	Collombatti-Clybucca	490351	6576487	0.7	2.8	4
17907	Collombatti-Clybucca	492762	6576196	0.7	2.1	4.5
7844	Collombatti-Clybucca	492364	6579088	1.9	1.1	6
7845	Collombatti-Clybucca	492804	6579388	1.7	1.2	5
7846	Collombatti-Clybucca	492204	6576538	0.6	1.8	5.5
7847	Collombatti-Clybucca	492704	6576918	0.5	1.6	5
7878	Collombatti-Clybucca	490854	6572408	1.4	2.2	5
7879	Collombatti-Clybucca	491204	6572088	1.7	1.2	6
7881	Collombatti-Clybucca	495404	6575188	1.6	2	4.5
15758	Frogmore/Austral Eden/Verges Swamp	494524	6561568	0.8	1.7	3.5
15759	Frogmore/Austral Eden/Verges Swamp	494004	6560678	1.0	1.5	5
4814	Frogmore/Austral Eden/Verges Swamp	491254	6565188	1.5	1.2	5.5
4820	Frogmore/Austral Eden/Verges Swamp	489804	6564688	1.6	1	5.5
4872	Frogmore/Austral Eden/Verges Swamp	495204	6560688	0.7	1	4.5
4875	Frogmore/Austral Eden/Verges Swamp	495314	6565048	1.5	1.05	5
4876	Frogmore/Austral Eden/Verges Swamp	495224	6564588	1.1	0.85	5.5
4877	Frogmore/Austral Eden/Verges Swamp	495174	6564138	1.8	1.05	5.5
5065	Frogmore/Austral Eden/Verges Swamp	493624	6561338	0.6	1.5	4.5

eSPADE profile ID	Subcatchment	Easting	Northing	Surface elevation (m AHD)*	Total profile depth (m)	Minimum pH**
5066	Frogmore/Austral Eden/Verges Swamp	493684	6560518	1.0	1.2	5.5
15756	Kinchela Creek	499224	6560328	0.3	1.6	4.5
15763	Kinchela Creek	500854	6565788	0.4	2	4
4791	Kinchela Creek	499704	6566888	0.9	0.9	5.5
4884	Kinchela Creek	497404	6562508	1.4	1	5.5
4885	Kinchela Creek	497704	6562828	0.6	1.5	5
4886	Kinchela Creek	497904	6563048	0.4	0.9	4.5
4887	Kinchela Creek	497004	6567428	0.7	0.7	5.5
4888	Kinchela Creek	499144	6567958	0.9	2	5
5073	Kinchela Creek	501884	6567308	1.8	2.3	5
15719	Pola Creek	486214	6560788	2.2	2.5	4.5
17872	Raffertys/Saltwater Inlet	503813	6579824	1.3	1.25	5.5
17873	Raffertys/Saltwater Inlet	498540	6574074	1.3	1.95	5.5
17874	Raffertys/Saltwater Inlet	500921	6573829	0.6	1.95	4.5
17875	Raffertys/Saltwater Inlet	502904	6572238	0.8	0.7	4.5
17876	Raffertys/Saltwater Inlet	502789	6573411	0.5	2.1	4.5
17890	Raffertys/Saltwater Inlet	501785	6580849	1.2	1	4.5
17891	Raffertys/Saltwater Inlet	501864	6579483	1.0	2.3	5
17895	Raffertys/Saltwater Inlet	502811	6576546	0.6	3.1	4.5
7883	Raffertys/Saltwater Inlet	501904	6576558	1.4	2.3	5
7884	Raffertys/Saltwater Inlet	502354	6576488	1.4	1.5	5.5
15012	Raffertys/Saltwater Inlet	503614	6580368	1.3	0.87	5.5
17849	Rainbow Reach	497693	6577399	1.5	1.9	8.5
17852	Rainbow Reach	497651	6576475	1.3	1.95	8
17853	Rainbow Reach	499498	6575755	1.6	1.95	6
17854	Rainbow Reach	499067	6576388	0.5	1.5	5.5
17869	Rainbow Reach	500504	6577888	0.4	1.95	4
17870	Rainbow Reach	500600	6581019	0.9	1.95	5
17899	Rainbow Reach	502080	6577407	1.2	2.2	5
17900	Rainbow Reach	502154	6577438	1.1	2.4	5.5
7871	Rainbow Reach	498604	6575888	1.1	1.2	5.5
7872	Rainbow Reach	500454	6576118	0.9	2.1	6
7873	Rainbow Reach	501104	6576888	1.1	1.8	6.5
17888	Summer Island	494235	6572067	1.2	2.6	5
17889	Summer Island	495701	6573232	0.6	2.8	4.5

eSPADE profile ID	Subcatchment	Easting	Northing	Surface elevation (m AHD)*	Total profile depth (m)	Minimum pH**
7874	Summer Island	498054	6572408	2.8	2.3	6
7875	Summer Island	497904	6572238	2.3	2	9
7876	Summer Island	497564	6572068	1.0	1.2	5
7882	Summer Island	495354	6574688	1.4	2	4.5
17845	Yarrahapinni	499004	6579188	1.1	0.8	6
17846	Yarrahapinni	498004	6581888	0.9	0.9	6
17847	Yarrahapinni	498287	6581911	0.5	1.6	3.5
17848	Yarrahapinni	498375	6582230	0.3	0.9	3.5
17850	Yarrahapinni	498382	6577654	1.1	1.3	5.5
17877	Yarrahapinni	496517	6589624	1.4	1	5
17878	Yarrahapinni	496480	6586119	0.7	2.3	4
17879	Yarrahapinni	497219	6585054	0.4	1.5	6
17904	Yarrahapinni	495972	6585098	1.3	1.65	4
17905	Yarrahapinni	497493	6583550	0.2	2	3.5
7829	Yarrahapinni	498104	6583088	0.7	1.6	4
7830	Yarrahapinni	497004	6583688	0.9	1.8	7.5
7831	Yarrahapinni	496444	6583928	1.6	1.1	6.5

D2.2 Other literature

Published and grey literature were investigated for other soil profiles within the Macleay River floodplain, which included data from thesis documents (Smith, 2005), journal articles (Edeson et al., 2004) and previous WRL investigations (Rayner et al., 2020b). Locations of the profiles are shown in Figure D-2. 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 Macleay floodplain. The location of all relevant soil profiles from the literature within the study area is presented 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-2.

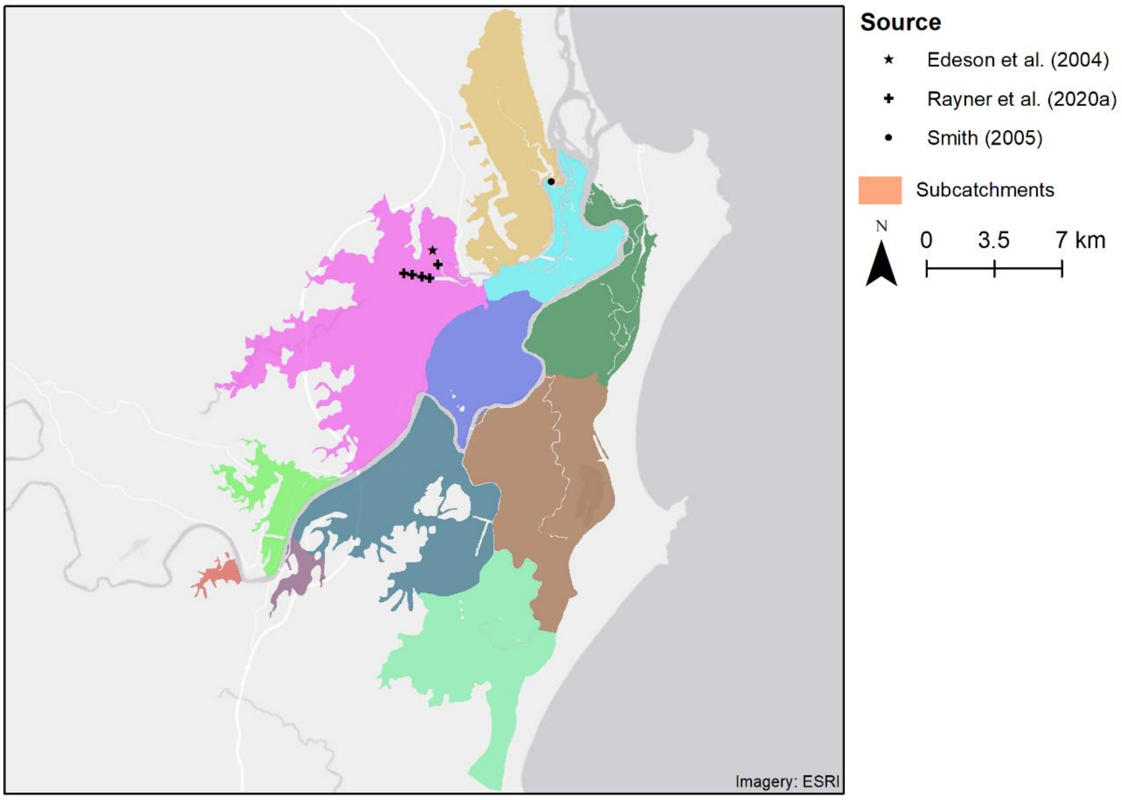

Figure D-2: Location of applicable soil profiles from literature in the study region

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

Profile	Subcatchment	Easting	Northing	Surface Elevation (m AHD)	Total Profile Depth (m)	Minimum pH
Rayner_2020_1	Collombatti-Clybucca	493341	6577141	0.4	3	4.9
Edeson_2004	Collombatti-Clybucca	493076	6577893	0.2	3.1	3.4
Smith_2005_JSML1	Rainbow Reach	499210	6581460	-0.2	18	7.4
CLYB-BH01	Collombatti-Clybucca	493341	6577141	0.42	3	4.9
CLYB-BH02	Collombatti-Clybucca	492912	6576433	0.37	3	4.1
CLYB-BH03	Collombatti-Clybucca	492510	6576502	0.37	2.56	4.8
CLYB-BH04	Collombatti-Clybucca	492005	6576597	0.28	2.25	4.3
CLYB-BH05	Collombatti-Clybucca	491586	6576670	0.34	2.35	5

D3 Field campaign

Following a data collation and data gaps analysis, a targeted field campaign was undertaken to collect data in areas with limited information. Information on field data collection methods can be found in Appendix A of the Methods report (Rayner et al., 2020a). The location of an additional 23 soils profiles collected for this study is shown in Figure D-3, and a summary of the soil profile data, including approximate surface elevation and minimum profile pH (within the tidal range), is provided in Table D-3. Detailed data logs of each of soil profile is provided in Appendix K .

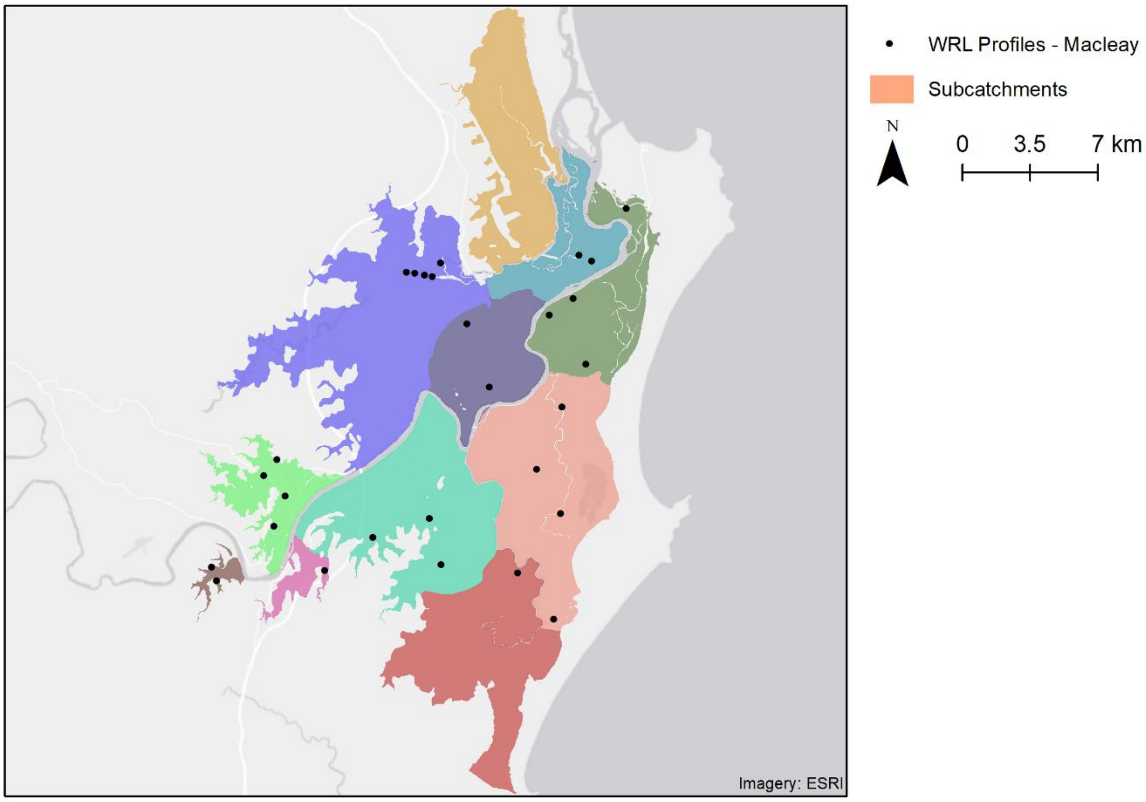

Figure D-3:Location of soil profiles from WRL field investigations

Table D-3: Summary of relevant soil profiles from WRL field investigations

Profile	Subcatchment	Easting	Northing	Surface Elevation (m AHD)	Total Profile Depth (m)	Minimum pH
MA_02_PA	Belmore Swamp	497314	6561083	-0.26	1.75	3.5
MA_08_P	Pola Creek	487336	6561202	1.21	2.2	5
MA_11_A	Euroka Creek	481495	6561380	0.76	1.6	5.3
MA_11_P	Euroka Creek	481738	6560678	0.99	2.7	4.3
MA_13_A	Christmas Creek	484731	6563502	1.62	3.6	4.5
MA_13_P	Christmas Creek	484878	6566954	0.90	1.65	4.9
MA_16_A	Rainbow Reach	501162	6577247	0.30	1.8	5.6
MA_16_PA	Rainbow Reach	500488	6577536	0.50	1.45	7.3
MA_22_P	Raffertys/Saltwater Inlet	500840	6571886	0.36	1.26	4.3
MA_23_A	Frogmore/Austral Eden/Verges Swamp	489837	6562911	1.01	3.45	4.4
MA_23_PA	Raffertys/Saltwater Inlet	500194	6575287	0.54	2.18	5.5
MA_26_P	Kinchela Creek	499197	6558684	0.06	1.85	4.8
MA_28_A	Summer Island	495851	6570710	0.89	2.65	5.7
MA_31_A	Kinchela Creek	498294	6566463	0.06	1.6	4.3
MA_33_P	Christmas Creek	485307	6565077	1.32	2.3	4.7
MA_34_A	Frogmore/Austral Eden/Verges Swamp	493372	6561524	0.30	1.6	4.4
MA_36_A	Kinchela Creek	499550	6564150	0.10	1.5	4.1
MA_36_P	Frogmore/Austral Eden/Verges Swamp	492761	6563913	0.96	2.8	4.3
MA_37_A	Kinchela Creek	499608	6569673	1.48	2.5	6.1
MA_38_A	Raffertys/Saltwater Inlet	498958	6574452	0.83	3.27	6.4
MA_39_A	Raffertys/Saltwater Inlet	502951	6579962	1.02	1.6	5.1
MA_41_A	Christmas Creek	484179	6566135	0.80	2.3	4.3
MP_20_C	Summer Island	494704	6573976	0.98	1.9	5.9

D4 Summary of soil acidity for prioritisation

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

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

All else being equal, a higher hydrogen concentration (i.e. more acidic) and larger contributing depth is an indicator of a greater potential for acid generation and export. More information on how these are calculated can be found in Section 4. 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 Macleay 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
Belmore Swamp	23.2	1.2	27.9	35
Christmas Creek	24.0	1.2	28.8	16
Collombatti-Clybucca	35.6	1.2	42.8	27
Euroka Creek	6.2	1.1	6.8	2
Frogmore/Austral Eden/Verges Swamp	29.5	1.2	35.4	13
Kinchela Creek	11.9	1.2	14.2	13
Pola Creek	11.9	1.2	14.2	2
Raffertys/Saltwater Inlet	8.7	1.5	13.0	15
Rainbow Reach	2.9	1.5	4.3	14
Summer Island	5.2	1.2	6.3	8
Yarrahapinni	27.4	1.5	41.1	16

D5 Data confidence

As shown in Table D-4, the number of profiles in each catchment varies quite significantly. There are two (2) catchments in particular that only have two (2) profiles in the area:

- Pola Creek; and
- Euroka Creek.

Confidence in this data is therefore limited, so information in literature on ASS or water quality has been consulted to provide greater certainty in the pH factor.

Spot measurements of water quality in Pola Creek were measured by Kempsey Shire Council between 2015 and 2018. The mean pH in these measurements was 7.9 (from 85 measurements) and all but two (2) of the measurements were above 5.5. Two (2) measurements, both in March 2018, read a pH of 3.4 and 3.7. However, rainfall data from Kempsey indicated that this was not associated with a rainfall event, so it is unclear whether this is associated with acid sulfate soils. The pH factor at Pola Creek was calculated as 14.2, which is the 6th highest in the Macleay River catchment. The water quality data available is insufficient to determine whether the two (2) available profiles are representative. More soil profile investigations are recommended. No changes have been made to the pH factor.

Similarly, spot measurements of water quality in Euroka Creek had a mean pH in these measurements of 7.2 (from 86 measurements) and all but two (2) of the measurements were above 5.5. Two (2) measurements, both in March 2018, read a pH of 2.1 and 4.4, in the same period as the low measurements in Pola Creek. Again, this is insufficient to determine whether the two (2) available profiles are representative, and more soil profile investigations are recommended. No changes have been made to the pH factor.

Appendix E Blackwater elevation threshold

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 Macleay River. The water level analysis undertaken is summarised in Section 5 of the Methods report (Rayner et al., 2020a).

E2 Water level gauges

There are seven (7) water level gauges operated by NSW DPIE Manly Hydraulics Laboratory (MHL) in the Macleay 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.

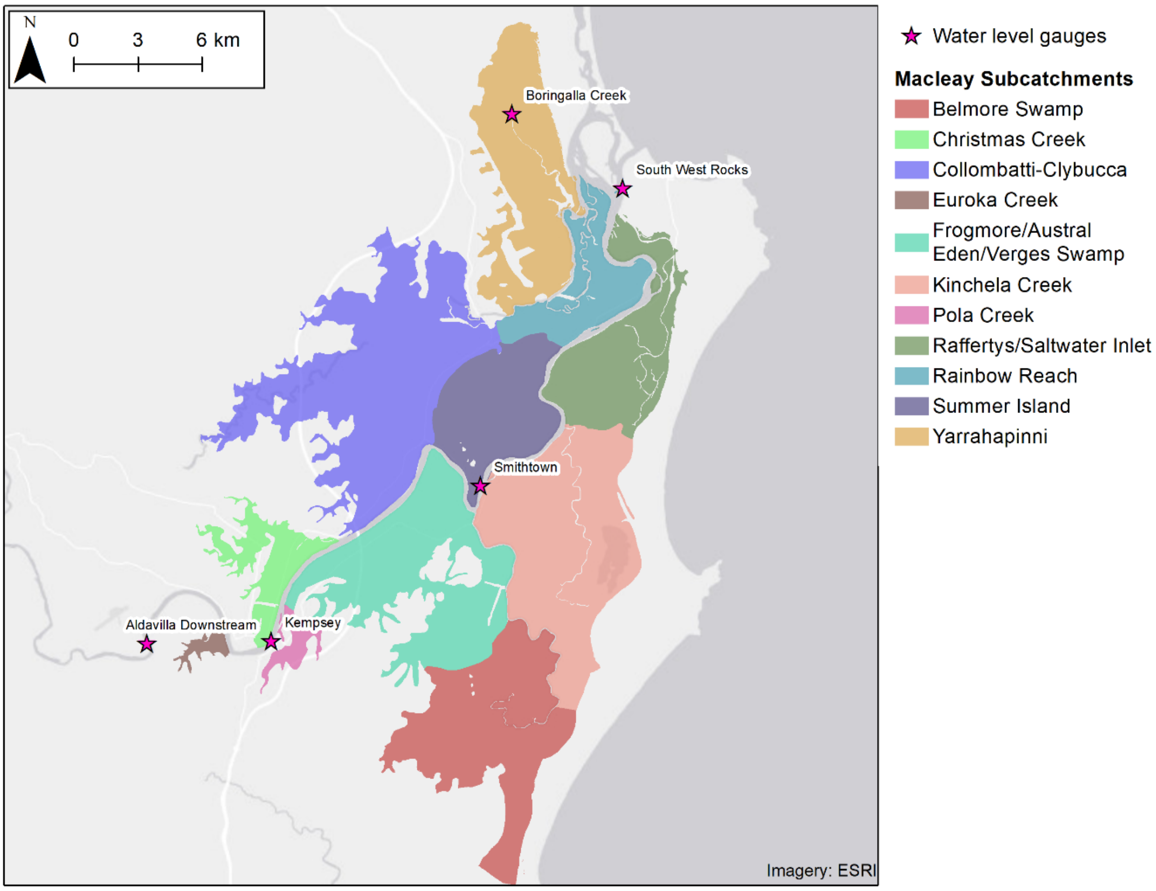

Figure E-1: Locations of water level gauges used for blackwater elevation thresholds

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)
South West Rocks	2.2	31.4	0.5
Boringalla Creek	Not on main river	11.9	N/A**
Smithtown	24.0	33.2	0.4
Kempsey	41.5	35.3	0.5
Aldavilla Downstream	50.9	11.9	0.5

* Excluding data gaps of greater than 6 hours.
** Minimum level of 0.5 assumed from South West Rocks.

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)
South West Rocks	0.5	0.5	0.5	0.5
Boringalla Creek	0.5	1.1	1.0	1.1
Smithtown	0.4	1.1	1.6	3.7
Kempsey	0.5	2.2	2.6	5.6
Aldavilla Downstream	0.5	1.4	3.0	6.7

E3 Subcatchment elevation thresholds

The subcatchments of the Macleay 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 are 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 is 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
Belmore Swamp*	Assumed to be the same as Frogmore-Austral Eden-Verges Swamp
Christmas Creek	0.33 x Smithtown + 0.67 x Kempsey
Collombatti-Clybucca*	Assumed to be the same as Yarrahapinni
Euroka Creek	0.77 x Kempsey + 0.23 x Aldavilla Downstream
Frogmore-Austral Eden-Verges Swamp	0.92 x Smithtown + 0.08 x Kempsey
Kinchela Creek	0.23 x South West Rocks + 0.77 x Smithtown
Pola Creek	0.09 x Smithtown + 0.91 x Kempsey
Raffertys-Saltwater Inlet	0.50 x South West Rocks + 0.50 x Smithtown
Rainbow Reach	0.82 x South West Rocks + 0.18 x Smithtown
Summer Island	0.35 x South West Rocks + 0.65 x Smithtown
Yarrahapinni	Boringalla Creek

* Neither Collombatti-Clybucca or Belmore Swamp 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 Macleay River floodplain

Subcatchment	Minimum level (m AHD)	Median level (m AHD)	Mean level (m AHD)	Maximum level (m AHD)
Belmore Swamp	0.4	1.2	1.7	3.8
Christmas Creek	0.5	1.9	2.3	5
Collombatti-Clybucca	0.5	1.1	1.0	1.1
Euroka Creek	0.5	2	2.7	5.9
Frogmore-Austral Eden-Verges Swamp	0.4	1.2	1.7	3.8
Kinchela Creek	0.4	1	1.3	3
Pola Creek	0.5	2.1	2.5	5.4
Raffertys-Saltwater Inlet	0.5	0.8	1.0	2.1
Rainbow Reach	0.5	0.6	0.7	1.1
Summer Island	0.4	0.9	1.2	2.6
Yarrahapinni	0.5	1.1	1.0	1.1

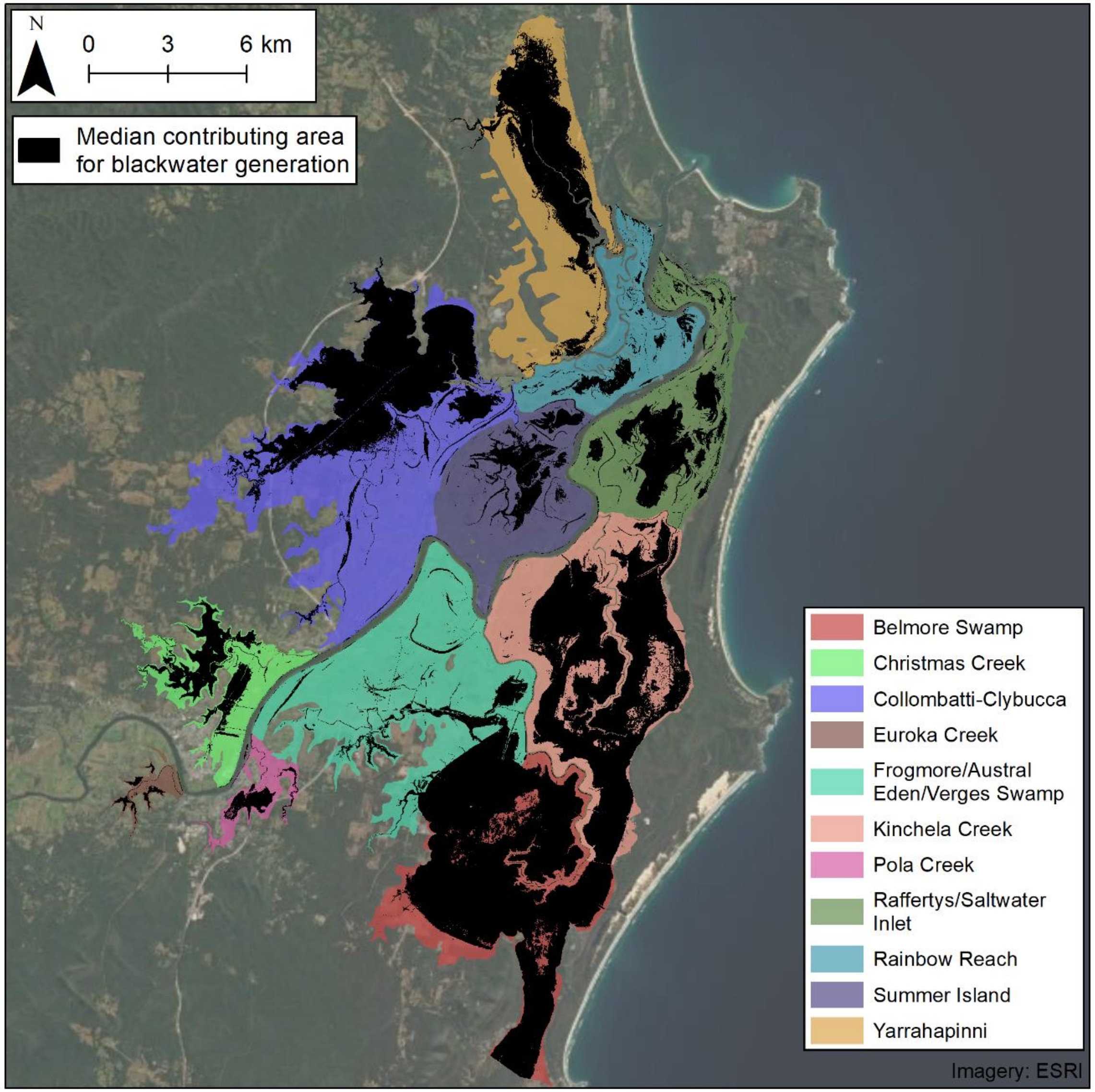

Figure E-2: Areas in the Macleay River floodplain below the median elevation threshold

Appendix F Floodplain infrastructure

F1 Preamble

A range of floodplain infrastructure exists across the Macleay River floodplain for the purpose of drainage and inundation protection (tidal and flooding). Included within this infrastructure are 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 Macleay River floodplain. This includes results of a data gaps analysis, an assessment of data for critical floodplain infrastructure and details of infrastructure condition and maintenance programs. Data tables containing information on floodplain infrastructure are provided.

F2 Data gaps analysis

F2.1 Existing infrastructure data

Prior to the data collection program undertaken as part of this study, the existing data available for floodplain infrastructure was collated. Floodplain infrastructure data was reviewed from the following sources and has been summarised in Table F-1.

- Floodgate and levee data provided by Kempsey Shire Council (KSC);
- Hydrodynamic modelling completed for Yarrahapinni Wetlands National Park (Glamore et al., 2012);
- A feasibility study of remediation options for the Collombatti-Clybucca floodplain (Glamore and Rayner, 2017); and
- Flood modelling completed for the Macleay River floodplain (Chong, 2019).

Table F-1: Description of existing data sources

Source	Description
KSC - GIS	GIS shapefiles containing location and ownership information for floodgates and levees managed by KSC. Invert levels of structures have been derived from flood mitigation drawings and inspections of a number of structures indicated that the levels are design levels and as built. Note, invert levels appear to be provided in Standard Datum.
KSC - spreadsheets	A spreadsheet containing invert and dimension information for flood mitigation structures. Information summarises data from flood mitigation design drawings. Note, approximate invert levels have been provided in Standard Datum. Inspections of a number of structures indicated that levels are design levels and as built.
KSC - CAD	CAD files containing crest level information for levee structures on the Macleay River floodplain.
KSC - photos	Photos taken of flood mitigation structure condition completed during assessment completed in 2012.
KSC - PDFs	Design drawing for flood mitigation structures that were constructed from the 1950s to 1970s. Drawings are provided in Standard Datum. Inspection of a number of structures indicated that levels are design levels and not work as executed. Inspection reports for flood mitigation structure condition completed in 2012.
Glamore et al. (2012)	A hydrodynamic model was completed to assess rehabilitation options for the Yarrahapinni Wetlands. During the investigation fieldwork was completed which included survey measurements of the main headworks for the system.
Glamore and Rayner (2017)	A feasibility study was completed to assess possible actions that could be undertaken to remediate acid sulfate soils on the Collombatti-Clybucca floodplain. As part of the investigation survey measurements were taken for key floodplain infrastructure including the Menarcobrinni floodgates. Reporting presented the elevation outline in the flood mitigation design drawings. Survey measurements of the invert completed during the study differed from the flood mitigation design drawings.
Chong (2019)	A TUFLOW model was developed for the purpose of flood modelling of the Macleay River floodplain and included information on levee crest elevations and some culvert inverts. Data for the flood model was collated from data provided by KSC and field investigations.

Across the Macleay River floodplain existing data for floodplain infrastructure is generally limited to location information. The majority of data available for invert, obvert elevation measurements was found to be in Standard Datum, was from design drawings and not as constructed elevations. Where no other data was available, conversions from Standard Datum to Australian Height Datum has been completed. This process included converting data from feet to metres and then subtracting a 0.11 m correction. This correction value has been calculated by the NSW Department of Finance and Services (2012) for the closest available survey mark (PM7460). For levee structures, detailed data collected for flood modelling and during asset audit inspections, along with LiDAR observations, means that crest elevation data is well represented across the floodplain (information specific to levees has been addressed in Section F3.2).

During the data gaps analysis, aerial imagery and waterways spatial datasets were used to determine possible locations for end of system infrastructure that was not included in the existing infrastructure data sources. Verification of the existence of these structures was undertaken, where possible, during the data collection campaign. Where inspection of these structures was not possible due to access restrictions, the structure has been marked as “unknown”. In these circumstances the existence of the structure and structure geometry requires confirmation.

A summary table of existing structure data is provided in Section F6. Note that during the gaps analysis only data for end of system structures such as floodgates that discharge directly to the Macleay River estuary were assessed. Subsequently, there may be existing data available for structures that are located upstream of end of system infrastructure which do not directly discharge to the Macleay River estuary.

F2.2 Data collection

Field investigations were completed to obtain invert and dimension data for floodplain infrastructure within the Macleay River floodplain. Focus of the investigations was on collecting data for primary end of system floodgate structures, however, data was also collected opportunistically for other floodplain infrastructure. Figure F-1 summarises the data available for end of system floodplain structures. A summary table of all structure data measured during the field investigations is provided in Section F6. In 2021, additional floodgate survey was collected by Abbott & Macro to fill remaining data gaps, which is also summarised in Section F6.

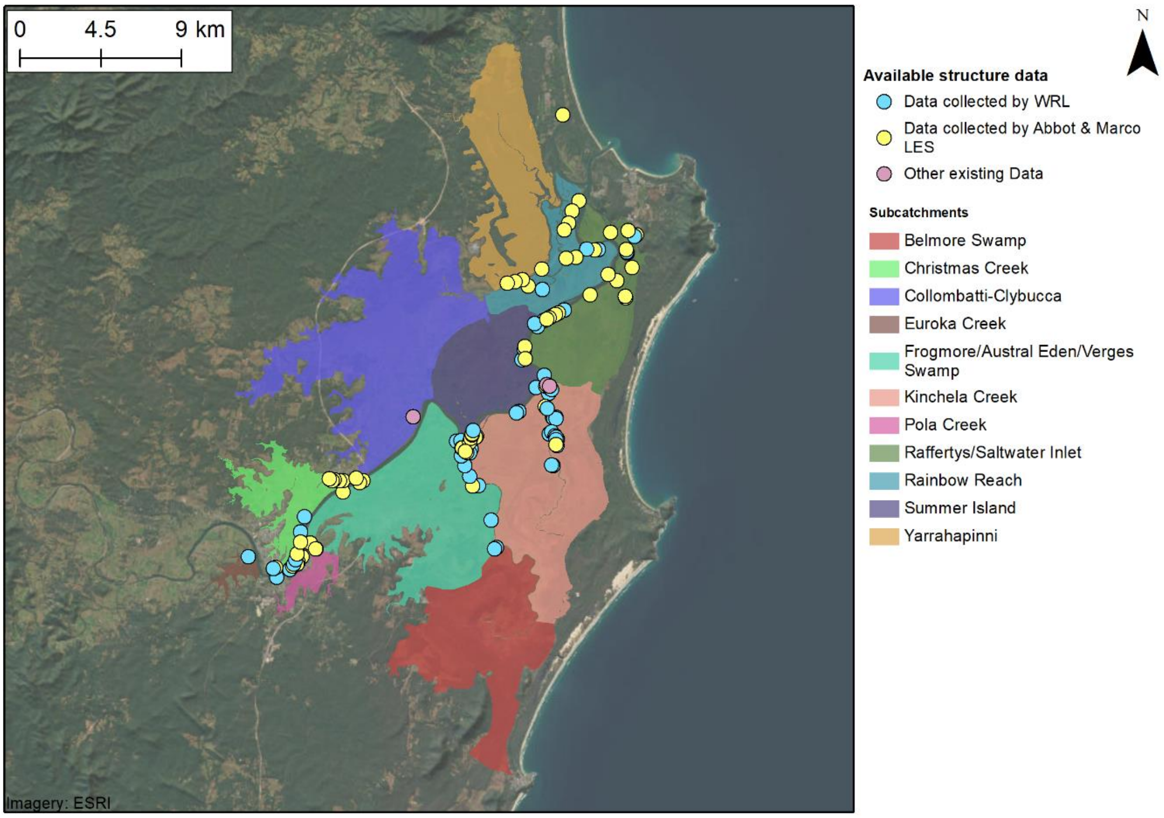

Figure F-1: Summary of end of system infrastructure with data available for the Macleay River floodplain

F3 Assessment of critical floodplain infrastructure

F3.1 End of system structures

A floodplain infrastructure assessment was completed with particular focus given to end of system (EOS) structures which act as barriers to prevent the upstream flow of tidal waters and limit the risk of backwater flooding from the river. Examples of EOS structures include weirs or one-way floodgates which work alongside levee banks to facilitate drainage while preventing inundation of the floodplain, often where agricultural land use practices are undertaken. These EOS structures have been separated into two categories:

1. Primary EOS structures: floodplain infrastructure that plays a significant role in draining the upstream catchment. An example of a primary EOS structure is the Menarcobrinni floodgates on Clybucca Creek.
2. Secondary EOS structures: floodplain infrastructure that provides drainage for small floodplain areas which are insignificant when compared to the total catchment drainage. An example of a secondary EOS structure would be a 300 mm diameter floodgate draining local catchment runoff on a paddock scale.

The location and condition of individual EOS structures have management implications due to their operation as drainage and flood mitigation devices. For this reason, EOS structures have been carefully considered during the development of the management options. Furthermore, EOS structures are vulnerable to sea level rise as a result of climate change, resulting in reduced drainage potential. A detailed vulnerability assessment has been completed for EOS floodgate structures (see Section 7). Figure F-2 provides the locations, category and survey status for the 153 EOS structures which have been identified within the Macleay River floodplain.

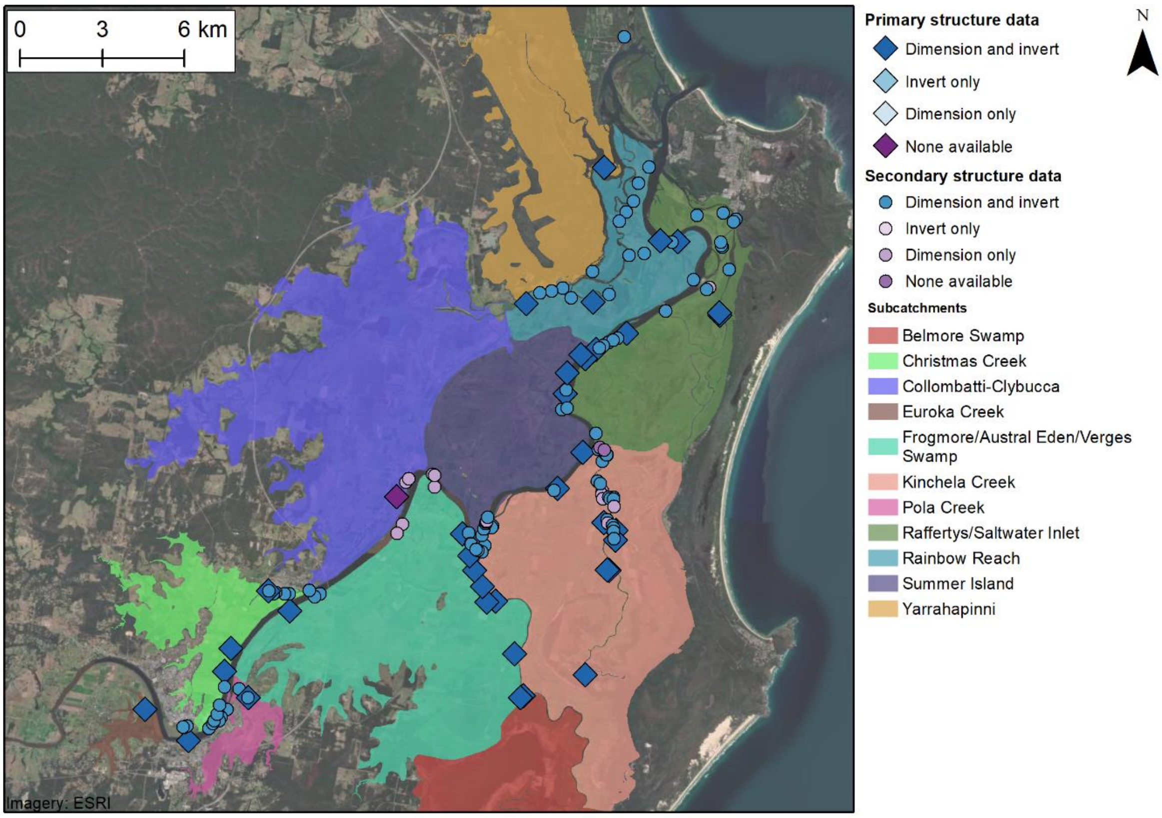

Figure F-2: Summary of data available for end of system structures of the Macleay River floodplain

F3.2 Levees

Levee structures are generally constructed to protect the floodplain from extreme flood events. They can also protect the floodplain from inundation due to high tidal levels. Within the Macleay River floodplain there are a number of levee systems that protect urban areas from flooding. Flood modelling indicated that many levees across the floodplain only provided protection for events with an average exceedance per year (EY) less than 0.2 EY. The townships of Frederickton and Hat Head have levees that are able to protect them from a 5% annual exceedance probability (AEP) flood event, however, local catchment flooding occurs before the levees are overtopped (Chong, 2019). Modelling showed that levee structures within Kempsey area protected against a 10% AEP event (Retallick et al., 2017). The First Lane Levee was an exception to this as it overtops during a 0.2 EY event. Figure F-3 shows the locations of flood mitigation levees across the Macleay River floodplain. All levees are actively managed by Kempsey Shire Council.

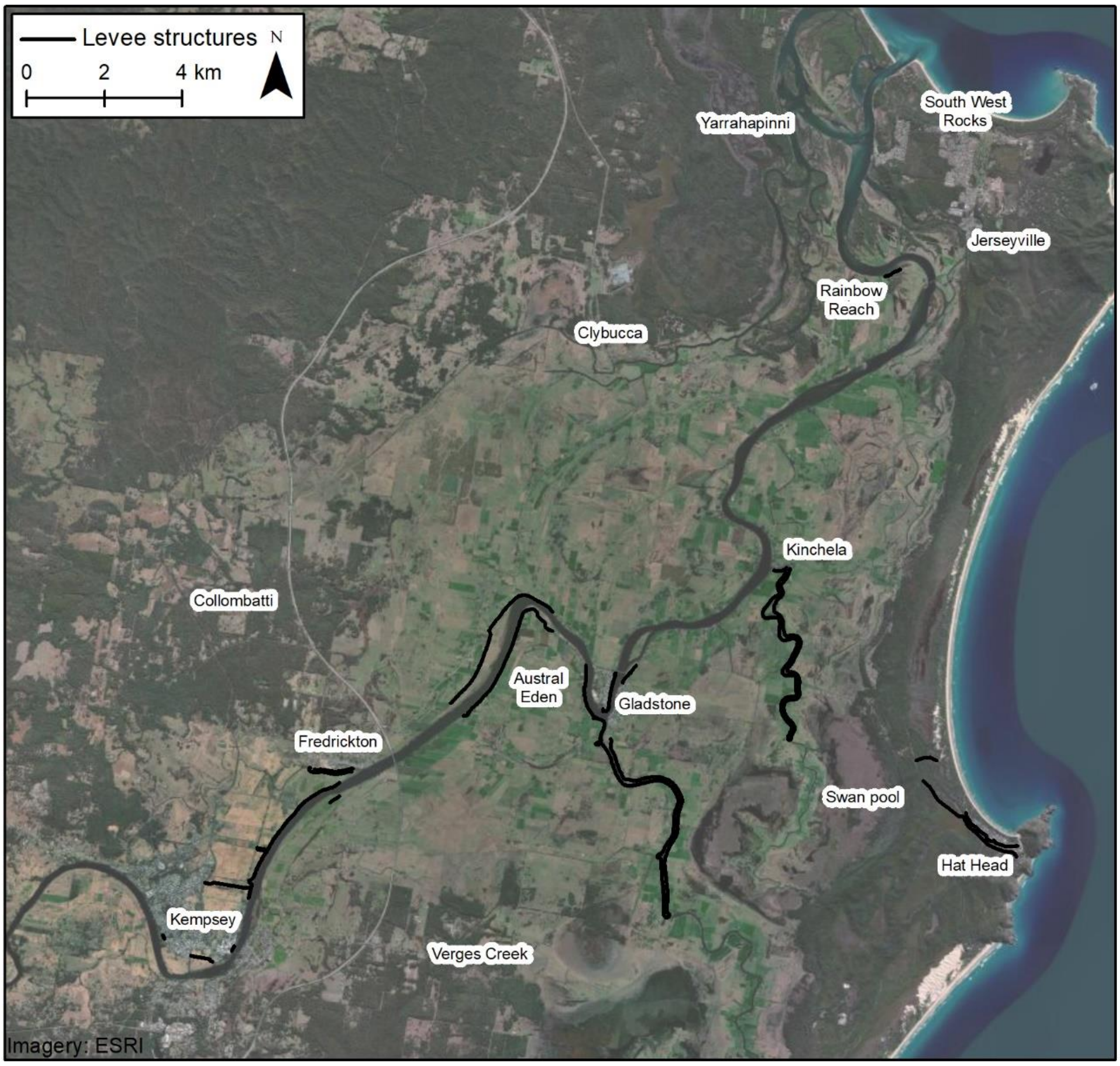

Figure F-3: Location of flood mitigation levee structures on the Macleay River floodplain managed by Kempsey Shire Council

F4 Infrastructure tenure and maintenance

F4.1 Infrastructure tenure

Information on the tenure of EOS structures across the Macleay River floodplain is presented in Figure F-4.

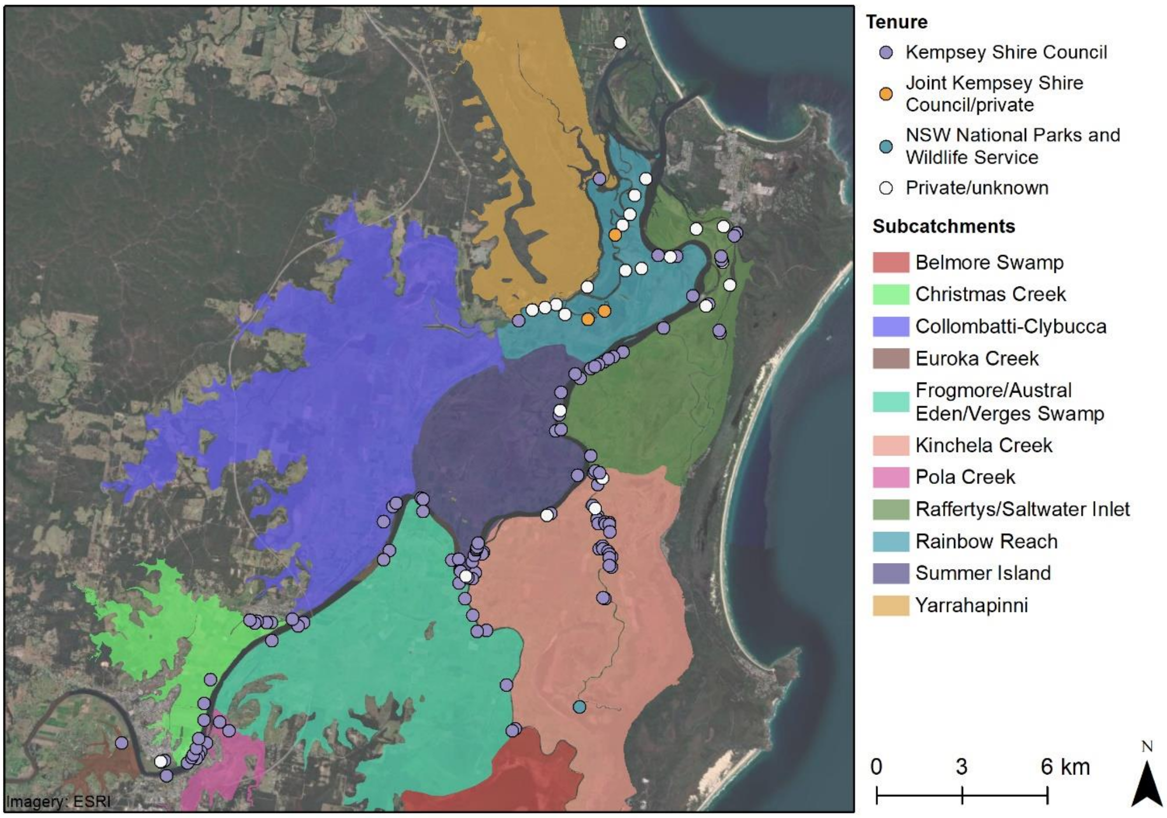

Figure F-4: Tenure of end of system structures on the Macleay River floodplain

F4.2 Maintenance schedule

Kempsey Shire Council (KSC) has a drainage asset management plan for ongoing maintenance of floodplain infrastructure (Kempsey Shire Council, 2014). This plan outlines:

- The required level of service for maintenance of assets;
- The current and projected future demand for management of infrastructure;
- A lifecycle management plan for drainage infrastructure;
- A summary of financial requirements and allocation for drainage infrastructure management;
- Asset management practices;
- Continued monitoring to ensure assets are receiving the required management; and
- A plan for continued improvement of the drainage asset management plan.

In addition to the asset management plan, KSC have developed individual floodgate management plans for key infrastructure across the Macleay River floodplain. These plans are designed to improve operation of infrastructure allowing best practice management for floodgates, drains flowing into floodgates and the land surrounding drains flowing into floodgates. Floodgate management plans have been created for the following end of system structures:

- Belmore River headworks (017G1) (Kempsey Shire Council, 2015a);
- Christmas Creek headworks (013G1) (Kempsey Shire Council, N.D.-a);
- Clancy's Drain floodgates (005G1) (Kempsey Shire Council, 1999);
- Euroka Creek headworks (010G1) (Kempsey Shire Council, N.D.-b);
- Kinchela Creek headworks (024G1) (Kempsey Shire Council, 2015b);
- Marriotts Drain floodgates (007G1) (Kempsey Shire Council, 2000);
- Rafferty's Drain headworks (070G1) (Kempsey Shire Council, 2005);
- Saltwater Inlet floodgates (UNK30) (Kempsey Shire Council, 2004b); and
- Union Drain floodgates (085G1) (Kempsey Shire Council, 2002).

Ongoing maintenance of floodplain infrastructure is important in ensuring that the way structures affect water quality and connectivity across the floodplain remains as per their design specifications. The level of maintenance floodplain infrastructure receives, directly impacts the management option recommendations for the subcatchment where the structures are located. It has been assumed that for structures where the tenure was identified as private or unknown, that routine maintenance is completed on an as required basis by the landholder.

F4.3 Condition assessment

During the fieldwork program, structures which were inspected were also assessed for condition. Floodgate structures were only assessed when access to the downstream (gated) side of the structure was available and the structure was above the water level. The condition assessment was completed using an approach similar to Walsh et al. (2012) as outlined in Table F-2. Where data was available, the structure condition has been considered during the development of remediation actions plans.

Table F-2: Condition assessment criteria

Condition	Description
Good	The structure is in good working order. For floodgates, the seals work well. The structure does not require any maintenance in the near future.
Fair	The structure is functioning well however it is starting to become damaged. Issues such as rust or broken seals (for floodgates) are starting to become evident and affect the structure's performance. For floodgates some vegetation, oysters or debris may be partially blocking the gate or preventing it from closing. The structure will require some maintenance in the near future.
Poor	The structure is no longer functioning well. For floodgates, the flaps no longer close properly or have holes. There may be extensive rust or concrete cancer in the structure. Sections of the culvert may have collapsed. For floodgates, the flap may be blocked or obstructed from opening. The structure requires maintenance to allow it to function correctly.
Other	The structure is broken and irreparable or has been removed.

F5 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.

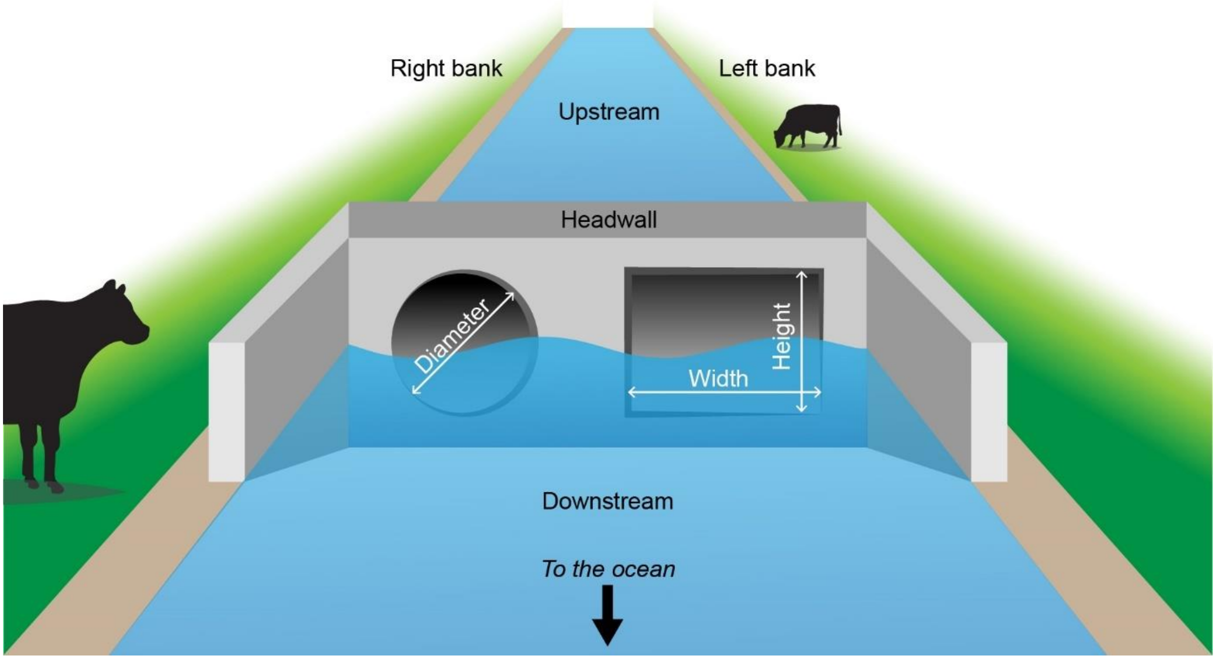

Figure F-5: Example of culverts controlling water in an agricultural drain

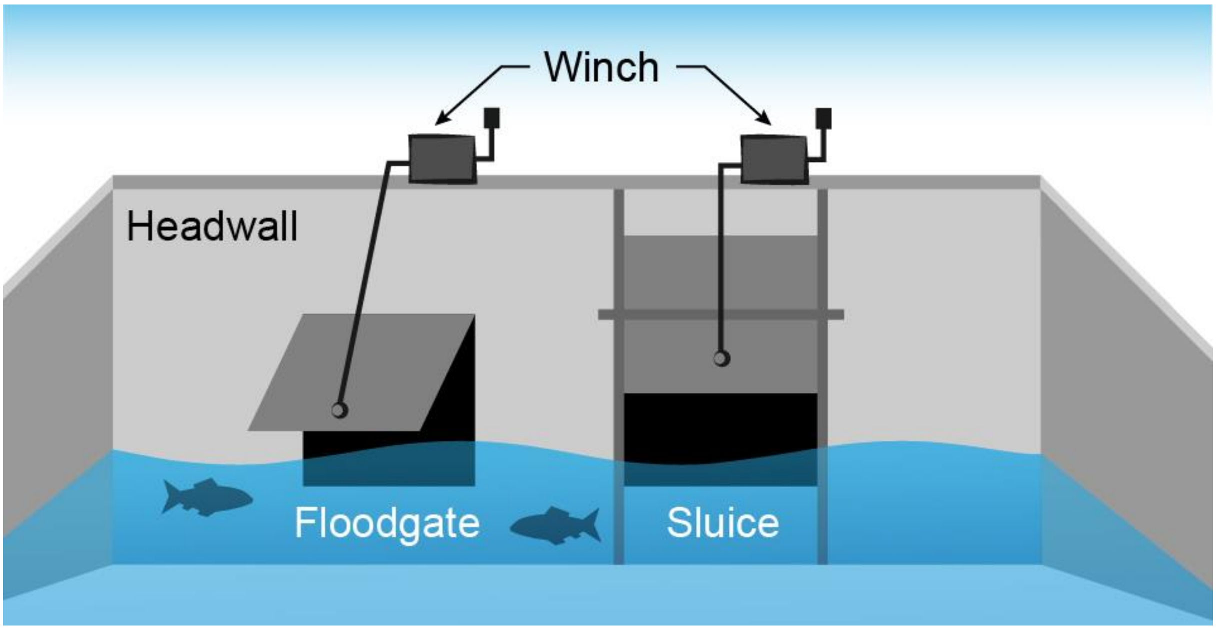

Figure F-6: Example of floodgate and sluice structures which can be fitted to culverts to control flow using a winch

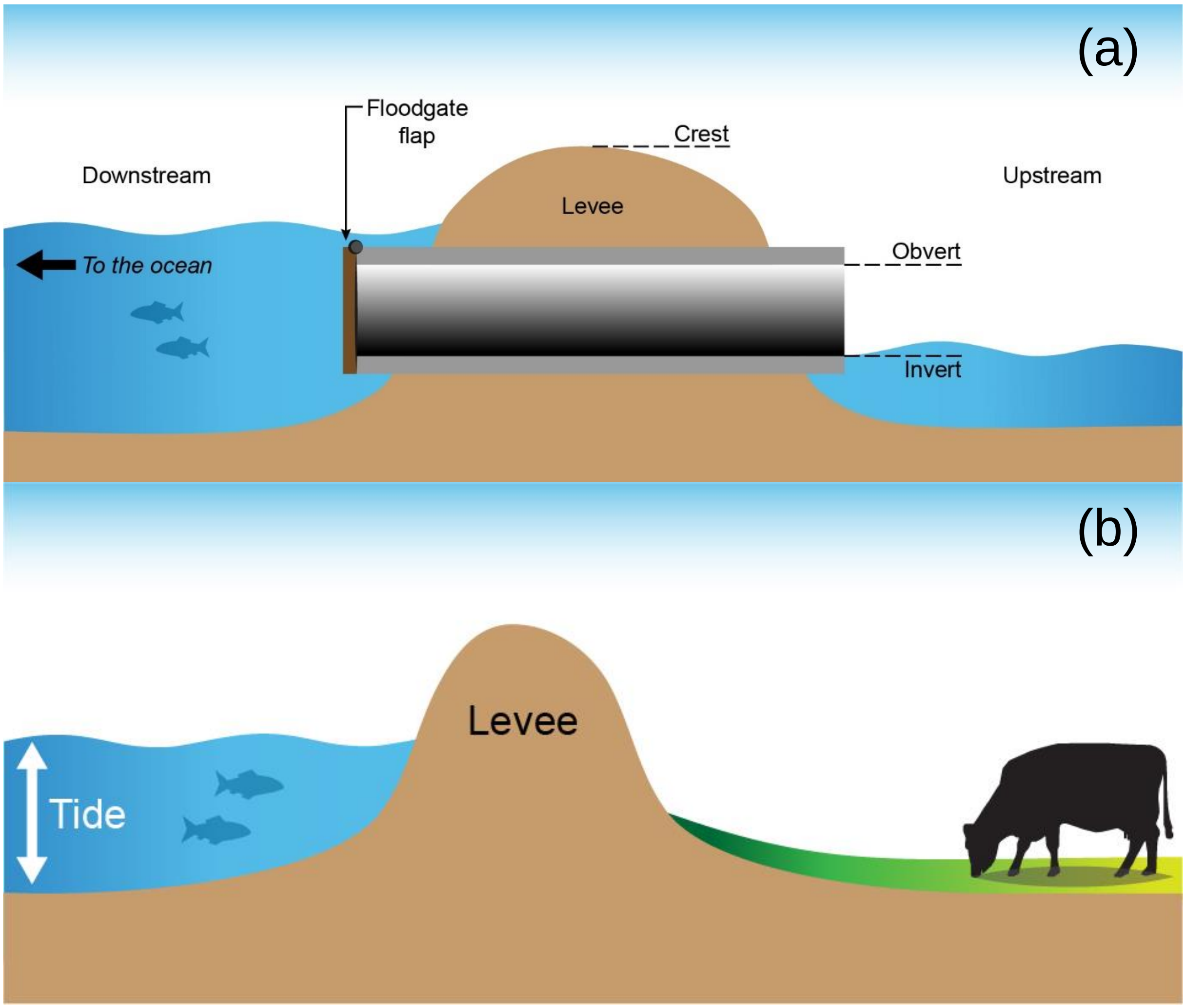

Figure F-7: Example of (a) a floodgate structure ensuring water levels upstream of a levee remain at the low tide level and (b) a levee preventing tidal inundation of the floodplain

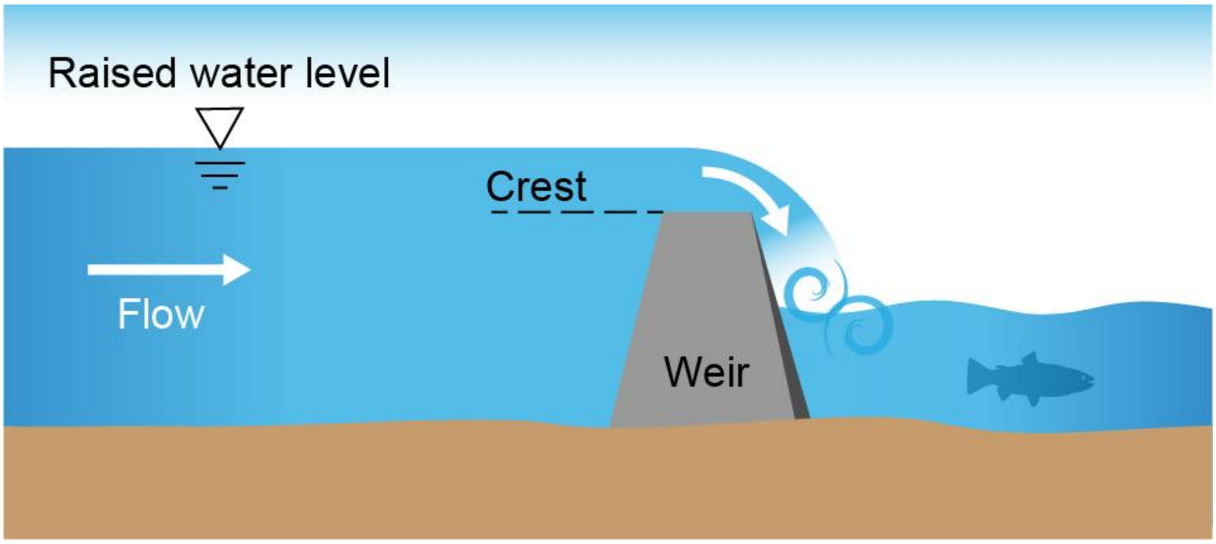

Figure F-8: Example of a weir ensuring a raised water level on the upstream side

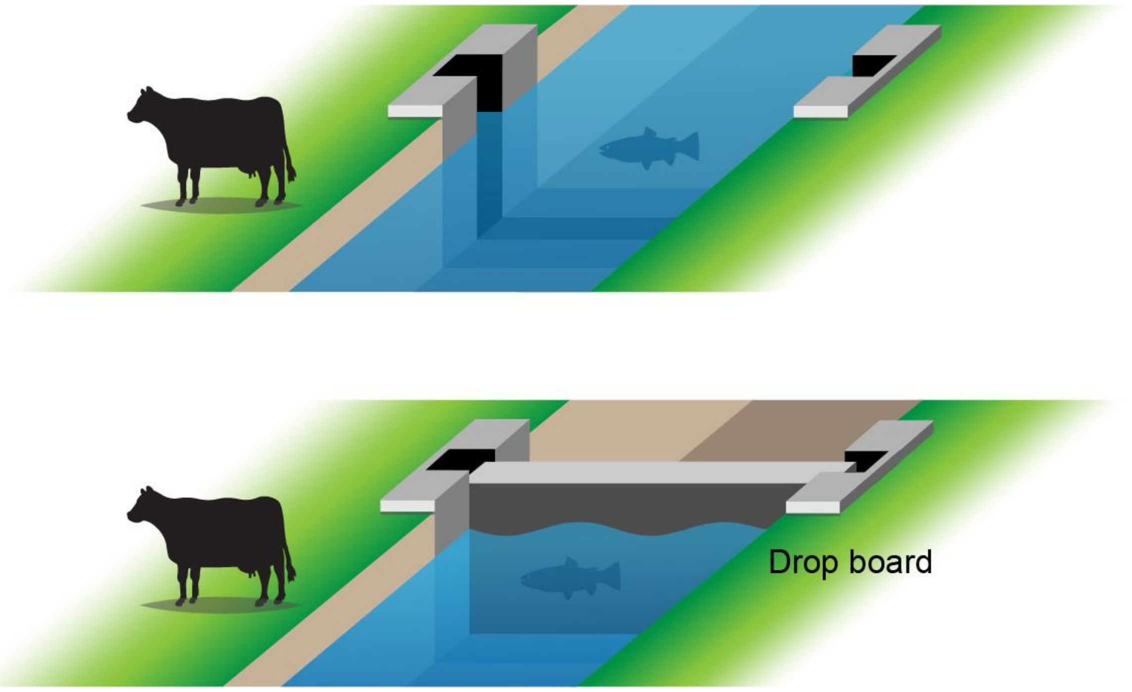

Figure F-9: Example of a drop board structure which can be used to control water levels and prevent inundation

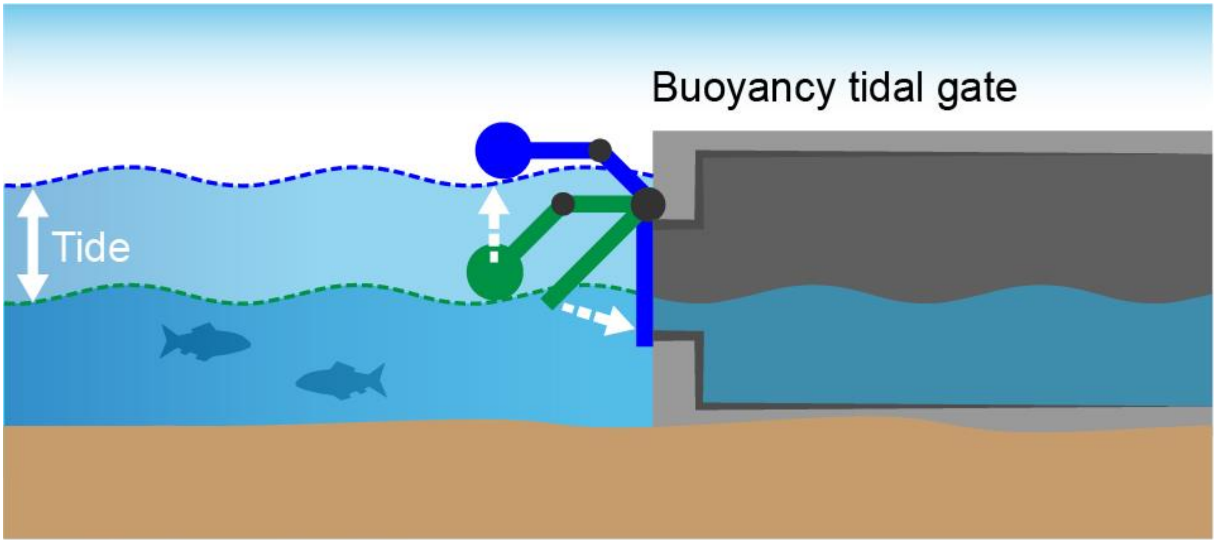

Figure F-10: Example of a buoyancy controlled auto-tidal gate that lets a controlled level of tidal water upstream of the structure (green) before closing due to a buoyancy mechanism and preventing further water ingress (blue)

F6 Floodplain infrastructure data tables

The following section includes:

1. A summary table for structures surveyed for this current project (Table F-3);
2. A summary table for structures where data was sourced from literature, or included in data collection by Abbott and Macro in 2021 (Table F-4), and
3. A summary table for structures that were not surveyed (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
002G1	9/09/2019	Floodgate	1	1.5			497723	6572751		0.59	Poor	Secondary	Kempsey Shire Council	Invert is approximate. Gate is leaking.
003G1	2/03/2020 12:54	Floodgate	5		2.1	2.4	497850	6573326	-1.58	-1.71	Good	Primary	Kempsey Shire Council	Upstream invert and water quality measured on 9/09/2019. Flood mitigation drawings indicate 6' wide by 7' high (1.8 m wide by 2.1 m high) - measurements indicate this is different for as built design.
005G1	2/03/2020 15:12	Floodgate	2		1.8	2.5	498505	6571196	-1.48	-1.54	Good	Primary	Kempsey Shire Council	Upstream invert and water quality measured on 9/9/2019.
006G1	9/09/2019, 2/03/2020 12:32:07 PM	Floodgate	2	1.8			498423	6574754	-0.89	-0.82	Good	Primary	Kempsey Shire Council	Flap was octagonal, culvert size assumed from flood mitigation drawings and size of flap.
007G1	11/09/2019	Culvert	1	1.8			498581	6574605		-0.88	Other	Secondary	Kempsey Shire Council	Floodgate flap has been removed.
008G1	11/09/2019	Floodgate	1	1.8			498971	6574925		-0.32	Other	Primary	Kempsey Shire Council	The structure has been moved downstream and floodgate flaps removed from the former structure. The new structure was not accessible. The invert of the new structure looks similar to the invert of the former structure. Invert was taken approximately using the former structure.
010G1	9/09/2019	Floodgate	2		1.8	2.2	482515	6561814	0.10		Fair	Primary	Kempsey Shire Council	Two large floodgates winched open.
011G1	3/03/2020 10:04	Floodgate	4		1.8	2.6	485652	6564035	-0.77	-1.09	Good	Primary	Kempsey Shire Council	Upstream invert measured on 9/9/19.
014G1	3/03/2020 9:14	Floodgate	2		1.5	1.8	494354	6567425		-0.62	Good	Primary	Kempsey Shire Council	
015G1	2/03/2020 16:19	Floodgate	9		1.8	2.6	496005	6563855		-1.28	Good	Primary	Kempsey Shire Council	Buoyancy tidal gate on gates 7 and 8 (from the left bank).
016G1	2/03/2020 16:49	Sluice gate	4		5.65	3	496212	6562247		-1.80	Good	Primary	Kempsey Shire Council	Large sluice gate structure. Gates open at time of survey.
017G1	2/03/2020 16:35	Floodgate	6		1.8	2.75	496299	6562314	-1.98	-1.94	Good	Primary	Kempsey Shire Council	Gates fully open at time of survey. Upstream invert and water quality measured on 10/9/19.
018G1	10/09/2019	Floodgate	5	1.2			497398	6561349		-0.56	Good	Secondary	Kempsey Shire Council	
019G1	2/03/2020 15:24	Floodgate	10		1.8	2.8	497571	6569900	-0.92	-0.48	Good	Primary	Kempsey Shire Council	Upstream invert measured on 10/9/19.
020G1	10/09/2019	Floodgate	4		1.8	2.1	498126	6557713	-1.14		Fair	Secondary	Kempsey Shire Council	
021G1	10/09/2019	Floodgate	4		2.23	2.1	498343	6559883	-1.15		Fair	Secondary	Kempsey Shire Council	Culvert width measured at right angle to culvert wall.
022G1	10/09/2019	Floodgate	3		1.8	2.1	498538	6560174	-1.09		Good	Secondary	Kempsey Shire Council	

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
023G1	11/09/2019	Floodgate	5		1.23	1.86	499249	6568628		-0.74	Good	Primary	Kempsey Shire Council	There is a road bridge approximately 10 m downstream. Water upstream of the floodgates is orange in colour.
024G1	2/03/2020 13:51	Floodgate	3		1.8	2.6	499450	6566880	-1.37	-1.21	Good	Primary	Kempsey Shire Council	Gates open. Blackwater. Upstream invert and water quality measured on 11/9/19.
025G1	2/03/2020 14:15	Sluice gate	3				499439	6566912		-0.30	Good	Primary	Kempsey Shire Council	Sluice gates. One square culvert (2.23 m wide by 1.9 m high) and two trapezoidal (1.9 m high and 3 m wide) extending upwards at a slope of 2(Vertical):3(Horizontal) (dimensions from flood mitigation plans). Blackwater observed. Water depth was 0.655 m.
026G1	11/09/2019	Sluice gate	3				499669	6567985	-0.26		Good	Primary	Kempsey Shire Council	One rectangular and two trapezoidal sluice gates. One square culvert (2.23 m wide by up to 2.7 m high) and two trapezoidal (3 m wide and up to 2.7 m high) extending upwards at a slope of 2(Vertical):3(Horizontal) (dimensions from flood mitigation plans).
027G1	11/09/2019	Floodgate	5		1.2	1.8	499696	6568338	-0.67		Good	Primary	Kempsey Shire Council	
028G1	11/09/2019	Floodgate	3		1.2	1.86	499618	6569553	-0.41		Good	Secondary	Kempsey Shire Council	Algae upstream and sludge downstream of culvert. Another culvert under a road located approximately 10 m further downstream.
029G1	11/09/2019	Floodgate	5		2.05	2.15	499899	6566658	-1.44		Good	Secondary	Kempsey Shire Council	Culvert width measured at right angle to culvert wall.
031G1	2/03/2020 15:41	Floodgate	3	1.2			494551	6566882		-0.24	Good	Primary	Kempsey Shire Council	Hexagonal floodgate.
032G1	11/09/2019	Floodgate	4		1.5	1.86	500109	6565738	-0.48		Good	Secondary	Kempsey Shire Council	
070G1	11/09/2019, 2/03/2020	Floodgate	2	1.8			500093	6575521		-1.10	Good	Primary	Kempsey Shire Council	Large fish observed upstream. Buoyancy tidal gate on left gate.
070G1 buoyancy	11/09/2019	Buoyancy gate	1		0.4	0.85	500088	6575530		-0.45	Good		Kempsey Shire Council	Buoyancy tidal gate on left flap of structure 070G1.
074G1	11/09/2019	Floodgate	1	0.75			503987	6579600		-0.22	Poor	Secondary	Kempsey Shire Council	
075G1	10/09/2019	Floodgate	2		1.2	1.25	501319	6578900		-0.45	Good	Primary	Kempsey Shire Council	Electrical conductivity was measured higher on the upstream side. Elevation adjusted during quality checks to -0.45m AHD.
082G1	3/03/2020 11:51	Floodgate	2		1.5	1.8	494100	6568221		-0.61	Good	Primary	Kempsey Shire Council	
083G1	2/03/2020 11:57	Floodgate	1	1.2			501961	6578880		-0.79	Good	Primary	Kempsey Shire Council	
084G1	10/09/2019	Floodgate	1	1.2			494825	6566292		0.59	Good	Secondary	Kempsey Shire Council	Invert approximate. Could not access upstream side.
095G1	3/03/2020 10:46	Floodgate	1	1.2			484092	6560668		0.50	Poor	Secondary	Kempsey Shire Council	Gate winched half open. Gate does not completely cover culvert.
096G1	3/03/2020 11:18	Floodgate	1		1.8	1.8	485455	6563194		-0.24	Good	Primary	Kempsey Shire Council	
098G1	9/09/2019	Culvert	2	0.6			485140	6561636		0.03	Good	Secondary	Kempsey Shire Council	Very undercut.
099G1	9/09/2019	Floodgate	1	0.4			485030	6561408		0.05	Fair	Secondary	Kempsey Shire Council	Gate is rusting.
101G1	9/09/2019	Floodgate	1	0.6			484833	6561115		-0.16	Fair	Secondary	Kempsey Shire Council	Silt has built up in front of the gate, however, it can still open.
113G1	10/09/2019	Floodgate	1	0.6			494325	6568259		0.66	Good	Secondary	Kempsey Shire Council	

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
117G1	10/09/2019	Floodgate	1	0.46			494939	6568572		0.61	Good	Secondary	Kempsey Shire Council	
118G1	10/09/2019	Floodgate	1	0.58			494810	6567571		0.35	Fair	Secondary	Kempsey Shire Council	Has been slightly filled in with silt in front of the floodgate, however, it can still open.
128G1	3/03/2020 14:54	Floodgate	1	1.2			498854	6576671	-0.85		Good	Primary	Joint Kempsey Shire Council/private	
130G1	2/03/2020 16:00	Floodgate	1	1.2			495289	6565728		-0.68	Good	Secondary	Kempsey Shire Council	
134G1	10/09/2019	Floodgate	1	0.375			495006	6568810		2.81	Good	Secondary	Kempsey Shire Council	
136G1	9/09/2019	Culvert	1	0.75			483921	6561166		4.71	Other	Secondary	Kempsey Shire Council	Flap has been removed.
141G1	10/09/2019	Culvert	1	0.6			503521	6578868		-0.23	Other	Secondary	Kempsey Shire Council	Structure submerged underwater at time of the survey. Floodgate flap has fallen off. Diameter is approximate.
142G1	10/09/2019	Floodgate	1	0.9			503539	6578743		-0.43	Good	Secondary	Kempsey Shire Council	Structure submerged underwater at time of the survey. Diameter is approximate.
144G1	10/09/2019	Floodgate	1	0.45			494908	6567788		1.14	Fair	Secondary	Kempsey Shire Council	Lots of weeds in front though still in working order. At high elevation compared to the river. Poor invert accuracy.
152G1	10/09/2019	Floodgate	1	0.3			495197	6568509		3.18	Poor	Secondary	Kempsey Shire Council	Very blocked gate - cannot open due to silt build up in front.
154G1	11/09/2019	Floodgate	1	0.45			498964	6571894		1.55	Good	Secondary	Kempsey Shire Council	
163G1	11/09/2019	Floodgate	1	0.375			499205	6570878		1.95	Poor	Secondary	Kempsey Shire Council	Gate is open. Some siltation in the base. Lots of weeds and a steel pipe across it on the downstream side.
166G1	11/09/2019	Floodgate	1	0.375			499372	6568732	1.61		Good	Secondary	Kempsey Shire Council	Irrigation pipe through structure.
169G1	11/09/2019	Floodgate	1	0.375			499608	6568311		1.33	Poor	Secondary	Kempsey Shire Council	Downstream side was blocked and covered in weeds. Dimension measurement was approximate.
170G1	11/09/2019	Floodgate	1	0.375			499608	6568436		1.52	Poor	Secondary	Kempsey Shire Council	Downstream side was blocked and covered in weeds. Dimension measurement was approximate.
171G1	11/09/2019	Floodgate	1	0.375			499566	6568538		1.01	Poor	Secondary	Kempsey Shire Council	Lots of weeds surrounding the floodgate. Floodgate in very poor condition and no longer appears to be used. Dimension measurements are approximate. Flap is in poor condition.
173G1	11/09/2019	Floodgate	1	0.375			499604	6569484		1.56	Good	Secondary	Kempsey Shire Council	Dimensions are approximate.
174G1	11/09/2019	Floodgate	1	0.375			499480	6569499		1.49	Fair	Secondary	Kempsey Shire Council	Measurements are approximate as no access to structure.
WRL_MAC_01	9/09/2019	Culvert	1	0.45			483893	6561170		5.22	Good	Secondary	Private/unknown	
WRL_MAC_02	9/09/2019	Culvert	2		3	2.15	498024	6574215		-0.30	Good	Secondary	Private/unknown	No floodgates. 200 mm of silt at the bottom of culverts. Culvert width measured at right angle to culvert wall.
WRL_MAC_05	10/09/2019	Floodgate	1		1.2	0.8	497073	6557280		0.03	Fair	Secondary	Private/unknown	Width and height approximate from floodgate (access to downstream side only).
WRL_MAC_06	11/09/2019	Culvert	1	0.375			499367	6571097		2.47	Poor	Secondary	Private/unknown	Culvert blocked and has dense weeds in front of it.
WRL_MAC_07	11/09/2019	Culvert	1	0.375			499984	6565517		-0.88	Fair	Secondary	Private/unknown	Weeds and sediment build up on the downstream side.
WRL_MAC_08	11/09/2019	Floodgate	5	1.2			499920	6565325		-1.18	Good	Secondary	Private/unknown	Could not access floodgate. Approximate invert taken from water level. Culvert dimensions assumed from inspection from distance.

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
WRL_MAC_09	11/09/2019	Floodgate	1	0.375			499122	6570047		1.59	Poor	Secondary	Private/unknown	Size and invert approximate due to floodgate being infilled. No longer opens.
WRL_MAC_10	11/09/2019	Floodgate	1	0.375			497429	6569809	3.16		Good	Secondary	Private/unknown	Invert very high compared to the river.

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

Table F-4: Summary of existing data

Structure ID	Type	# Culverts	Diameter (m)	Width (m)	Height (m)	Easting (m)	Northing (m)	Invert (m AHD)	Category	Tenure	Condition	Data source	Comment
UNK03	Floodgate	1 of 3		1.2	0.6	503005	6577140	-0.05	Secondary	Private/unknown	Fair	Abbot and Macro	1 of 3 gates, silted up and needs cleaning
UNK03	Floodgate	1 of 3	0.6			503004	6577140	0.23	Secondary	Private/unknown	Fair	Abbot and Macro	1 of 3 gates, silted up and needs cleaning
UNK03		1 of 3	0.6			503003	6577139	0.49	Secondary	Private/unknown	Fair	Abbot and Macro	1 of 3 gates, silted up and needs cleaning
138G1		1	0.375			485218	6561399	1.14	Secondary	Kempsey Shire Council	Good	Abbot and Macro	
085G1	Floodgate	1	1.2			494984	6565734	0.33	Primary	Kempsey Shire Council	Good	Abbot and Macro	Has winch and rope
104G1	Floodgate	1	0.75			485494	6561822	1.56	Secondary	Kempsey Shire Council	Good	Abbot and Macro	
114G1	Floodgate	1	0.6			494585	6567660	1.55	Secondary	Private/Unknown	Good	Abbot and Macro	
161G1	Floodgate	1	0.375			499096	6575007	1.38	Secondary	Kempsey Shire Council	Fair	Abbot and Macro	Floodgate not working, full of silt
103G1	Floodgate	6	0.9			485128	6561271	2.10	Secondary	Kempsey Shire Council	Good	Abbot and Macro	Piece of wood used to keep flap open
072G1	Floodgate	1 of 2	1.2			503493	6576207	-0.80	Primary	Kempsey Shire Council	Good	Abbot and Macro	1 of 2 floodgates
072G1	Floodgate	1 of 2				503495	6576199	-0.15	Primary	Kempsey Shire Council		Abbot and Macro	Restrictor board for the floodgate see photos
133G1	Floodgate	1	0.45			494809	6568172	1.35	Secondary	Kempsey Shire Council	Good	Abbot and Macro	Large headwall frp flap
115G1	Floodgate	1	0.3			494659	6567608	1.62	Secondary	Kempsey Shire Council	Good	Abbot and Macro	
116G1	Floodgate	1	0.45			494870	6568396	0.99	Secondary	Kempsey Shire Council	Fair	Abbot and Macro	
139G1	Culvert	1	0.225			485288	6561525	2.06	Secondary	Kempsey Shire Council	Fair	Abbot and Macro	Pipe found 100m upstream of geotag location
140G1	Culvert	1	0.6			503522	6578870	-0.24	Secondary	Kempsey Shire Council	Fair	Abbot and Macro	Floodgate flap fallen off
155G1	Culvert	1	0.375			497924	6572818	2.39	Secondary	Kempsey Shire Council	Fair	Abbot and Macro	Silt in bottom of pipe
178G1	Floodgate	1	0.45			499318	6571130	1.69	Secondary	Kempsey Shire Council	Good	Abbot and Macro	
168G1	Culvert	1	0.45			499619	6568040	1.15	Secondary	Kempsey Shire Council	Fair	Abbot and Macro	No floodgate, pipe blocked with metal plate, silted up
UNK06	Floodgate	1	0.45			501751	6578864	-0.03	Secondary	Private/unknown	Good	Abbot and Macro	
165G1	Floodgate	1	0.375			499438	6569557	1.78	Secondary	Kempsey Shire Council	Fair	Abbot and Macro	Bottom blocked with mud
162G1	Culvert	1	0.375			499368	6571099	2.65	Secondary	Kempsey Shire Council	Fair	Abbot and Macro	Bottom blocked with mud
164G1	Floodgate	1	0.375			499023	6570151	1.30	Secondary	Kempsey Shire Council	Good	Abbot and Macro	Flood debris
121G1	Floodgate	1	1.2			487789	6565412	-0.64	Primary	Kempsey Shire Council	Good	Abbot and Macro	Tidal sluice gate working
100G1	Culvert	1	0.45			484976	6561306	0.48	Secondary	Kempsey Shire Council	Good	Abbot and Macro	
097G1	Culvert	1	0.3			484031	6561209	5.48	Secondary	Kempsey Shire Council	Good	Abbot and Macro	
146G1	Floodgate	1	0.6			487194	6566025	1.71	Secondary	Kempsey Shire Council	Good	Abbot and Macro	

Structure ID	Type	# Culverts	Diameter (m)	Width (m)	Height (m)	Easting (m)	Northing (m)	Invert (m AHD)	Category	Tenure	Condition	Data source	Comment
149G1	Floodgate	1	0.45			494404	6567844	3.24	Secondary	Kempsey Shire Council	Fair	Abbot and Macro	Needs silt cleared from flap
119G1	Floodgate	1	0.45			495160	6568451	2.51	Secondary	Kempsey Shire Council	Good	Abbot and Macro	
132G1	Floodgate	1	0.3			494957	6568646	2.86	Secondary	Kempsey Shire Council	Good	Abbot and Macro	
107G1	Floodgate	1	0.375			488506	6566162	3.98	Secondary	Kempsey Shire Council	Good	Abbot and Macro	
087G1	Floodgate	1	0.45			488701	6565922	0.38	Secondary	Kempsey Shire Council	Fair	Abbot and Macro	Needs silt cleared from flap
086G1	Floodgate	1	0.9			488892	6566038	2.05	Secondary	Kempsey Shire Council	Good	Abbot and Macro	
120G1	Floodgate	1	0.45			485949	6562561	2.17	Secondary	Kempsey Shire Council	Good	Abbot and Macro	
102G1	Floodgate	1	0.45			485229	6561976	0.37	Secondary	Kempsey Shire Council	Good	Abbot and Macro	
137G1	Floodgate	1	0.9			485413	6562632	0.46	Secondary	Kempsey Shire Council	Good	Abbot and Macro	
159G1	Floodgate	1	0.375			499419	6575190	1.29	Secondary	Kempsey Shire Council	Good	Abbot and Macro	
157G1	Floodgate	1	0.375			499742	6575365	0.85	Secondary	Kempsey Shire Council	Fair	Abbot and Macro	Half pipe full of silt
160G1	Floodgate	1	0.375			499232	6575087	1.21	Secondary	Kempsey Shire Council	Fair	Abbot and Macro	Silted up not working
158G1	Floodgate	1	0.375			499584	6575288	1.27	Secondary	Kempsey Shire Council	Good	Abbot and Macro	
UNK28	Culvert	1	0.45			503576	6578677	0.22	Secondary	Private/unknown	Fair	Abbot and Macro	Pipes broken
073G1	Floodgate	5		1.8	1.6	503456	6576273	-0.94	Primary	Kempsey Shire Council	Good	Abbot and Macro	Auto tidal sluice installed, 1 of 5 floodgates
073G1	Floodgate	5		1.8	1.6	503457	6576274	-0.94	Primary	Kempsey Shire Council	Good	Abbot and Macro	1 of 5 floodgates
073G1	Floodgate	5		1.8	1.6	503459	6576275	-0.94	Primary	Kempsey Shire Council	Good	Abbot and Macro	1 of 5 floodgates
073G1	Floodgate	5		1.8	1.6	503461	6576276	-0.94	Primary	Kempsey Shire Council	Good	Abbot and Macro	1 of 5 floodgates
073G1	Floodgate	5		1.8	1.6	503462	6576277	-0.94	Primary	Kempsey Shire Council	Good	Abbot and Macro	1 of 5 floodgates
UNK14	Floodgate	1	1.5			500069	6579970	-0.89	Secondary	Private/unknown	Good	Abbot and Macro	
071G1	Floodgate	1	1.8			501511	6576362	-0.59	Secondary	Kempsey Shire Council	Good	Abbot and Macro	A bit rusty but still functions ok
UNK16	Floodgate	1	0.6			498060	6576838	0.27	Secondary	Private/unknown	Good	Abbot and Macro	
UNK15	Culvert	1	0.9			500732	6578448	0.05	Secondary	Private/unknown	Fair	Abbot and Macro	
UNK20	Culvert	1	0.45			496916	6577004	0.10	Secondary	Private/unknown	Fair	Abbot and Macro	
UNK07	Culvert	1	0.3			500902	6581599	0.30	Secondary	Private/unknown	Fair	Abbot and Macro	Pvc pipe
UNK18	Floodgate	1	0.9			497755	6577192	-0.37	Secondary	Private/unknown	Good	Abbot and Macro	Half pipe full of silt
UNK19	Culvert	1	0.45			497353	6577081	-0.10	Secondary	Private/unknown	Fair	Abbot and Macro	Piece of rubber used to block pipe
UNK10	Culvert	1	0.45			499993	6586362	0.00	Secondary	Private/unknown	Fair	Abbot and Macro	Flap fallen off
UNK11	Floodgate	1	0.45			500507	6581013	0.36	Secondary	Private/unknown	Good	Abbot and Macro	
UNK12	Culvert	1	0.6			500332	6580355	0.13	Secondary	Private/unknown	Good	Abbot and Macro	
127JG1	Culvert	1	0.9			500173	6578387	-0.27	Secondary	Joint Kempsey Shire Council/private	Fair	Abbot and Macro	Flap fallen off

Structure ID	Type	# Culverts	Diameter (m)	Width (m)	Height (m)	Easting (m)	Northing (m)	Invert (m AHD)	Category	Tenure	Condition	Data source	Comment
UNK17	Culvert	1	0.9			498844	6577803	-0.55	Secondary	Private/unknown	Fair	Abbot and Macro	Flap fallen off
125G1	Culvert	1	0.6			502527	6577494	-0.29	Secondary	Kempsey Shire Council	Fair	Abbot and Macro	Flap fallen off
012G1	Floodgate	3		1.6	2.8	486271	6562239	0.03	Primary	Kempsey Shire Council	Good	Abbot and Macro	1 of 3 floodgates, all have winches
012G1	Floodgate	3		1.6	2.8	486272	6562240	0.03	Primary	Kempsey Shire Council	Good	Abbot and Macro	1 of 3 floodgates, all have winches
012G1	Floodgate	3		1.6	2.8	486275	6562240	0.03	Primary	Kempsey Shire Council	Good	Abbot and Macro	1 of 3 floodgates, all have winches
105G1	Floodgate	1	0.6			487279	6566085	2.34	Secondary	Kempsey Shire Council	Good	Abbot and Macro	
106G1	Floodgate	1	0.6			487598	6566039	2.19	Secondary	Kempsey Shire Council	Good	Abbot and Macro	
145G1	Floodgate	1	0.6			487774	6566039	2.03	Secondary	Kempsey Shire Council	Good	Abbot and Macro	
148G1	Floodgate	1	0.45			494391	6567862	0.70	Secondary	Kempsey Shire Council	Good	Abbot and Macro	
153G1	Floodgate	1	0.45			499062	6571294	1.71	Secondary	Kempsey Shire Council	Good	Abbot and Macro	
UNK26	Floodgate	5		1	1.8	497878	6573471	-0.50	Secondary	Private/unknown	Good	Abbot and Macro	
UNK26	Floodgate	5		1	1.8	497879	6573473	-0.50	Secondary	Private/unknown	Good	Abbot and Macro	
UNK26	Floodgate	5		1	1.8	497880	6573474	-0.50	Secondary	Private/unknown	Good	Abbot and Macro	
UNK26	Floodgate	5		1	1.8	497880	6573475	-0.50	Secondary	Private/unknown	Good	Abbot and Macro	
UNK26	Floodgate	5		1	1.8	497881	6573477	-0.50	Secondary	Private/unknown	Good	Abbot and Macro	
103G1	Floodgate	5		1.8	2.8	487016	6566131	-1.32	Secondary	Kempsey Shire Council	Good	Abbot and Macro	1 of 5 floodgates, 2 gates winched open, all gates have winches
103G1	Floodgate	5		1.8	2.8	487017	6566133	-1.32	Secondary	Kempsey Shire Council	Good	Abbot and Macro	1 of 5 floodgates, 2 gates winched open, all gates have winches
103G1	Floodgate	5		1.8	2.8	487018	6566134	-1.32	Secondary	Kempsey Shire Council	Good	Abbot and Macro	1 of 5 floodgates, 2 gates winched open, all gates have winches
103G1	Floodgate	5		1.8	2.8	487019	6566137	-1.32	Secondary	Kempsey Shire Council	Good	Abbot and Macro	1 of 5 floodgates, 2 gates winched open, all gates have winches
103G1	Floodgate	5		1.8	2.8	487020	6566138	-1.32	Secondary	Kempsey Shire Council	Good	Abbot and Macro	1 of 5 floodgates, 2 gates winched open, all gates have winches
UNK04	Floodgate	2	0.3			503606	6579919	0.40	Secondary	Private/unknown	Good	Abbot and Macro	Floodgate and one overflow pipe, 1 of 2 floodgates
UNK04	Floodgate	2	0.3			503614	6579926	0.73	Secondary	Private/unknown	Good	Abbot and Macro	1 of 2 floodgates
147G1	Floodgate	3	0.75			504075	6579704	0.36	Secondary	Kempsey Shire Council	Fair	Abbot and Macro	Outlet overgrown needs clearing, flaps blocked, 1 of 3 floodgates
147G1	Floodgate	3	0.75			504077	6579703	0.36	Secondary	Kempsey Shire Council	Fair	Abbot and Macro	Outlet overgrown needs clearing, flaps blocked, 1 of 3 floodgates
147G1	Floodgate	3	0.75			504078	6579702	0.36	Secondary	Kempsey Shire Council	Fair	Abbot and Macro	Outlet overgrown needs clearing, flaps blocked, 1 of 3 floodgates
UNK01N	Floodgate	2	0.3			503833	6577866	0.25	Secondary	Private/Unknown	Good	Abbot and Macro	
UNK01N	Floodgate	2	0.3			503833	6577865	0.13	Secondary	Private/Unknown	Good	Abbot and Macro	
UNK29	Culvert	1		10	4	502659	6579835	-0.43	Secondary	Private/unknown		Abbot and Macro	No pipes just wooden bridge invert of creek given
UNK03_left	Floodgate	2		1.2	0.9	503004	6577135	1.84	Secondary	Private/Unknown		Chong (2019)	
UNK03_right	Culvert	2	0.6			503004	6577135	1.84	Secondary	Private/Unknown		Chong (2019)	

Structure ID	Type	# Culverts	Diameter (m)	Width (m)	Height (m)	Easting (m)	Northing (m)	Invert (m AHD)	Category	Tenure	Condition	Data source	Comment
009G1	Culvert	5		1.8	2.8	499265	6581589	-1.90	Primary	Kempsey Shire Council		Glamore et al (2012)	
001G1	Floodgate	21		1.8	2.7	496429	6576614	-2.29	Primary	Kempsey Shire Council		Kempsey Shire Council (2013)	
080C	Floodgate	2	0.6			503104	6577203		Secondary	Kempsey Shire Council		Kempsey Shire Council (2013)	
129JG1	Floodgate	1	1.5			499818	6579634	-0.52	Secondary	Joint Kempsey Shire Council/private		Kempsey Shire Council (2013)	
126JG1	Floodgate	1	0.25			499439	6576963	-0.70	Secondary	Joint Kempsey Shire Council/private		Kempsey Shire Council (2013)	
013G1	Floodgate	5		1.8	2.7	487013	6566135	-1.44	Primary	Kempsey Shire Council		Kempsey Shire Council (2013)	
109C	Floodgate	1	0.6			492032	6570104		Secondary	Kempsey Shire Council		Kempsey Shire Council (2013)	
110G1	Floodgate	1	0.3			492137	6570235		Secondary	Kempsey Shire Council		Kempsey Shire Council (2013)	
004G1	Floodgate	5	1.5			497915	6574102	-0.42	Primary	Kempsey Shire Council		Kempsey Shire Council (2013)	
177G1	Floodgate	1	0.375			499197	6569789		Secondary	Kempsey Shire Council		Kempsey Shire Council (2013)	
176G1	Floodgate	1	0.375			499187	6569662		Secondary	Kempsey Shire Council		Kempsey Shire Council (2013)	
175G1	Floodgate	1	0.375			499223	6569507		Secondary	Kempsey Shire Council		Kempsey Shire Council (2013)	
172G1	Floodgate	1	0.375			499622	6569218		Secondary	Kempsey Shire Council		Kempsey Shire Council (2013)	
167G1	Floodgate	1	0.375			499388	6568615		Secondary	Kempsey Shire Council		Kempsey Shire Council (2013)	
122G1	Floodgate	1	0.3			493078	6569937		Secondary	Kempsey Shire Council		Kempsey Shire Council (2013)	
150G1	Floodgate	1	0.525			491903	6568572		Secondary	Kempsey Shire Council		Kempsey Shire Council (2013)	
151G1	Floodgate	1	0.45			491705	6568243		Secondary	Kempsey Shire Council		Kempsey Shire Council (2013)	
111G1	Floodgate	1	0.3			493010	6570395		Secondary	Kempsey Shire Council		Kempsey Shire Council (2013)	
112G1	Floodgate	1	0.3			493078	6570362		Secondary	Kempsey Shire Council		Kempsey Shire Council (2013)	
114g1	Floodgate	1	0.6			494585	6567660		Secondary	Kempsey Shire Council		Kempsey Shire Council (2013)	
131G1	Floodgate	1	0.3			494977	6568690		Secondary	Kempsey Shire Council		Kempsey Shire Council (2013)	
The Lock	Floodgate	4		1.0	1.0	498682	6563277	-0.48 to -0.43	Primary	NSW National Parks and Wildlife Service	Good	Tucker and Rayner (2021)	Note, while the lock is owned by the NSW National Parks and Wildlife Service, maintenance has generally been completed by Kempsey Shire Council.

Table F-5 Summary of unsurveyed structures

Structure ID	Easting	Northing	Subcatchment	Comment
108G1	491691.1	6569579	Collombatti-Clybucca	Not inspected
143G1	499107.9	6571364	Kinchela Creek	Not inspected
179G1	499274.8	6571291	Kinchela Creek	Inspected not found
080C	503104	6577203	Raffertys/Saltwater Inlet	Inspected not found
109C	492032	6570104	Collombatti-Clybucca	Not inspected
110G1	492137	6570235	Collombatti-Clybucca	Not inspected
177G1	499197	6569789	Kinchela Creek	Inspected not found
176G1	499187	6569662	Kinchela Creek	Inspected not found
175G1	499223	6569507	Kinchela Creek	Inspected not found
172G1	499622	6569218	Kinchela Creek	Inspected not found
167G1	499388	6568615	Kinchela Creek	Inspected not found
122G1	493078	6569937	Frogmore/Austral Eden/Verges Swamp	Not inspected
150G1	491903	6568572	Frogmore/Austral Eden/Verges Swamp	Inspected not found
151G1	491705	6568243	Frogmore/Austral Eden/Verges Swamp	Inspected not found
111G1	493010	6570395	Summer Island	Not inspected
112G1	493078	6570362	Summer Island	Not inspected
131G1	494977	6568690	Summer Island	Inspected not found

Appendix G Cross-sections

During field investigations, floodplain drainage channels and waterways were surveyed opportunistically. Measurements were taken using Trimble GNSS RTK survey equipment as specified in Appendix A of the Methods report (Rayner et al., 2020a). Locations of cross-sectional measurements surveyed across the Macleay River floodplain are shown in Figure G-1. All sections were surveyed from left bank to right bank (when looking downstream). Table G-1 provides the start and end coordinates for each cross-section, and individual cross-section profiles are shown from Figure G-2 to Figure G-12.

Figure G-1: General location of cross-sections surveyed on the Macleay River floodplain

Table G-1: Coordinates for the start and end of each cross-sections profile

Cross-section ID	Coordinates (GDA 1994 MGA 56)			
	Start easting (m)	Start northing (m)	End easting (m)	End northing (m)
119	500812.2	6572043.8	500839.1	6572042.5
119	500812.2	6572043.8	500839.1	6572042.5
120	499655.7	6569650.1	499610.1	6569670.4
120	499655.7	6569650.1	499610.1	6569670.4
121	499136.4	6558702.7	499177.7	6558695.0
121	499136.4	6558702.7	499177.7	6558695.0
122	493232.6	6561580.5	493304.4	6561540.0
122	493232.6	6561580.5	493304.4	6561540.0
123	492670.4	6564017.6	492666.0	6563989.6
124	484859.8	6566839.9	484843.3	6566813.6
125	485320.0	6565066.2	485349.5	6565046.7

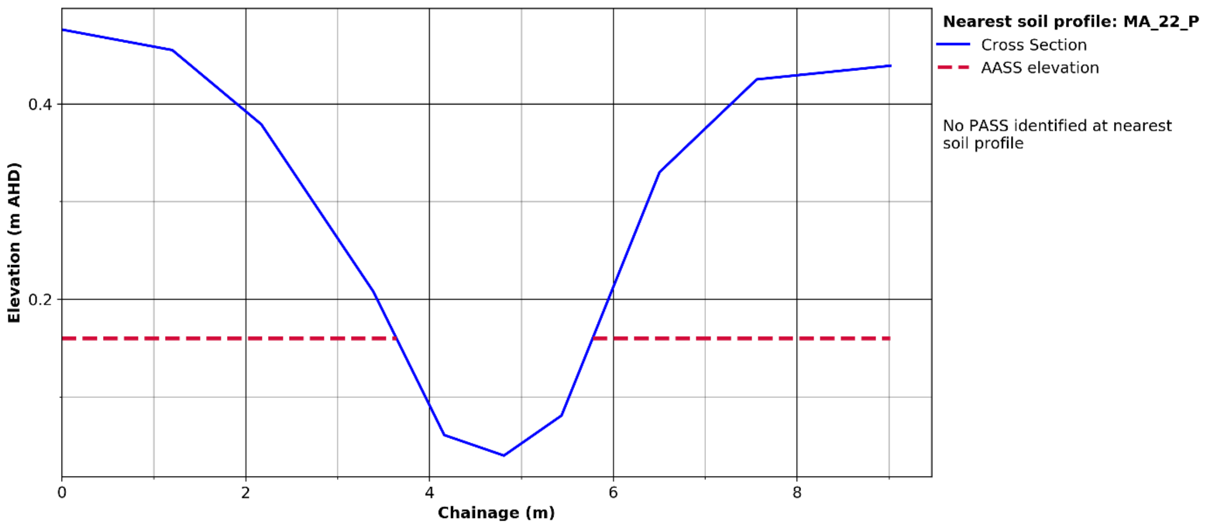

Figure G-2**: Macleay cross-section 119**

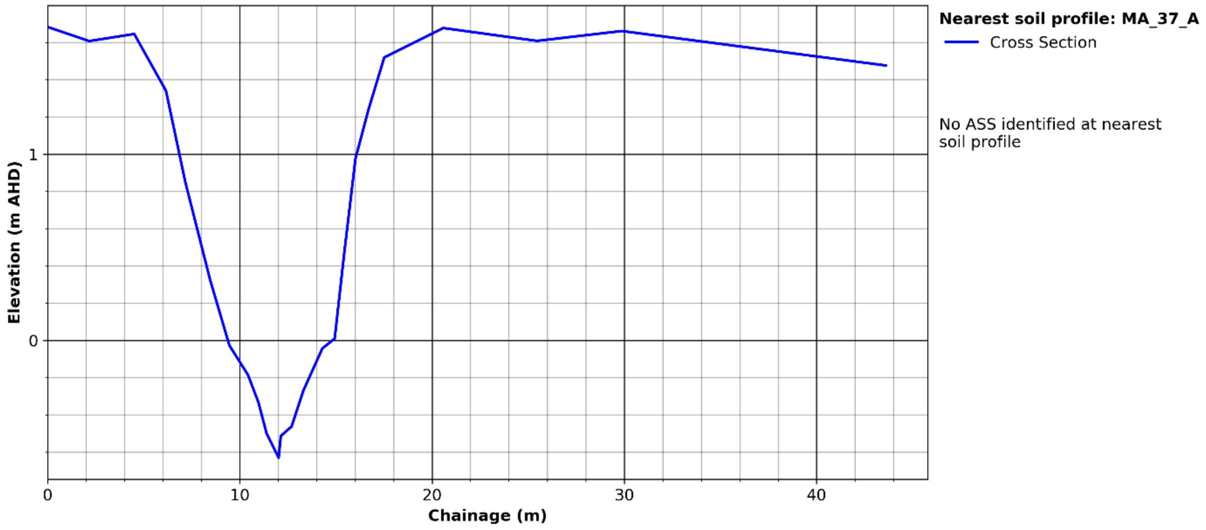

Figure G-3: Macleay cross-section 120

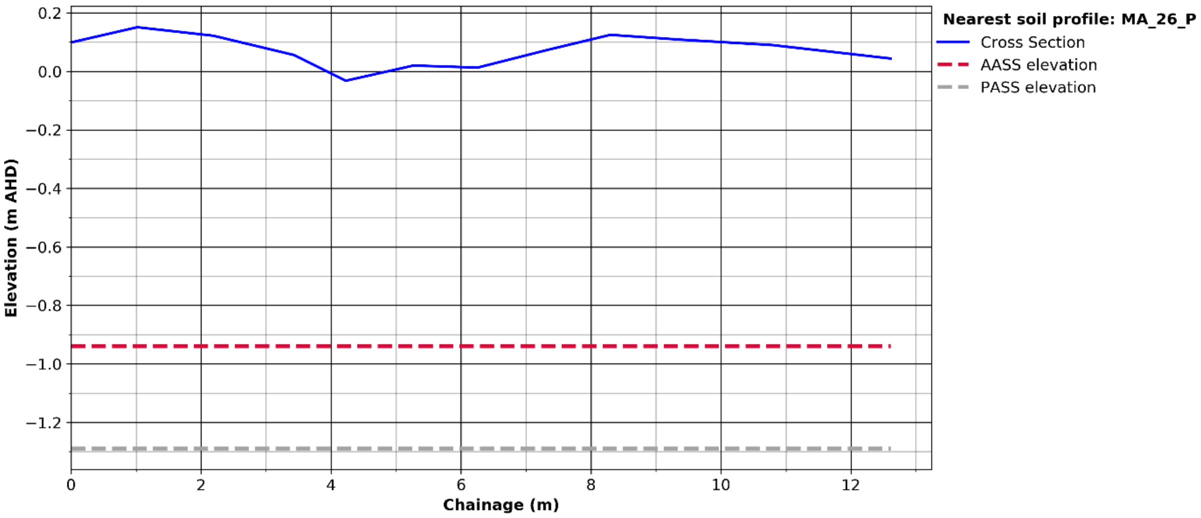

Figure G-4: Macleay cross-section 121

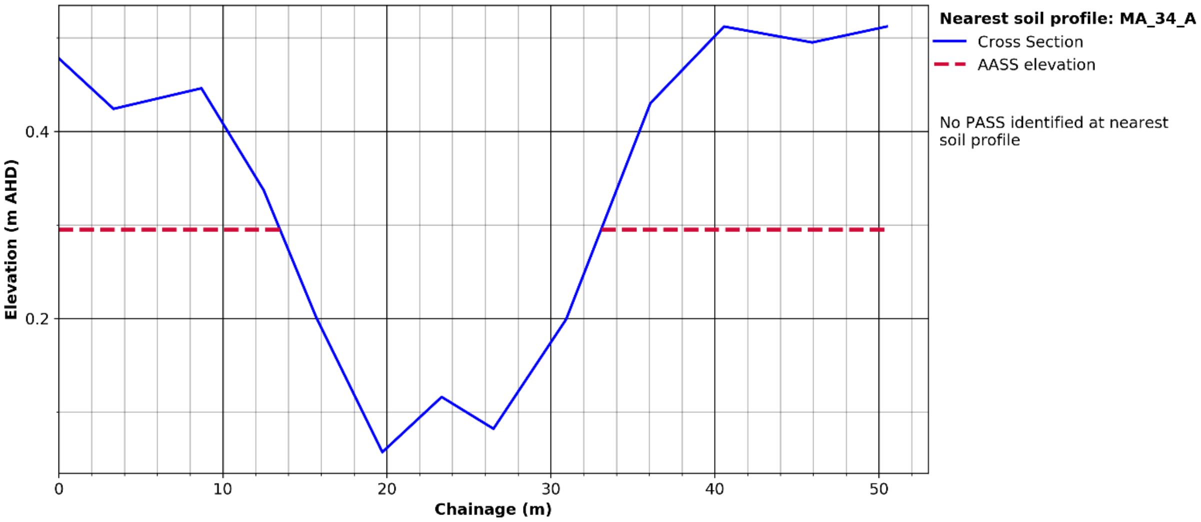

Figure G-5: Macleay cross-section 122

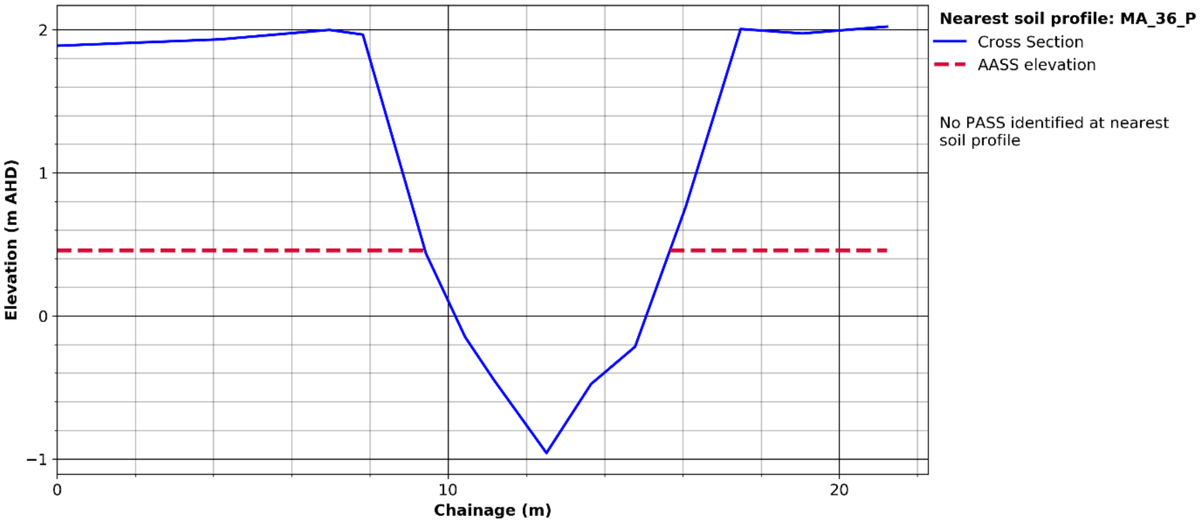

Figure G-6: Macleay cross-section 123

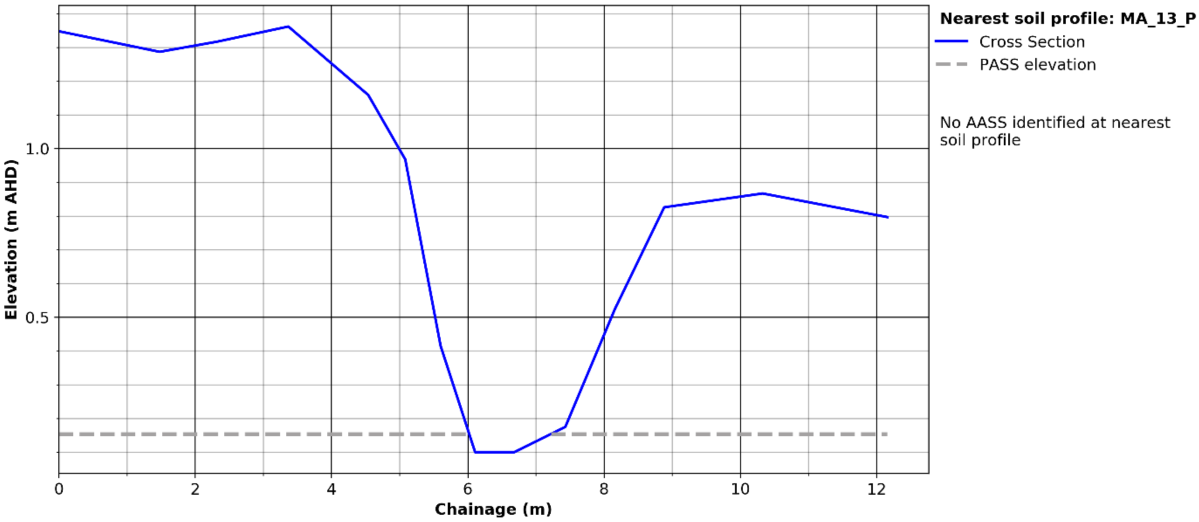

Figure G-7: Macleay cross-section 124

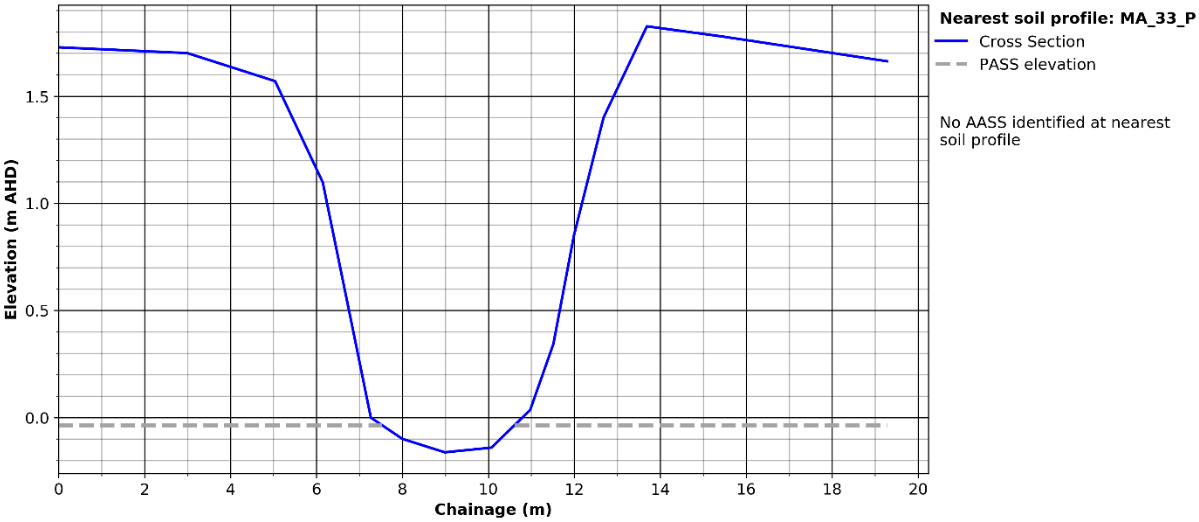

Figure G-8: Macleay cross-section 125

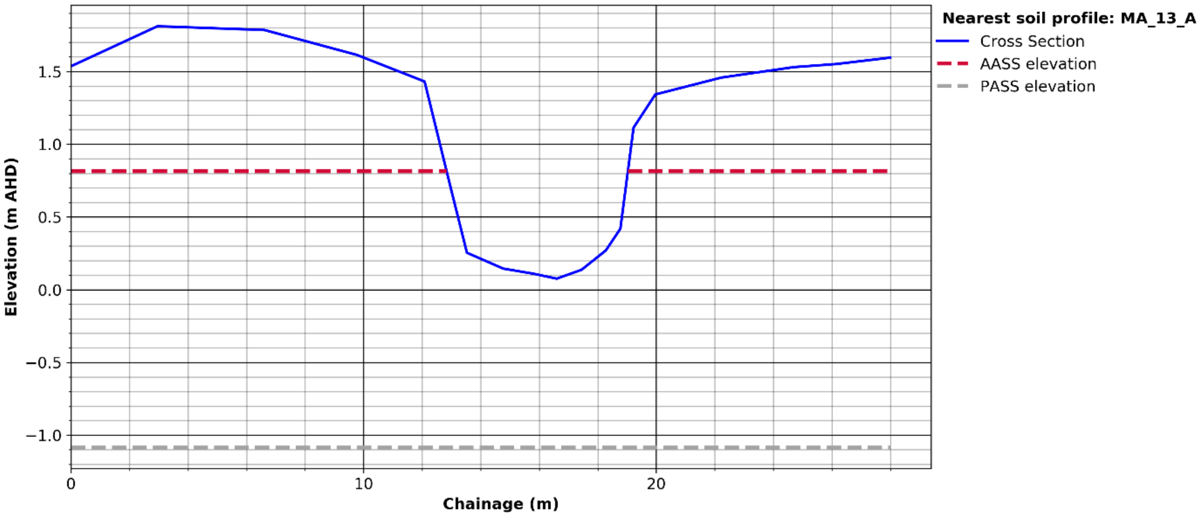

Figure G-9: Macleay cross-section 126

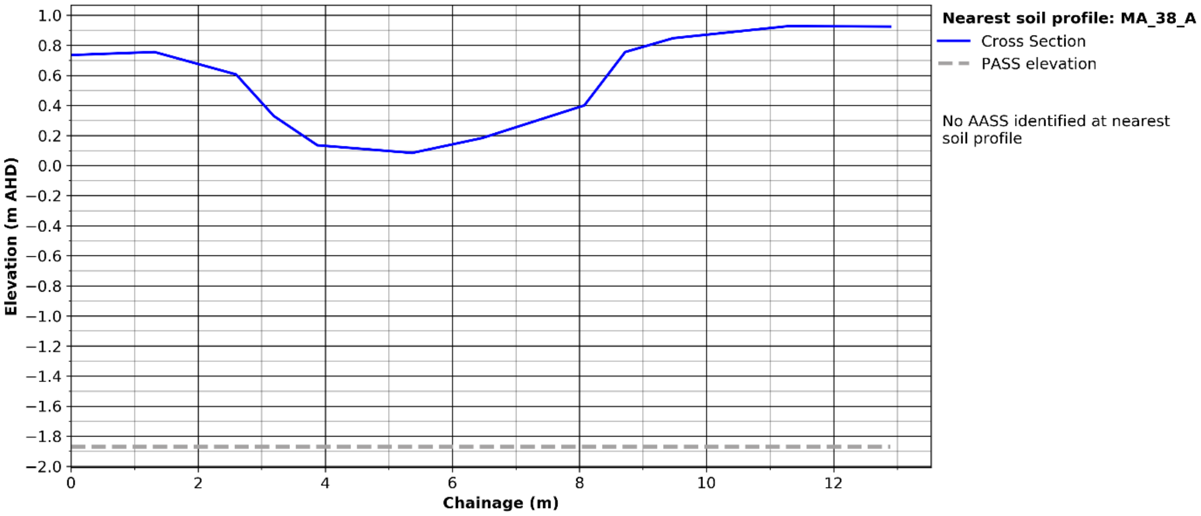

Figure G-10: Macleay cross-section 150

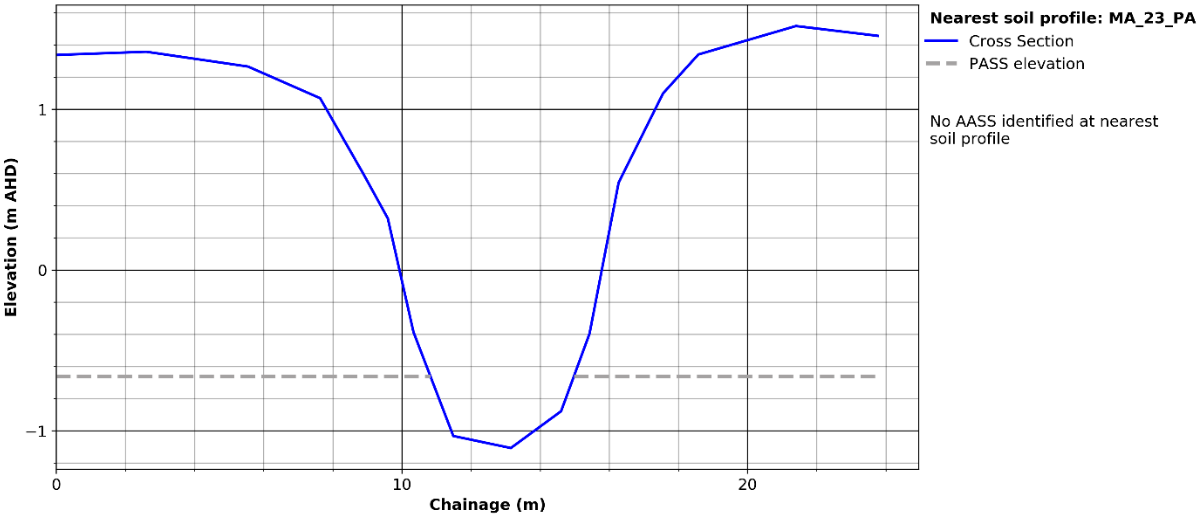

Figure G-11: Macleay cross-section 151

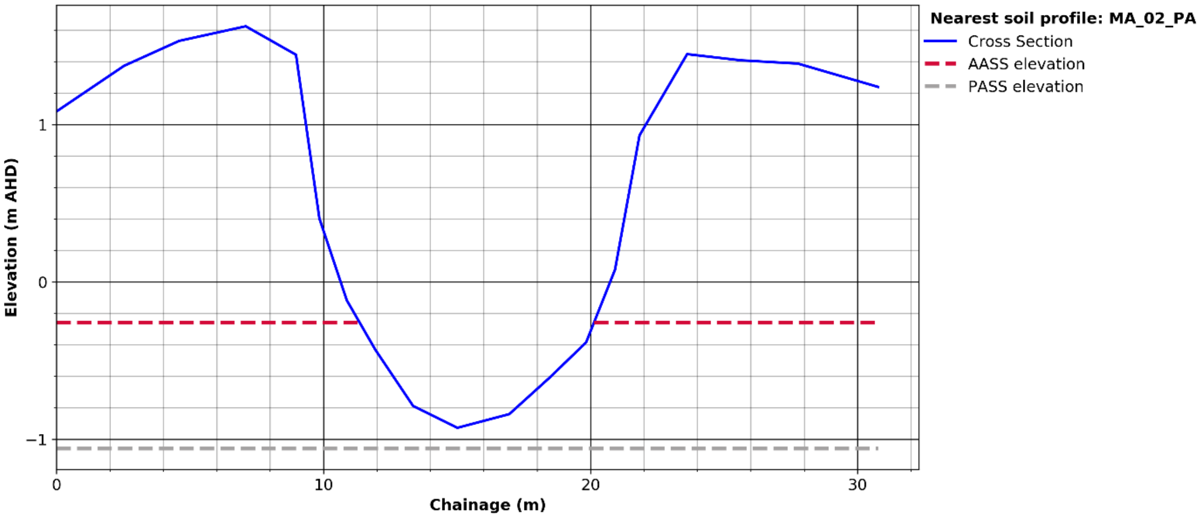

Figure G-12: Macleay cross-section 152

Appendix H Water quality

H1 Preamble

Water quality information provides an indication of the overall health of the marine estate. The following section outlines:

- The water quality objectives for the Macleay River estuary which are used to assess estuarine health;
- A literature review compiling and summarising historic water quality measurement data; and
- Water quality collected during this study.

The Macleay River estuary and its tributaries have been extensively monitored using a number of water quality parameters and often in an ad-hoc manner. Monitoring has typically focused on spot checks of water quality at various locations across the estuary, with some targeted monitoring programs being implemented. For the purpose of this study, a focus has been given to surface and groundwater physical-chemical parameters associated with the disturbance of acid sulfate soils (ASS) and low dissolved oxygen blackwater. Key water quality parameters that relate to these processes are; pH, electric conductivity (EC), nutrients (e.g. nitrogen and phosphorus), dissolved oxygen (DO) and metals (e.g. aluminium and iron).

H2 Macleay River water quality objectives

In 2006, water quality objectives (WQOs) were developed for the Macleay River catchment by the NSW Department of Planning, Industry and Environment (DPIE, formerly the Department of Environment, Climate Change and Water). The goal of the WQOs are to set out community values and uses for waterways and to provide a range of water quality indicators to assess the condition of these values and uses (DPIE, 2006). Trigger levels for the water quality indicators within the WQOs are based on the Australian and New Zealand guidelines for fresh and estuarine waters (ANZG, 2018, formerly ANZECC 2000) and the Australian Drinking Water Guidelines (NHMRC, 2011). WQOs have been identified for uncontrolled streams, national parks, nature reserves, state forests, estuaries and waterways affected by urban development within the study area for the Macleay River estuary and include objectives for the protection of:

- Aquatic ecosystems;
- Visual amenity;
- Primary and secondary contact recreation;
- Aquatic foods (cooked);
- Livestock, irrigation and homestead water supply; and
- Drinking water at point of supply (disinfection only, clarification and disinfection, and groundwater).

Table H-1 outlines key trigger levels for stressors applicable to the Macleay River estuary for each of the WQOs. Trigger levels (and their associated WQOs) have only been presented for dissolved oxygen, pH, electrical conductivity and nutrients due to their relevance to this study. Trigger levels for metals (e.g. iron and aluminium) are dependent upon different ecosystem conditions and could vary throughout the estuary. For a complete list of trigger values consult the ANZ guidelines (ANZG, 2018) and the Australian Drinking Water Guidelines (NHMRC, 2011).

Protection of aquatic ecosystems is governed by the trigger levels for dissolved oxygen, pH and nutrients. For estuaries and waterways affected by urban development no guidance is provided for electrical conductivity values as it is expected that high values will occur due to the continuous flushing of these waters by sea water. Trigger levels for electrical conductivity were provided for uncontrolled streams which are freshwater and upstream of the estuary.

Table H-1: Water quality objective trigger levels

WQOs	Dissolved oxygen (% saturation)	pH	EC (µS/cm)	Total nitrogen (µg/L)	Total phosphorus (µg/L)
Aquatic ecosystems	80 - 110	7.0 - 8.5	Not applicable	300	30
Primary contact recreation	Not specified	5.0 - 9	Not applicable	Not specified	Not specified
Livestock water supply	Not specified	Not specified	0 – 3,350 (varies for different livestock)	Not specified	Not specified
Irrigation water supply	Not specified	Not specified	< 950 - >12,200 (varies for different crop)	Not specified	Not specified
Homestead water supply	Not specified	6.5 - 8.5	<1,000	Not specified	Not specified
Drinking water (treated)	> 80	6.5 – 8.5	<1,500	Not specified	Not specified

H3 Existing floodplain water quality data

H3.1 Summary

This study has focused on identifying water quality information that provides information on sources and impacts of blackwater (caused through deoxygenation) and acid sulfate soils within the Macleay River floodplain. Table H-2 provides a detailed summary of historic water quality investigations including monitoring dates, monitoring locations, parameters measured and a brief summary of the study findings. Note, in addition to this summary, a number of reviews have been completed to identify existing water quality data across the Macleay River Estuary (Botting, 2000; Tulau and Naylor, 1999; Telfer, 2005; Hurrell et al., 2009; Geolink, 2010; Glamore and Rayner, 2017; Rayner and Glamore, 2017; Rayner et al., 2020b).

H3.2 Blackwater

Water quality measurements for nutrients (usually nitrogen and phosphorus) and dissolved oxygen can be used as an indicator for blackwater which results when oxygen is stripped from the water column. This usually happens via biological means (which can occur as a result of the breakdown of organic matter caused by eutrophication or prolonged inundation of water intolerant vegetation) or chemical means (as occurs when monosulfidic black ooze (MBO) is mobilised or acid sulfate soils are oxidised). Note, the blackwater prioritisation (see Section 4) has focused on the biological cause of blackwater specifically through prolonged inundation of water on floodplains resulting in the die off and decomposition of organic matter. This causes water to become ‘hypoxic’ whereby dissolved oxygen is consumed from a water body at a greater rate than they can be replenished. Alternative causes for blackwater have been assessed in literature and are discussed in this section. These include nutrient loading of waterways which causes eutrophication, which can lead to blackwater (in a mechanism similar to prolonged inundation) as biological matter breaks down, and also chemical causes of blackwater whereby minerals oxidise during chemical reactions stripping oxygen from the water column.

In their review, Tulau and Naylor (1999) found that low dissolved oxygen levels were observed in the Belmore River following rainfall events. Botting (2000) found that low dissolved oxygen levels occurred across the broader Macleay River further highlighting it as an issue. In March 2001, a major flood event occurred resulting in fish kills due to a blackwater event. Kennelly and McVea (2002) investigated this event and discovered that it took up to four (4) weeks before dissolved oxygen levels recovered in the estuary. Engenuity Design (2003) investigated low dissolved oxygen events at Collombatti-Clybucca and found that they occurred approximately two (2) weeks after extended rainfall events due to decomposition of vegetation. Hurrell et al. (2009) found that this was true for the broader estuary with poor water quality due to low dissolved oxygen occurring following rainfall events. Geolink (2010) attributed low dissolved oxygen events in the Macleay River Estuary to its backswamps. A number of investigations found this to be the case for the Collombatti-Clybucca backswamp (Glamore and Rayner, 2017; Rayner and Glamore, 2017; Rayner et al., 2020b). During field investigations completed as part of this study it was observed that significant rainfall in February 2020 had caused a blackwater event which originated in Kinchela Creek due to prolonged inundation of water intolerant vegetation (Figure H-1). In addition to blackwater occurring due to the breakdown of organic matter, a number of studies also noted that nutrient loads, usually from sewage treatment plants, also contributed to lower dissolved oxygen levels in the Macleay River (Botting, 2000; Telfer, 2005; Hurrell et al., 2009).

Figure H-1: Blackwater observed in Kinchela Creek on 2 March 2020 where rugged dissolved oxygen was measured to be 0.00%

H3.3 Acid sulfate soils

The oxidisation of acid sulfate soils (ASS) results in the development of acid which can be transported via groundwater to nearby waterways resulting in acidic water with a low pH. To understand the impact of ASS within the Macleay River estuary, a number of studies have measured water acidity (pH). Walker (1972) observed that acid was created within ASS during prolonged dry periods and expressed concern that extensive flood mitigation works completed across the Macleay River estuary would result in export of extremely low pH acid. Haskins (1999) completed a study on Collombatti-Clybucca and found that these concerns were coming to fruition, measuring pH levels less than two (2). Tulau and Naylor (1999) completed a comprehensive study of ASS and found that indeed there were a number of acid producing hot spots across the Macleay, namely: Yarrahapinni, Collombatti-Clybucca, Belmore, Frogmore, Kinchela and Raffertys. In 2001, Manly Hydraulics Laboratory (2001) completed a water quality measurement campaign at Yarrahapinni and found that following rainfall events acid was being discharged to Clybucca Creek. In the next few years remediation initiatives began in both the Yarrahapinni (Glamore et al., 2012; Wilkinson, 2003) and the Collombatti-Clybucca (Engenuity Design, 2003; Edeson et al., 2004; Cheeseman et al., 2004; Kempsey Shire Council, 2004a; McLennan et al., 2005; Bush et al., 2006) backswamps looking at mitigating the impacts of ASS. Restoration efforts at Yarrahapinni have been successful with recorded improvements in pH levels of water discharged from the catchment (Wilkinson, 2003). Efforts at Collombatti-Clybucca have continued in recent years with farm scale remediation approaches only marginally improving water quality (Glamore and Rayner, 2017; Rayner and Glamore, 2017; Rayner et al., 2020b; Bush et al., 2006). Rayner et al. (2020b) investigated these remediation approaches and found that a shift from farm scale to catchment wide remediation, as occurred at Yarrahapinni, would be the best method for improving water quality.

Table H-2: Existing water quality data for the Macleay River floodplain

Study	Sampling dates	Location	Parameters	Findings
Walker (1972)	1962 to 1968	Belmore River; Kinchela Creek	pH	Acid production from acid sulfate soils was found to occur following prolonged dry periods which was found to lower the water table. Artificial drainage has significant potential to export of water with extremely low acidity.
Haskins (1999)	July to September 1999	Collombatti-Clybucca	Electrical conductivity, pH, temperature,	Drainage combined with rainfall in July 1999 resulted in an acid runoff event with pH levels sustained below four (4). Acid drainage was prolonged and continued for the entire monitoring period following the rainfall event including periods in September where pH levels below two (2) were measured. Salinity levels are influenced by rainfall with runoff events resulting in a lowering of electrical conductivity.
Tulau and Naylor (1999)	Not applicable	Macleay River estuary	Not applicable	Contains a literature review including multiple datasets that are not all publicly available. A number of areas including Yarrahapinni, Collombatti-Clybucca, Belmore, Frogmore, Kinchela and Raffertys are noted as acid sulfate soil hotspots. There is significant anecdotal evidence and data indicating poor water quality being discharged from the Yarrahapinni Wetlands due to drainage of acid sulfate soils. Clybucca Creek is renowned for being the location of numerous fish kills and measurements of pH, iron and Aluminium indicate extensive acid sulfate soil drainage from the upstream area. Belmore Swamp has been highlighted as locations where fish kills occur following rainfall events due to low dissolved oxygen levels. There is also significant water quality measurement of pH and metals indicating acid sulfate soils. Artificial drainage resulting in acid export at Frogmore has resulted in instances where water in the drains is of such poor water quality that it is uninhabitable for aquatic life. Aluminium floc has been observed in Raffertys Drain which indicates oxidisation of acid sulfate soils.
Botting (2000)	Not applicable	Macleay River	Not applicable	Contains an extensive literature review including multiple datasets that are not all publicly available. Degraded agricultural land, urban runoff and sewage treatment plant effluent were recognised as the biggest contributor to poor water quality. Low dissolved oxygen levels across the river were observed and tended to be during low flow periods, however more evidence was needed to substantiate this.
Manly Hydraulics Laboratory (2001)	March 1996 to February 1999	Yarrahapinni	pH, electrical conductivity, temperature, dissolved oxygen	Acidic water was observed to discharge from the wetlands following rainfall events characteristic to drained acid sulfate soils. Acidic waters tended to be buffered in Clybucca Creek when salinity levels were raised.
Kennelly and McVea (2002)	March 2001 to March 2002	Macleay River estuary	Dissolved oxygen, pH, electrical conductivity/salinity, turbidity, temperature	It takes three (3) to four (4) weeks for dissolved oxygen and pH levels to return to normal after an event.
Engenuity Design (2003)	March 2002 to November 2002-	Collombatti-Clybucca	pH, electrical conductivity, temperature, dissolved oxygen, redox potential	Review of water quality data collected by Kempsey Shire Council. Higher pH levels were observed on the downstream side of floodgate infrastructure where higher electrical conductivity measurements were also observed. Low dissolved oxygen levels occurred approximately two (2) weeks after extended rainfall events. Low redox potential was observed to occur a week prior to low dissolved oxygen events.
Edeson et al. (2004)	21/03/2004	Collombatti-Clybucca	pH, redox potential, electrical conductivity	Water quality measurements were taken from ponded water across Mayes Swamp. Very acidic (pH < 4) and low electrical conductivity (<2,500µS/cm) measurements were observed at all sites.
Kempsey Shire Council (2004a)	June 2002 to June 2004	Collombatti-Clybucca	pH, electrical conductivity, temperature, dissolved oxygen, oxidation reduction potential, chloride, sulfate, iron	Sulfate levels were observed to increase in drains following rainfall events. Levels of chloride and sulfate were higher in the groundwater compared to the surface water. Two mechanisms were observed to acidify waterways: (1) overland flow during transporting acid from scalds during initial rainfall and (2) drainage of acidic groundwater once the water table lowered.
Allsop and Kadluczka (2004)	14 to 16 April 2003	Macleay River estuary	Density, temperature, salinity, dissolved oxygen, pH, chlorophyll a,	Measurements were typical for what could be expected for an estuary influenced by tides and winds with tides exerting a greater force. All measurements were within guideline levels.
Cheeseman et al. (2004)	20/04/2004 to 22/04/2004	Collombatti-Clybucca	pH, electrical conductivity, redox potential	A transect was completed across Yerbury's Scald which showed fresh water that varied in pH from acidic (pH<4) to neutral (pH~7).
McLennan et al. (2005)	17 to 22 April 2005	Collombatti-Clybucca	pH, electrical conductivity, dissolved oxygen, temperature	Measurements taken of ponded water across Mayes Swamp and Yerbury's Scald indicated that sparsity of vegetation cover correlated with poorer water quality.

Study	Sampling dates	Location	Parameters	Findings
Telfer (2005)	Not applicable	Macleay River estuary	Not applicable	Contains an extensive literature review including multiple datasets that are not all publicly available. It was noted that monitoring of nutrients is needed to understand the extensive growth of weeds in the Kempsey to Frederickton section of the Macleay River. Further analysis of tide data is required to determine tidal flushing times.
Smith (2005)	March 2000	Yarrahapinni	Electrical conductivity, pH, redox potential, dissolved oxygen, temperature, bicarbonate, carbon dioxide, nitrogen, phosphorus, iron, sulfides, arsenic, cations, anions, rare earth elements, environmental isotopes	Investigation into arsenic concentrations in coastal aquifers also observed high acid levels in the aquifer.
Bush et al. (2006)	March 2002 to July 2005	Collombatti-Clybucca	pH, electrical conductivity, dissolved oxygen, oxidation reduction potential	Monitoring of the effectiveness of remediation of acid sulfate soils was inconclusive due to variations in rainfall patterns between pre and post monitoring events. There was clear evidence of tidal buffering of pH which occurred downstream of floodgates.
Hurrell et al. (2009)	September 2006 to August 2007	Macleay River estuary	Electrical conductivity/salinity, dissolved oxygen, temperature, turbidity, pH, nitrogen, phosphorus, chlorophyll a, Secchi depth, total suspended solids	Contains a literature review including multiple datasets that are not all publicly available. Floods are observed to cause poor water quality resulting in loss of habitat due to low pH and low dissolved oxygen levels. Following flood events nutrient levels in the estuary increase as the flushing time of the estuary increases. In dry times nutrient loads from sewage treatment plants have been observed to increase algae growth.
Geolink (2010)	Not applicable	Macleay River estuary	Not applicable	Contains an extensive literature review including multiple datasets that are not all publicly available. Backswamp areas have been observed as major inputs of poor water quality due to low acid levels, deoxygenated water and iron/Aluminium.
Roper et al. (2011)	1970 to 2003	Macleay River estuary	Salinity, temperature, dissolved oxygen, pH, Secchi depth, turbidity, chlorophyll a, total suspended solids, nitrogen, phosphorus, silicon	Out of 101 NSW estuaries assessed for condition the Macleay River was given a ‘good’ rating (along with 38% of estuaries, 27% were ‘very good’). Out of 184 NSW estuaries assessed for susceptibility to environmental pressures the Macleay River was given a ‘moderate’ rating (along with 78% of all estuaries,6% were ‘high’ and no estuaries were ‘very high’).
Glamore et al. (2012)	Not applicable	Yarrahapinni	Not applicable	A number of water quality observations collected at Yarrahapinni were reviewed as part of the development of rehabilitation options.
Wilkinson (2014)	2007 to 2012	Yarrahapinni	pH, salinity, dissolved oxygen, aluminum, iron, sulfide	Inundation of low-lying land improved water quality by allowing gradual release of acidified water each tidal cycle and preventing build-up of acid.
Glamore and Rayner (2017)	February 2014 to August 2015	Collombatti-Clybucca	Salinity	Contains a review of literature containing water quality information for the Collombatti-Clybucca area. Observations of salinity at the Menarcobrinni floodgates range from fresh to 25ppt.
Rayner and Glamore (2017)	Not applicable	Collombatti-Clybucca	Not applicable	Review of multiple literature sources found that poor water quality from drained acid sulfate soils was discharging to the Macleay Estuary. Blackwater caused by die off of vegetation was also found to be an issue.
NSW Food Authority (2019)	2013 to 2019	Macleay River estuary	Temperature, salinity	Average salinity was recorded as 29.3ppt with a 10th percentile of 20.5ppt and 90th percentile of 33ppt.
NSW DPIE (2019)	2009, 2010, 2018, 2019	Macleay River estuary	Secchi depth, temperature, electrical conductivity (salinity), turbidity, chlorophyll a, colour, nitrogen, phosphorus, pH, CDOM, fDOM, dissolved oxygen, blue green algae, silicon	Salinity measured across the estuary varied from 1ppt to 20ppt, pH measurements varied from 7.2 to 7.9 (only measured in 2018 and 2019). Dissolved oxygen varied from 91.8% to 104% (only measured in 2018 and 2019).
Kempsey Shire Council (2019)	January 2015 to April 2019	Macleay River estuary	Thermotolerant coliforms, enterococci, temperature, pH, oxidation reduction potential, electrical conductivity, dissolved oxygen, total dissolved solids	Water quality observations at 31 locations across the Macleay River Estuary taken on a monthly basis. Detailed analysis has not been completed to determine data trends or statistics.
Rayner et al. (2020b)	26/07/2018 to 4/12/2018	Collombatti-Clybucca	pH, electrical conductivity, dissolved oxygen, chlorophyll a	Provides a comprehensive review of water quality literature for the Collombatti-Clybucca area. Evidence of Yerburys sill holding back acidic water was observed. In areas downstream of the sill buffering of water was observed with pH measurements rising from 4.5 to 6.7 over ten months.
Kempsey Shire Council (2020)	Not specified	Macleay River estuary	Not specified	Ten permanent and two (2) mobile water quality monitoring stations are positioned across the Macleay River Floodplain measuring continuous data as part of Kempsey Shire Councils Lower-Macleay water monitoring project. Data is not publicly available.

H4 Field investigations

During field investigations, surface water and groundwater water quality measurements were opportunistically collected at various locations across the Macleay River floodplain. Water quality parameters measured included pH and electrical conductivity (EC). Details on the instrumentation used to measure water quality parameters can be found in Appendix A of the Methods report (Rayner et al., 2020a).

Water quality data was collected during structure surveys (surface water quality upstream and downstream of the structures) and soil profile sampling (surface water quality of nearby waterways and groundwater quality within the soil sample holes). Water quality measurements taken during structure surveys upstream and downstream of the structures are summarised in Table H-3. Surface water quality measurements taken from nearby water bodies during soil profile sampling are summarised in Table H-4. Groundwater quality measurements taken during soil profile sampling are summarised in Table H-5. This data has also been spatially represented to show the variability of pH and electrical conductivity across the Macleay River floodplain. Surface water quality measurements for the Macleay River floodplain are presented in Figure H-2 and Figure H-3 for pH and electrical conductivity, respectively. Groundwater quality measurements for the Macleay River floodplain are presented in Figure H-4 and Figure H-5 for pH and electrical conductivity, respectively.

Table H-3 Summary of surface water quality measurements taken upstream and downstream of structures

Nearby structure ID	Date	Easting (m)	Northing (m)	Upstream of the structure		Downstream of the structure	
				pH	Electrical conductivity (µS/cm)	pH	Electrical conductivity (µS/cm)
003G1	2/03/2020	497850	6573326	9.3	12,800		
005G1	2/03/2020	498505	6571196	7.6	20,000	8.0	28,349
010G1	9/09/2019	482515	6561814	7.0	34,000		
017G1	2/03/2020	496299	6562314	7.1	18,000		
022G1	10/09/2019	498538	6560174	7.7	10,800		
023G1	11/09/2019	499249	6568628	3.3	15,700	7.3	24,200
028G1	11/09/2019	499618	6569553	7.3	27,500	7.5	25,200
029G1	11/09/2019	499899	6566658	6.9	18,300	7.0	21,000
075G1	10/09/2019	501319	6578900	8.5	47,788	8.1	41,000
024G1	2/03/2020	499450	6566880			7.0	21,370
027G1	11/09/2019	499696	6568338			7.2	13,300
074G1	11/09/2019	503987	6579600			7.3	45,700

Table H-4: Summary of surface water quality measurements taken in waterbodies near soil profile sample holes

Nearby soil profile ID	Date	Easting (m)	Northing (m)	pH	Electrical conductivity (µS/cm)	Notes
MA_13_A	1/10/2019	484731	6563502	6.8	1,247	
MA_13_P	1/10/2019	484878	6566954	3.7	11,281	
MA_22_P	3/10/2019	500840	6571886	3.3	8,180	
MA_33_P	1/10/2019	485307	6565077	6.6	9,737	
MA_34_A	1/10/2019	493372	6561524	5.0	751	
MA_36_A	3/10/2019	499550	6564150	6.4	21,431	
MA_36_P	2/10/2019	492761	6563913	7.4	12,194	
MA_37_A	3/10/2019	499608	6569673	8.4	26,217	
MA_39_A	4/10/2019	502941	6580042	7.5	48,807	Measured in the river
MA_39_A	4/10/2019	502949	6579912	7.4	4,189	Measured in nearby freshwater wetland
MA_31_A	20/11/2019	498294	6566463	2.9	11,692	
MA_02_PA	30/01/2020	497347	6561081		24,388	Measured upstream of nearby floodgate
MA_02_PA	30/01/2020	497349	6561092		20,827	Measured downstream of nearby floodgate
MA_16_PA	28/01/2020	500488	6577536	7.0	45,974	
MA_23_PA	29/01/2020	500194	6575287	8.9	9,842	
MA_38_A	29/01/2020	498958	6574452	8.1	33,970	

Table H-5: Summary of groundwater quality measurements taken from soil sample holes

Soil profile ID	Date	Easting (m)	Northing (m)	pH	Electrical conductivity (µS/cm)
MA_08_P	27/09/2019	487336	6561202	5.9	1,402
MA_11_A	30/09/2019	481495	6561380	5.4	1,411
MA_11_P	30/09/2019	481738	6560678	4.1	5,659
MA_13_P	1/10/2019	484878	6566954	4.7	1,667
MA_22_P	3/10/2019	500840	6571886	4.1	6,013
MA_26_P	2/10/2019	499197	6558684	4.5	2,671
MA_33_P	1/10/2019	485307	6565077	4.7	1,553
MA_34_A	1/10/2019	493372	6561524	3.6	3,936
MA_36_A	3/10/2019	499550	6564150	4.8	7,666
MA_36_P	2/10/2019	492761	6563913	4.6	1,883
MA_37_A	3/10/2019	499608	6569673	6.8	2,203
MA_39_A	4/10/2019	502951	6579962	5.7	2,825
MA_31_A	20/11/2019	498294	6566463	6.2	11,864
CLYB-BH02	22/11/2019	492912	6576433	6.4	9,205
MA_02_PA	30/01/2020	497314	6561083		6,525
MA_16_A	29/01/2020	501162	6577247	6.5	4,214
MA_16_PA	28/01/2020	500488	6577536	7.4	5,690
MA_23_PA	29/01/2020	500194	6575287	6.5	129

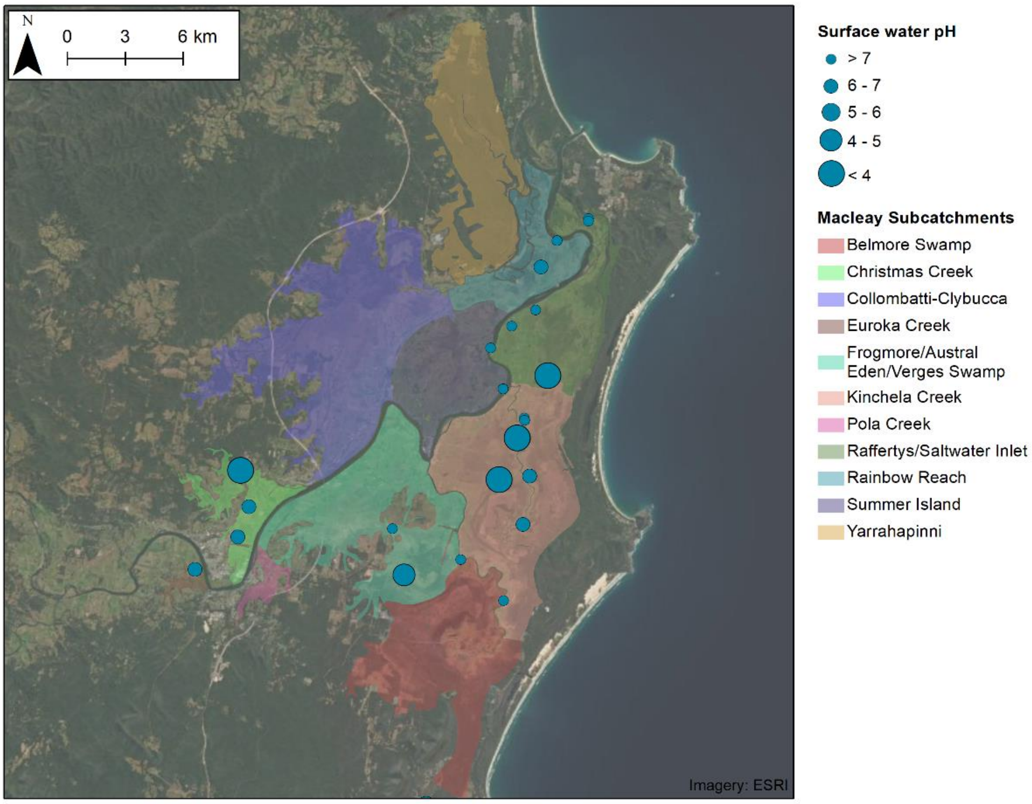

Figure H-2: Surface water pH measurements taken across the Macleay River floodplain

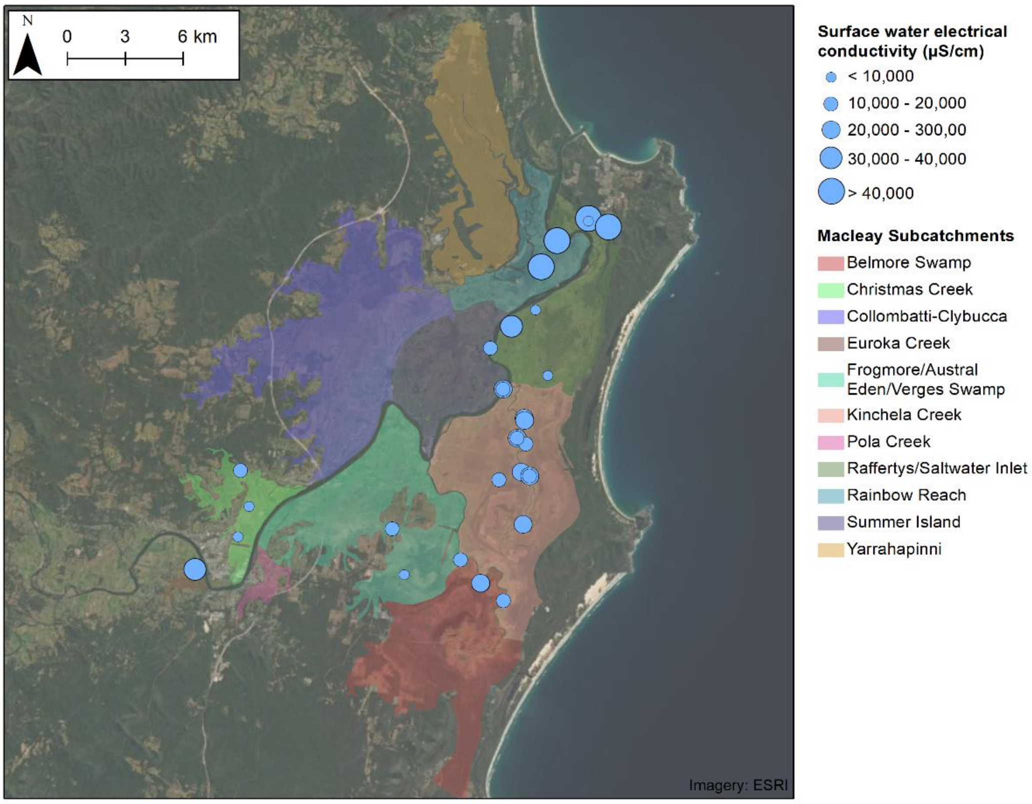

Figure H-3: Surface water electrical conductivity measurements taken across the Macleay River floodplain

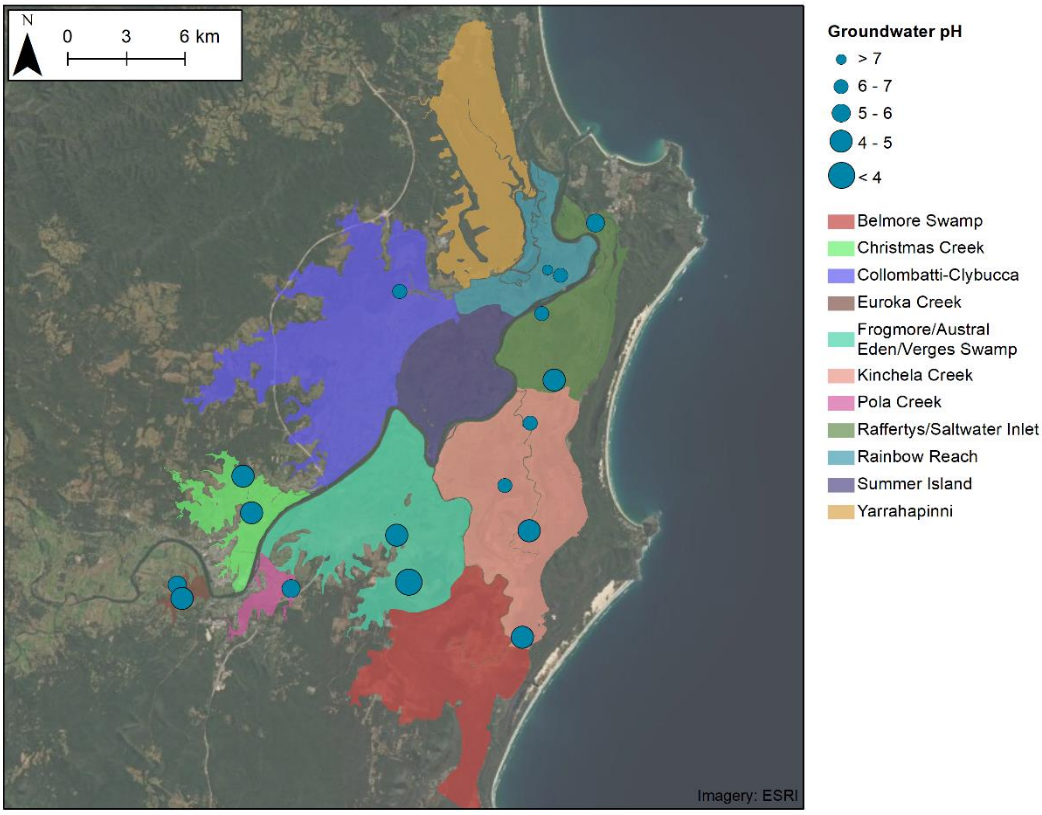

Figure H-4: Groundwater pH measurements taken across the Macleay River floodplain

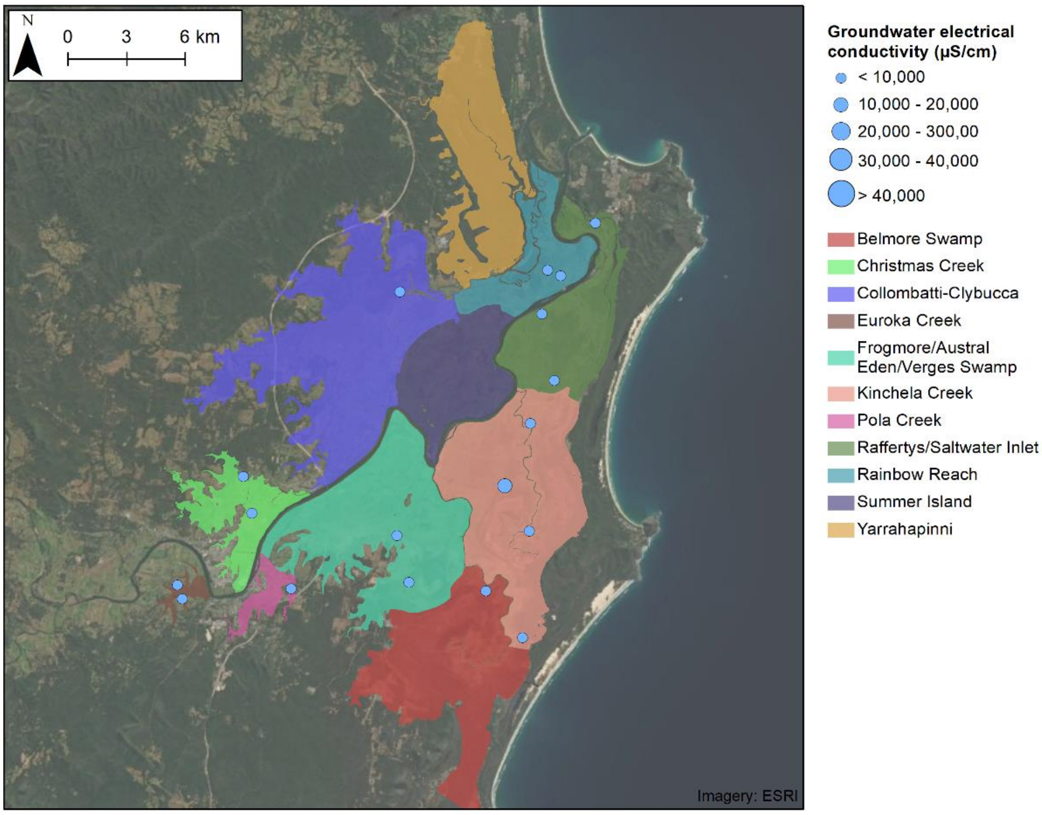

Figure H-5: Groundwater electrical conductivity measurements taken across the Macleay River

Appendix I Numerical modelling

I1 Preamble

The following section provides a description of the hydrodynamic numerical model used for the Macleay River estuary.

I2 Hydrodynamic model

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

I2.1 Numerical model

Numerical modelling of the Macleay 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 I-2:

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

Equation I-2

Where:

ε = horizontal eddy viscosity (m^2/s)

V = velocity (m/s)

α = non-dimensional scaling factor

Δ_{elt} = 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. across the 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.

I2.2 Model domain

A RMA-2 hydrodynamic model of the Macleay River Floodplain was adopted from the “Macleay River Estuary Process Study” (WMA, 2009). This model extended from the ocean entrance up to near Belgrave Falls, as well as the tidal reaches of the Macleay Arm, Clybucca Creek, Kinchela Creek and Belmore River. The WMA (2009) hydrodynamic model of the Macleay River estuary was used in this study to simulate the typical tidal water level variations within the estuary. The RMA-2 hydrodynamic model domain is shown in Figure I-1.

Figure I-1: Macleay River estuary – tidal hydrodynamic model extent (after WMA (2009))

I2.3 Model inputs

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

Channel geometry of the Macleay River hydrodynamic model utilised the same data as the RMA-2 numerical model developed by (WMA, 2009). This model was based on the 2003 bathymetric survey of the Macleay River estuary as well as available overbank survey data of major drainage channels (WMA, 2009).

Catchment inflows applied for this study were based on observed river flow data from WaterNSW gauging stations in the upper Macleay River catchment as shown in Figure I-2. The flow gauging stations are located upstream of the numerical model boundary, and therefore required adjustment to account for the additional catchment area and runoff that could occur in between the flow gauging location and the model inflow boundary. To account for this, catchment runoff data was scaled by the additional contributing catchment areas that were missed between the gauges and the model boundary. This was achieved using standard GIS methods to compare the upstream area of the gauging sites to the upstream area of the model domain. A summary table of the upstream inflow boundaries and scaling factors are provided in Table I-1. Localised floodplain subcatchment runoff inflows were excluded from the model as sensitivity testing indicated that day-to-day water levels in the lower reaches of the estuary were found to be dominated by tidal fluctuations. The downstream ocean tidal boundary of the model was based on the observed water levels from the NSW DPIE Manly Hydraulics Laboratory (MHL) offshore station at Port Macquarie (station number 207450).

Figure I-2: Location of WaterNSW River flow gauges relation to hydrodynamic model extent

Table I-1: Summary of model boundary conditions

Gauging station name	Data source	Station number	Scale factor
Macleay at Turners Flat	WaterNSW	206011	1.03
Port Macquarie Offshore	MHL	207450	NA

I2.4 Model calibration

The calibration of the hydrodynamic model for the Macleay River estuary was reproduced against water level and tidal flow gauging stations for 2003. The year 2003 was selected based on short-term tidal flow gauging of the Macleay estuary which were recorded at various locations within the estuary on 16 April 2003 (MHL, 2003). These locations are shown in Figure I-3. Water level data was sourced from NSW DPIE Manly Hydraulics Laboratory (MHL). These locations are shown in Figure I-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 value of 0.025 was adopted for the main channel and 0.045 near Yarrahapinni Wetlands and Clybucca Creek to achieve final calibrations.

The flow calibration results are shown in Figure I-5 to Figure I-9. The water level calibration results for a 4-day window during this period are shown in Figure I-10 to Figure I-12. The model was calibrated (for dry weather periods) to less than 0.15 m for the entire estuary.

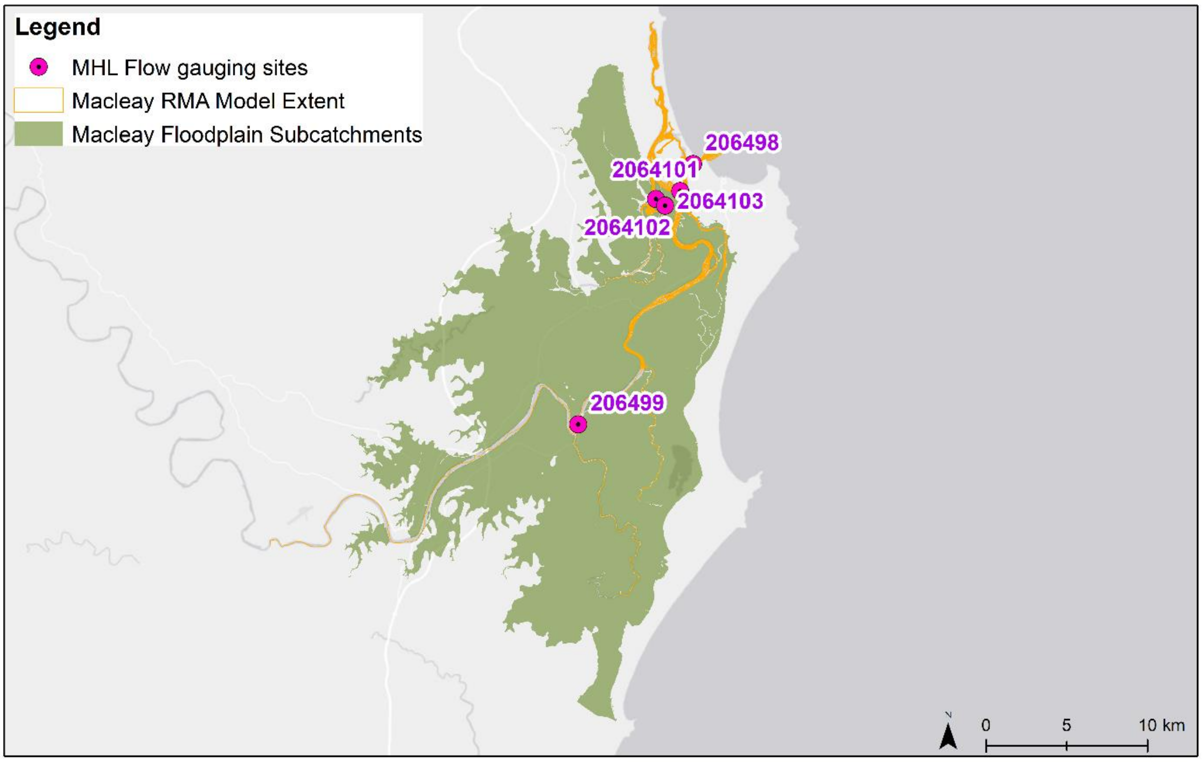

Figure I-3: Location of selected tidal flow gauging stations used for calibration of the Macleay River estuary hydrodynamic model

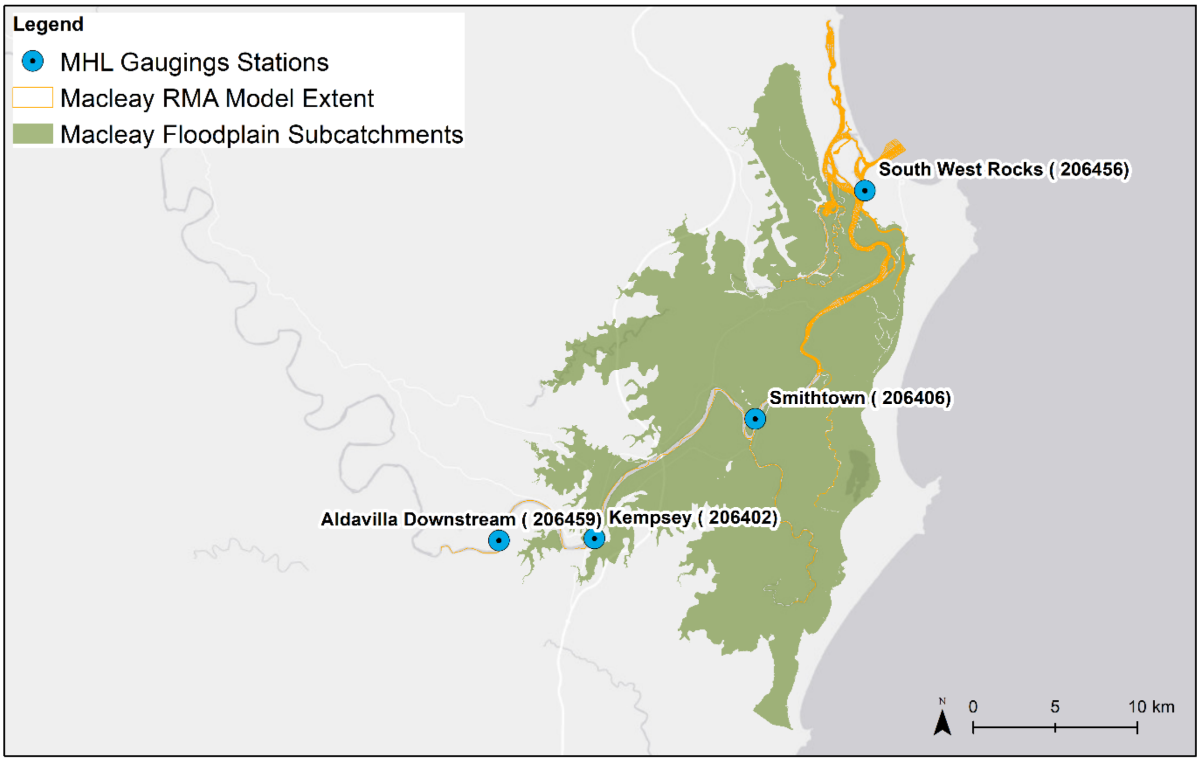

Figure I-4: Location of selected water level stations used for calibration of the Macleay River estuary hydrodynamic model

I2.5 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. Note that the downstream ocean boundary water levels for these simulations were substituted with water level data from the NSW DPIE Manly Hydraulics Laboratory (MHL) station at South West Rocks (station number 206456). This is because water level data from the Port Macquarie Offshore Gauge (station number 207450) did not extend across all periods required for this study. 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 Macleay Estuary for 2013 and 2019 are provided in Figure I-13 to Figure I-20.

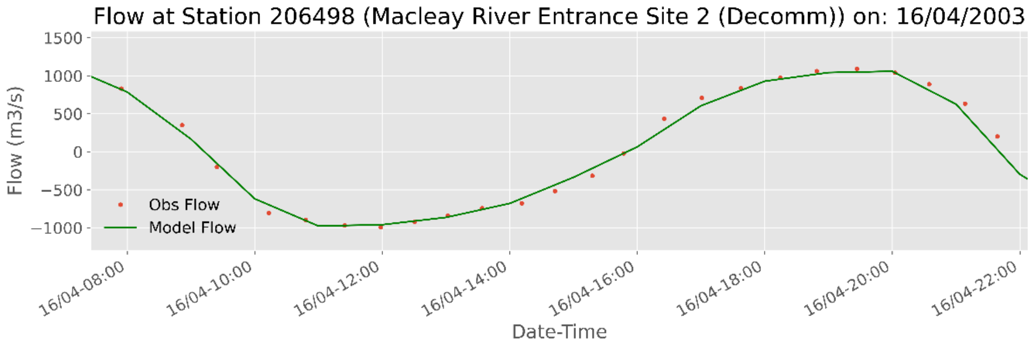

Figure I-5: Macleay hydrodynamic model flow calibrations at Station 206498

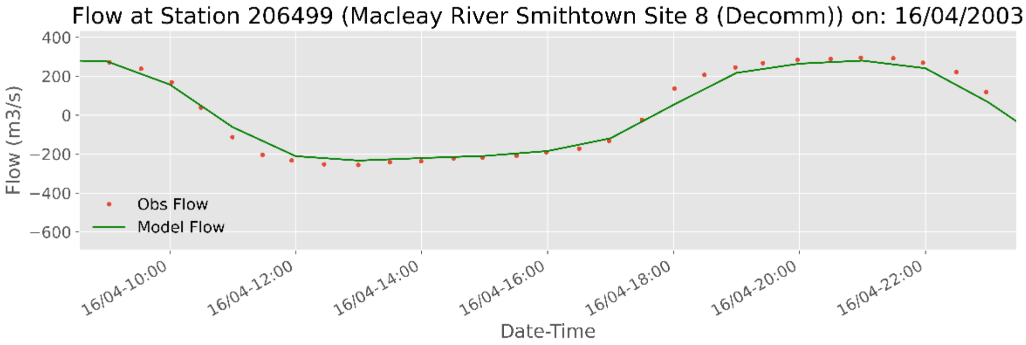

Figure I-6: Macleay hydrodynamic model flow calibrations at Station 206499

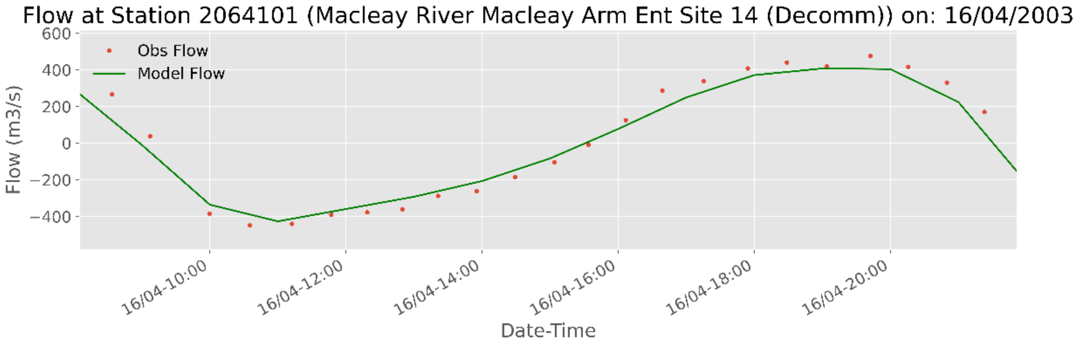

Figure I-7: Macleay hydrodynamic model flow calibrations at Station 2064101

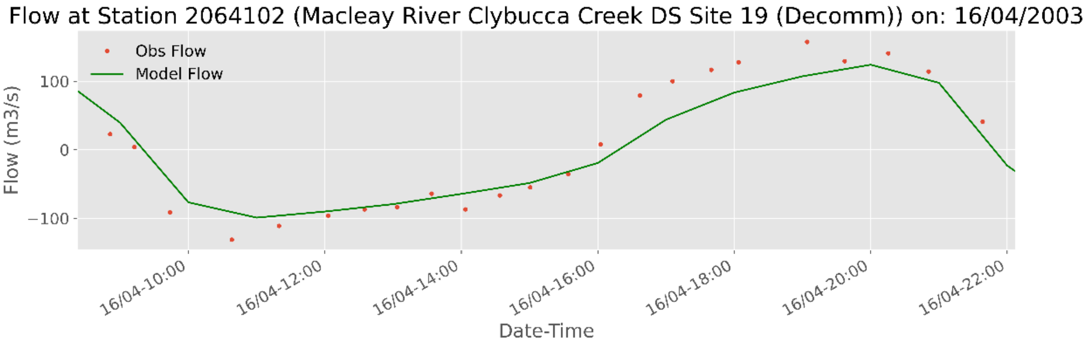

Figure I-8: Macleay hydrodynamic model flow calibrations at Station 2064102

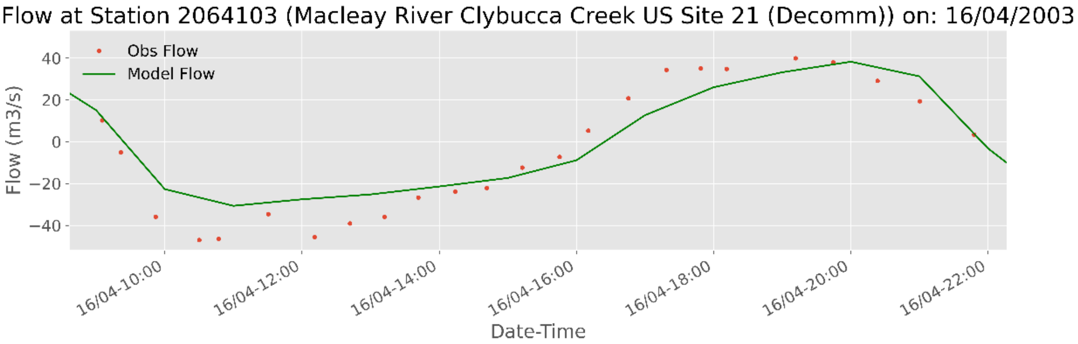

Figure I-9: Macleay hydrodynamic model flow calibrations at Station 2064103

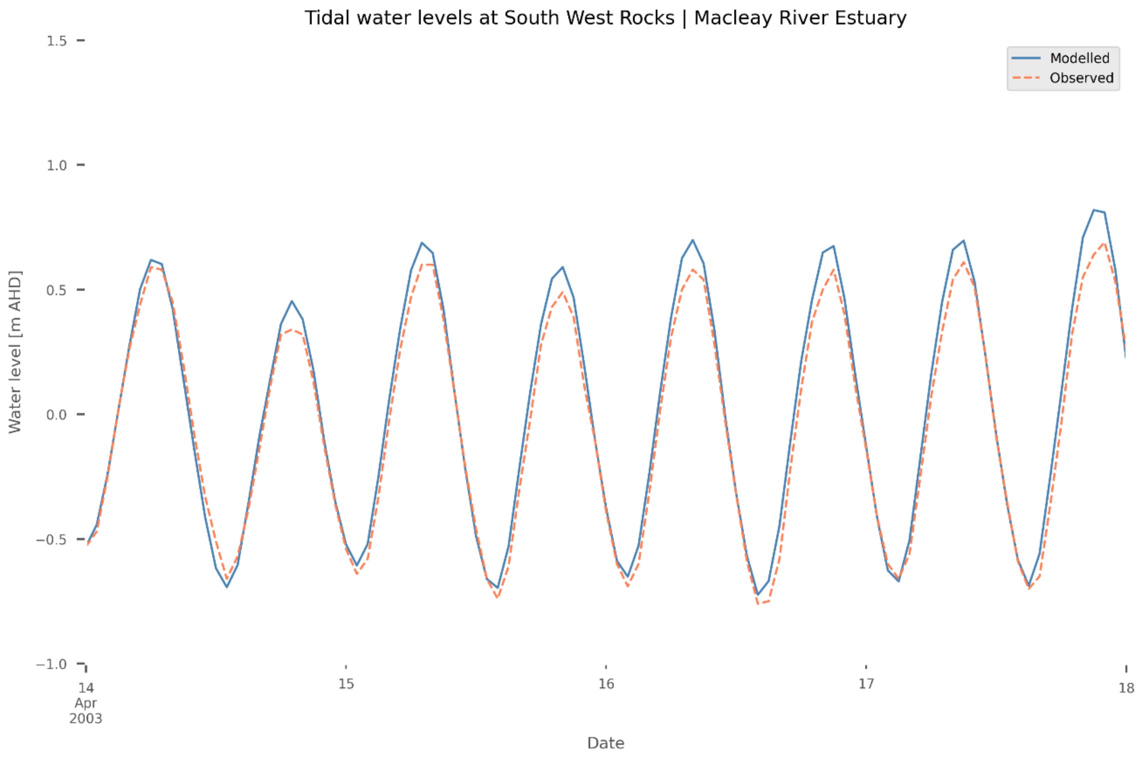

Figure I-10: Macleay hydrodynamic model calibration results at South West Rocks (206456)

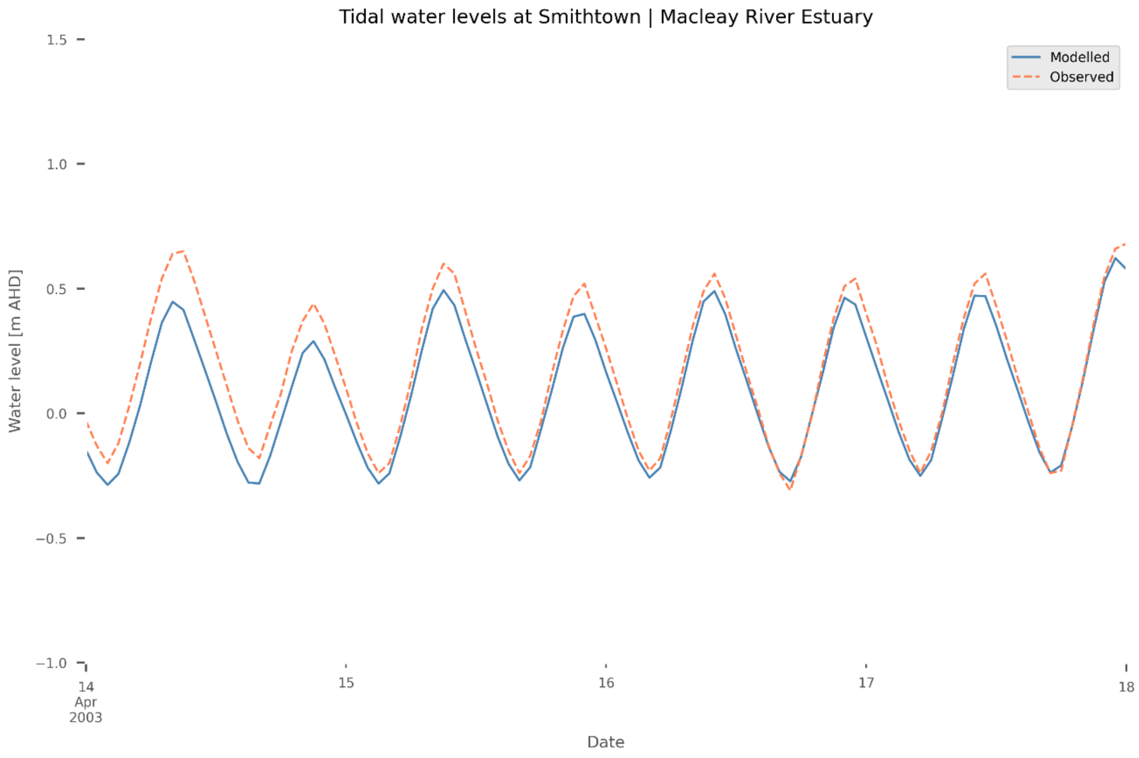

Figure I-11: Macleay hydrodynamic model calibration results at Smithtown (206406)

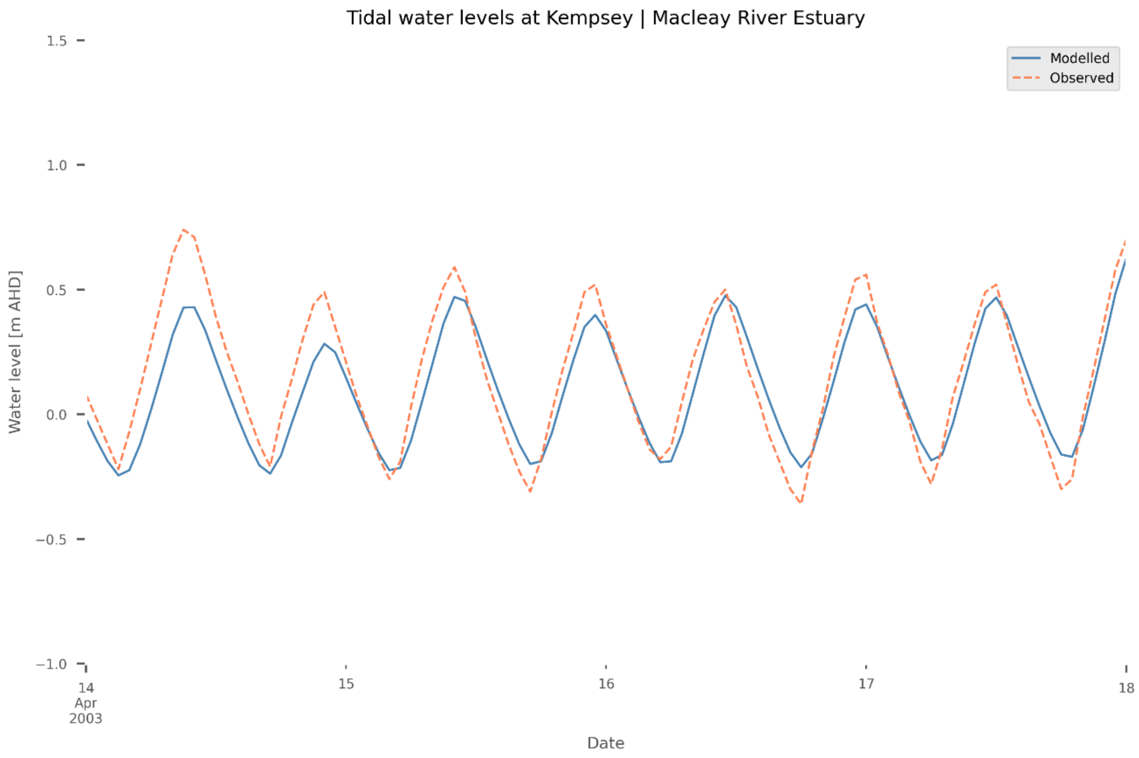

Figure I-12: Macleay hydrodynamic model calibration results at Kempsey (206402)

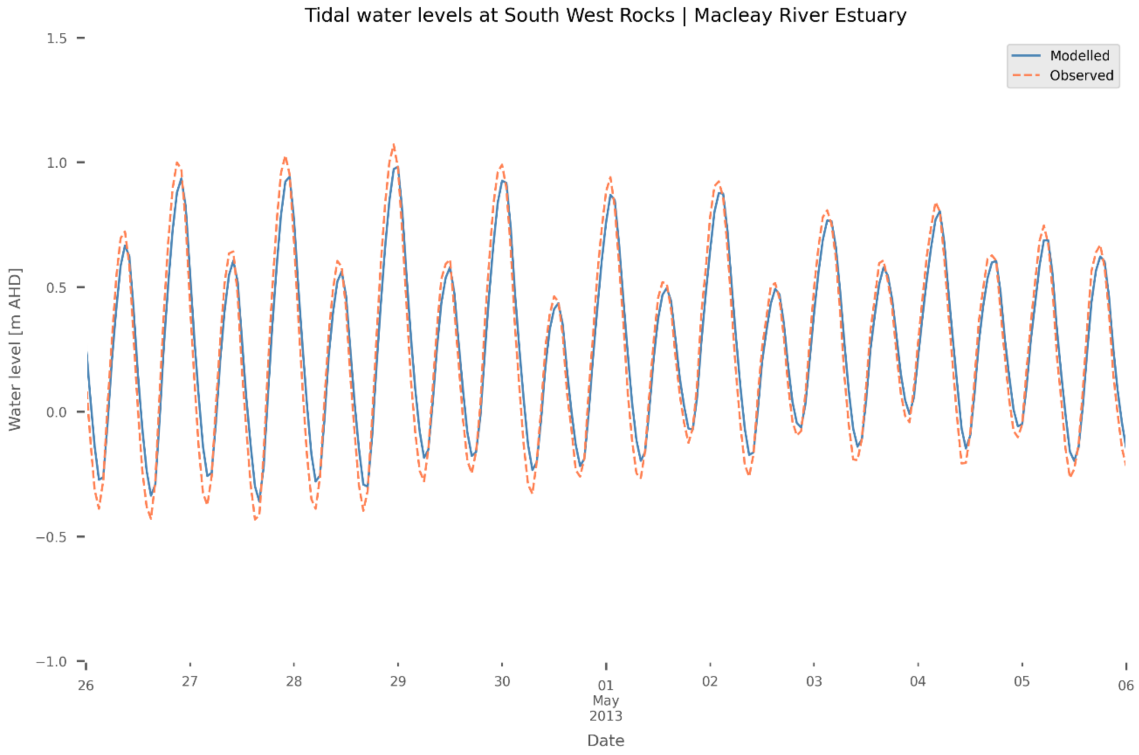

Figure I-13: Macleay hydrodynamic model verification results (2013) at South West Rocks (206456)

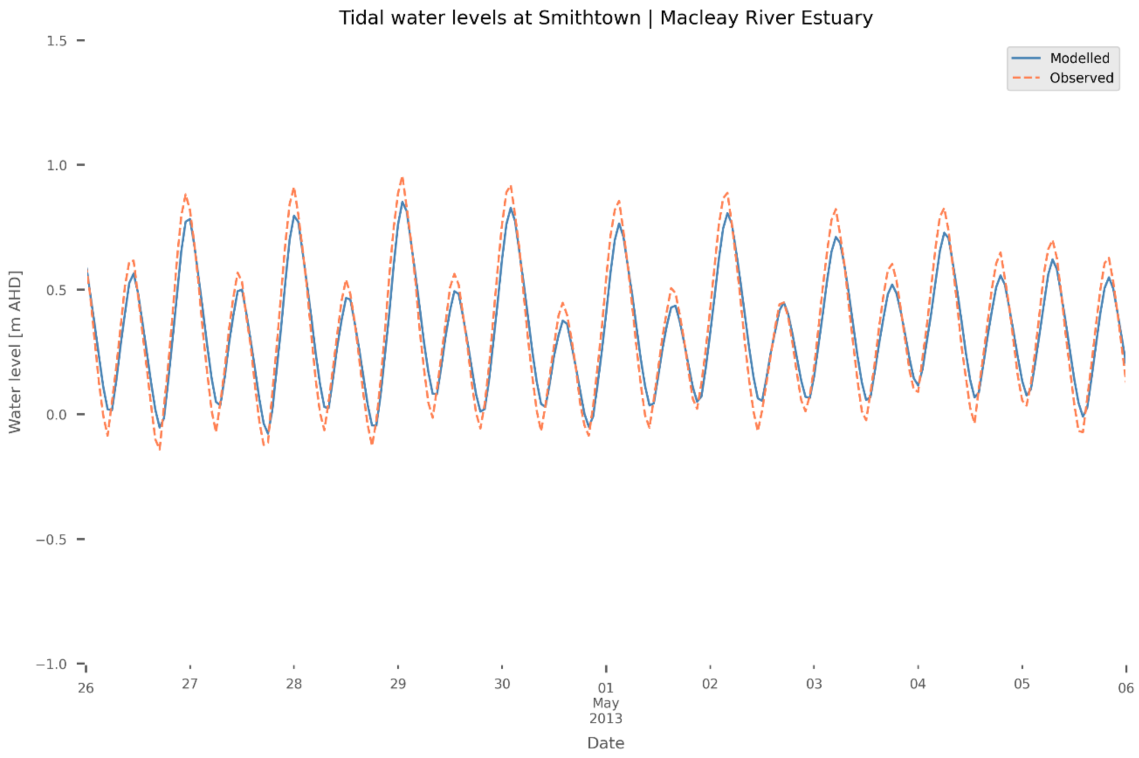

Figure I-14: Macleay hydrodynamic model verification results (2013) at Smithtown (206406)

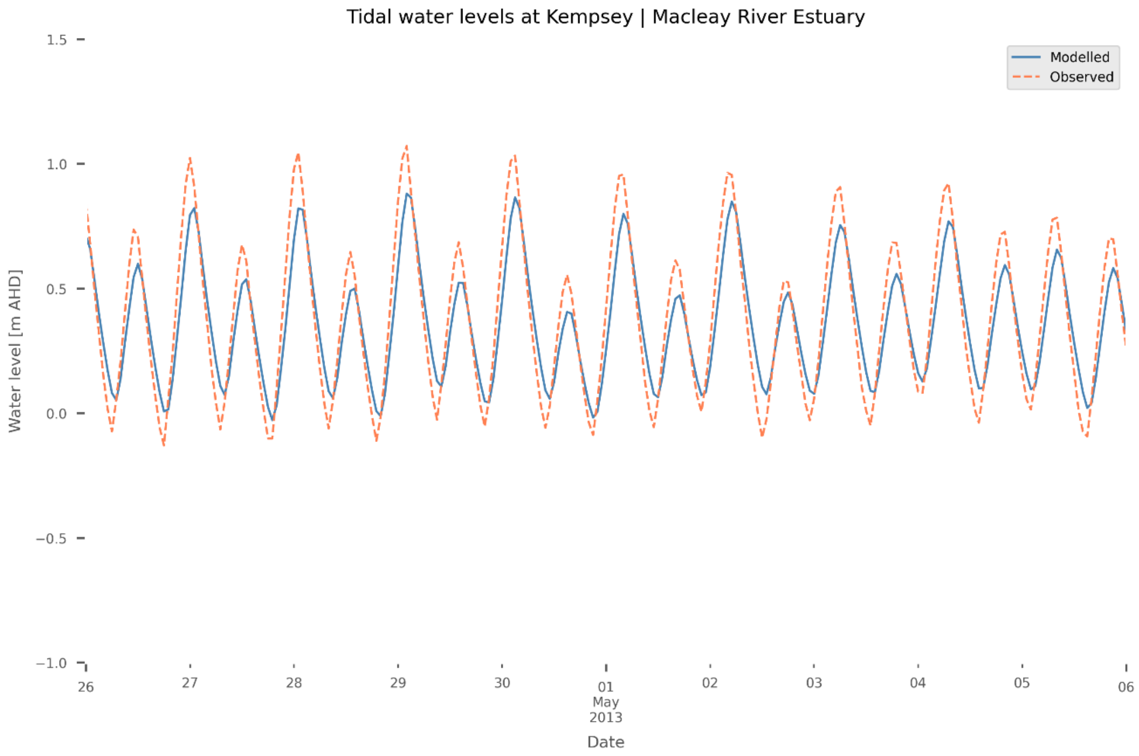

Figure I-15: Macleay hydrodynamic model verification results (2013) at Kempsy (206402)

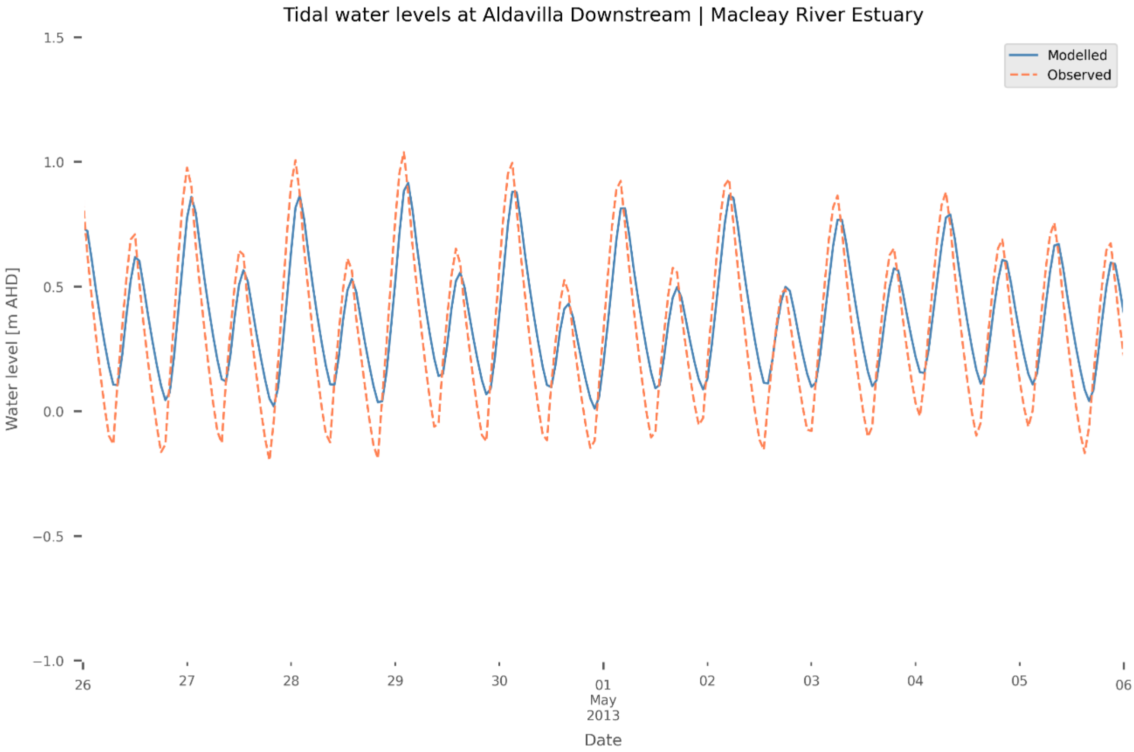

Figure I-16: Macleay hydrodynamic model verification results (2013) at Aldavilla Downstream (206459)

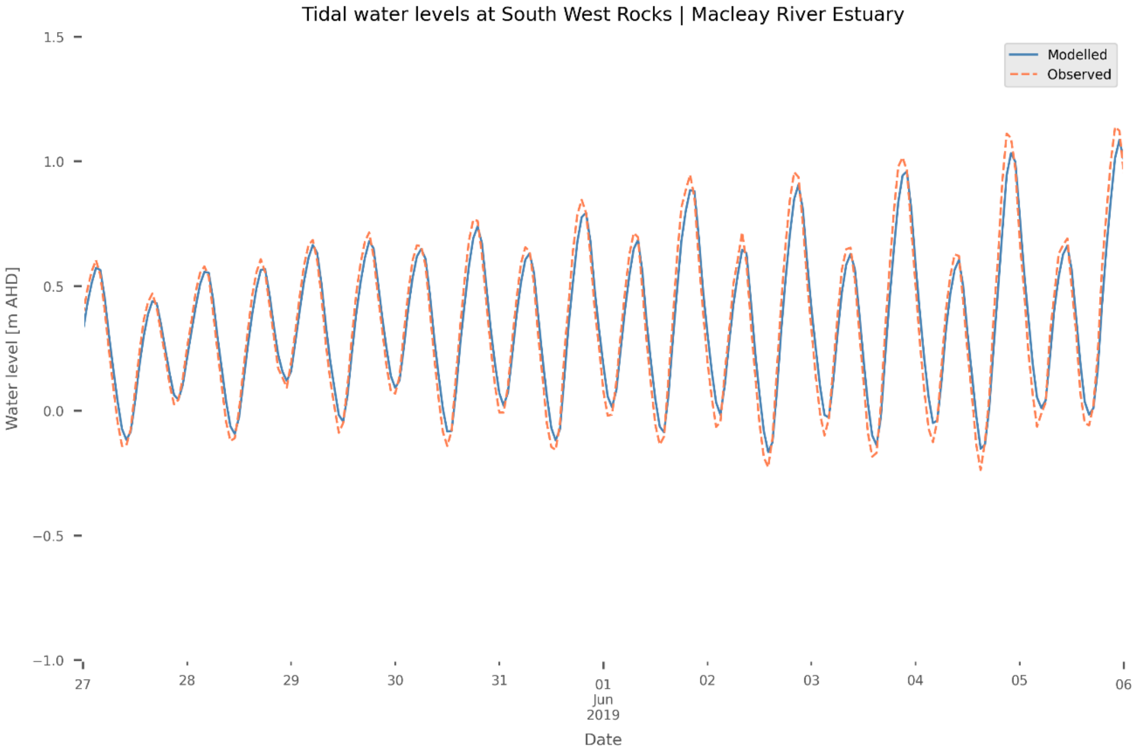

Figure I-17: Macleay hydrodynamic model verification results (2019) at South West Rocks (206456)

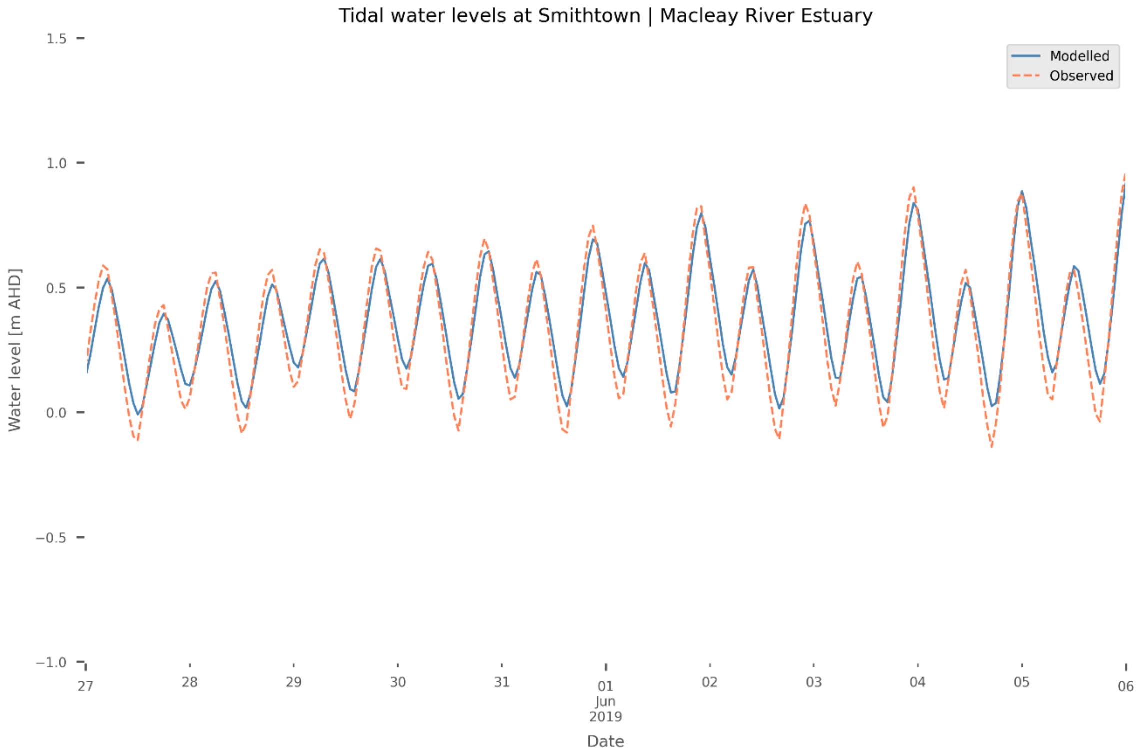

Figure I-18: Macleay hydrodynamic model verification results (2019) at Smithtown (206406)

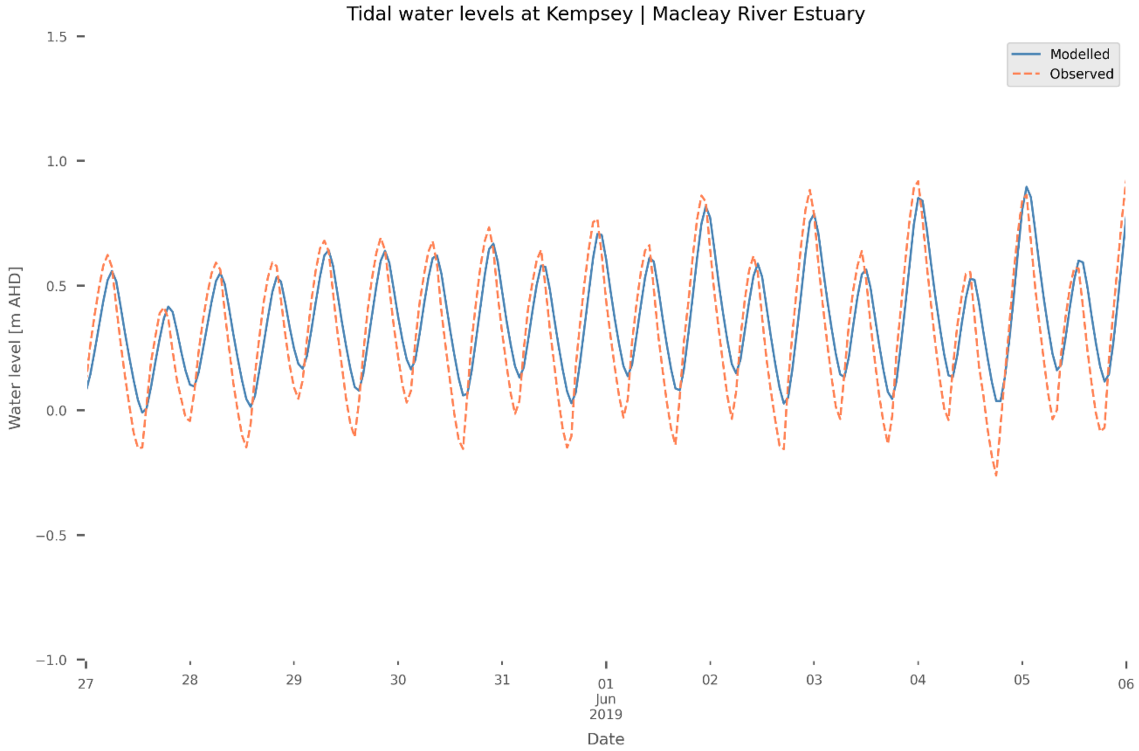

Figure I-19: Macleay hydrodynamic model verification results (2019) at Kempsey (206402)

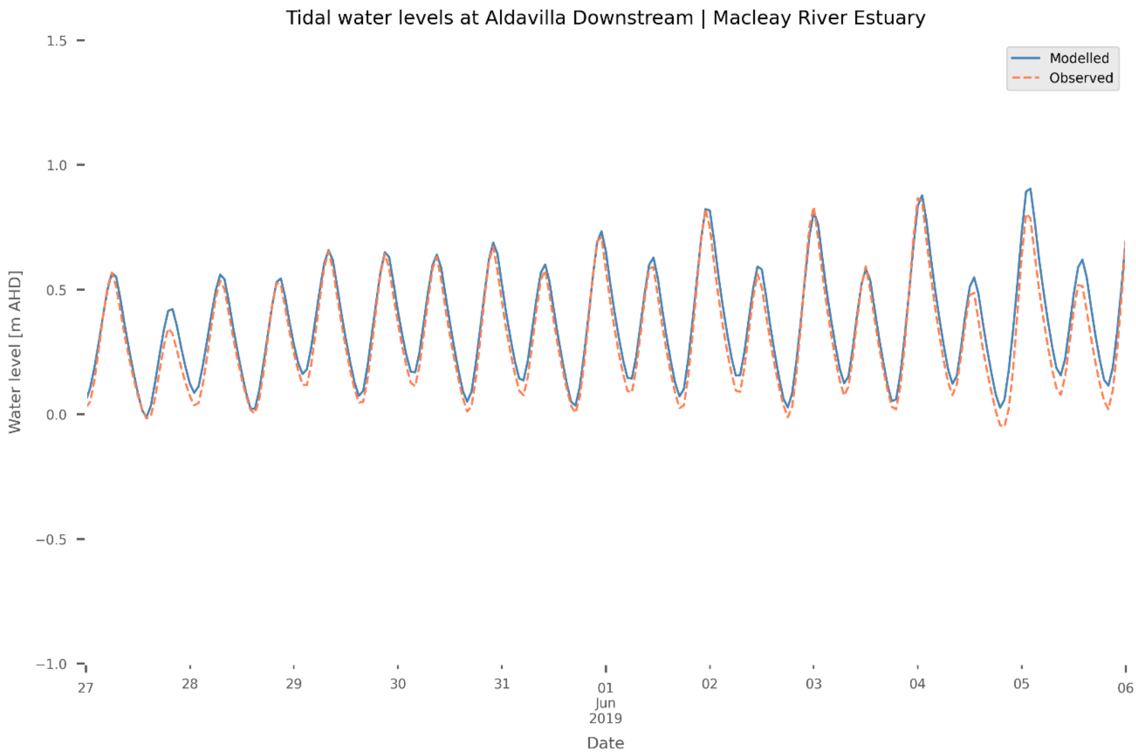

Figure I-20: Macleay hydrodynamic model verification results (2019) at Aldavilla Downstream (206459)

Appendix J Sensitive receivers

J1 Preamble

Acid discharges from ASS-affected floodplains are well reported to cause stress to sensitive environmental receivers (Rayner, 2010; Winberg and Heath, 2010; Glamore, 2003; Sammut et al., 1996). 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 Macleay 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 subcatchment.

J2 Sensitive environmental receivers of the Macleay 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 J-1 to Figure J-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 subcatchment in the study area to downstream stationary sensitive receivers was calculated as provided in Table J-1.

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

Subcatchment	Oyster leases	Estuarine macrophytes			Coastal wetlands	SER within subcatchment*
		Saltmarsh	Seagrass	Mangroves		
Belmore Swamp	23,500	20,500	24,200	18,000	0	Coastal wetland, key fish habitat
Christmas Creek	22,200	19,200	25,000	17,100	14,400	Key fish habitat
Collombatti-Clybucca	5,800	2,800	8,600	700	0	Coastal wetland, key fish habitat
Euroka Creek	30,100	27,200	32,900	25,000	19,600	Key fish habitat
Frogmore/ Austral Eden/ Verges Swamp	16,700	13,700	17,600	11,400	0	Coastal wetland, key fish habitat
Kinchela Creek	12,500	7,800	11,600	5,400	0	Coastal wetland, key fish habitat
Pola Creek	26,200	23,300	29,000	21,100	11,700	Key fish habitat
Raffertys/ Saltwater Inlet	0	0	0	0	0	Saltmarsh, mangroves, coastal wetland, key fish habitat
Rainbow Reach	0	0	0	0	0	Saltmarsh, mangroves, coastal wetland, key fish habitat
Summer Island	7,200	4,200	7,300	1,100	3,200	None
Yarrahapinni	0	0	0	0	0	Saltmarsh, mangroves, coastal wetland, key fish habitat

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

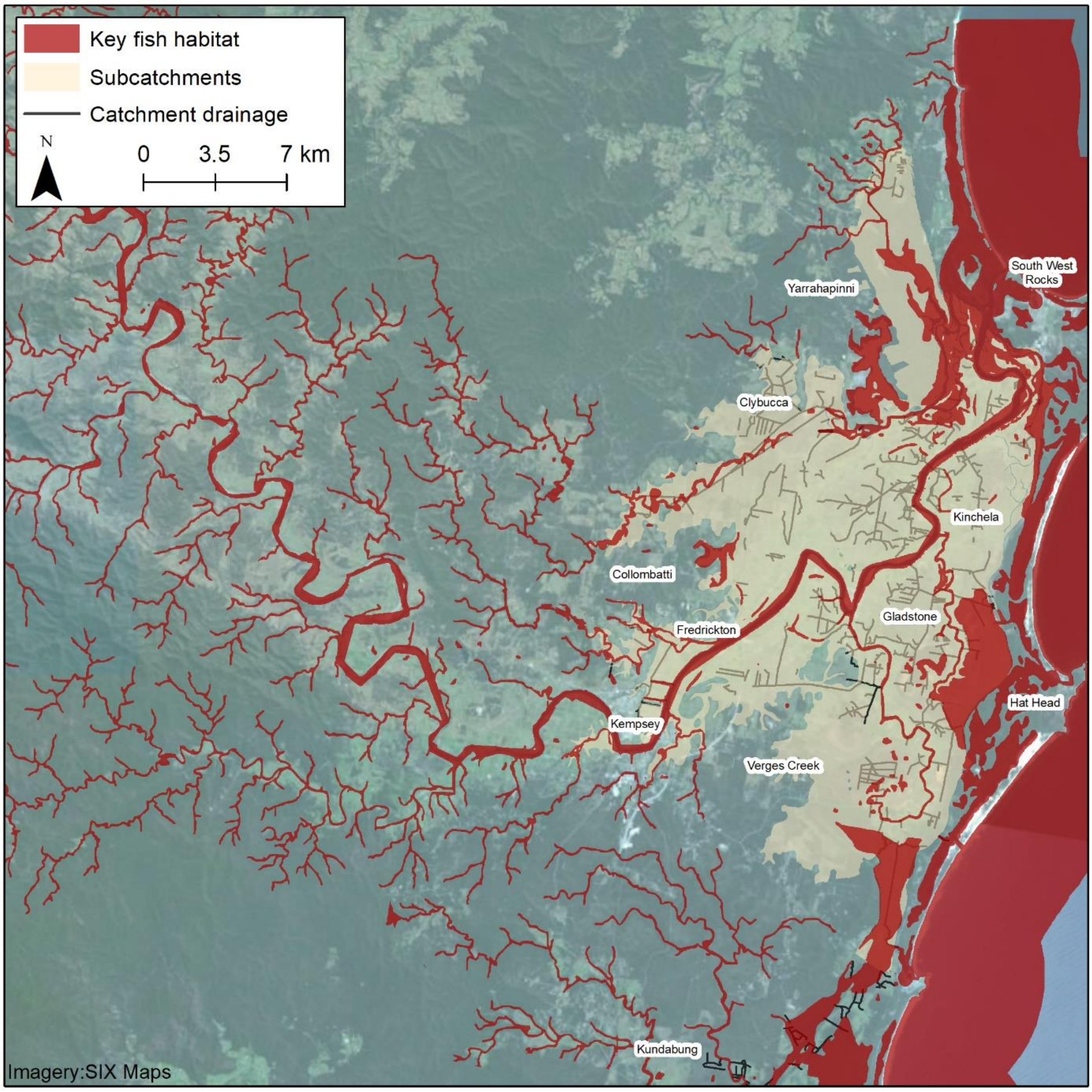

Figure J-1: Key fisheries habitat (Source: NSW DPI Fisheries)

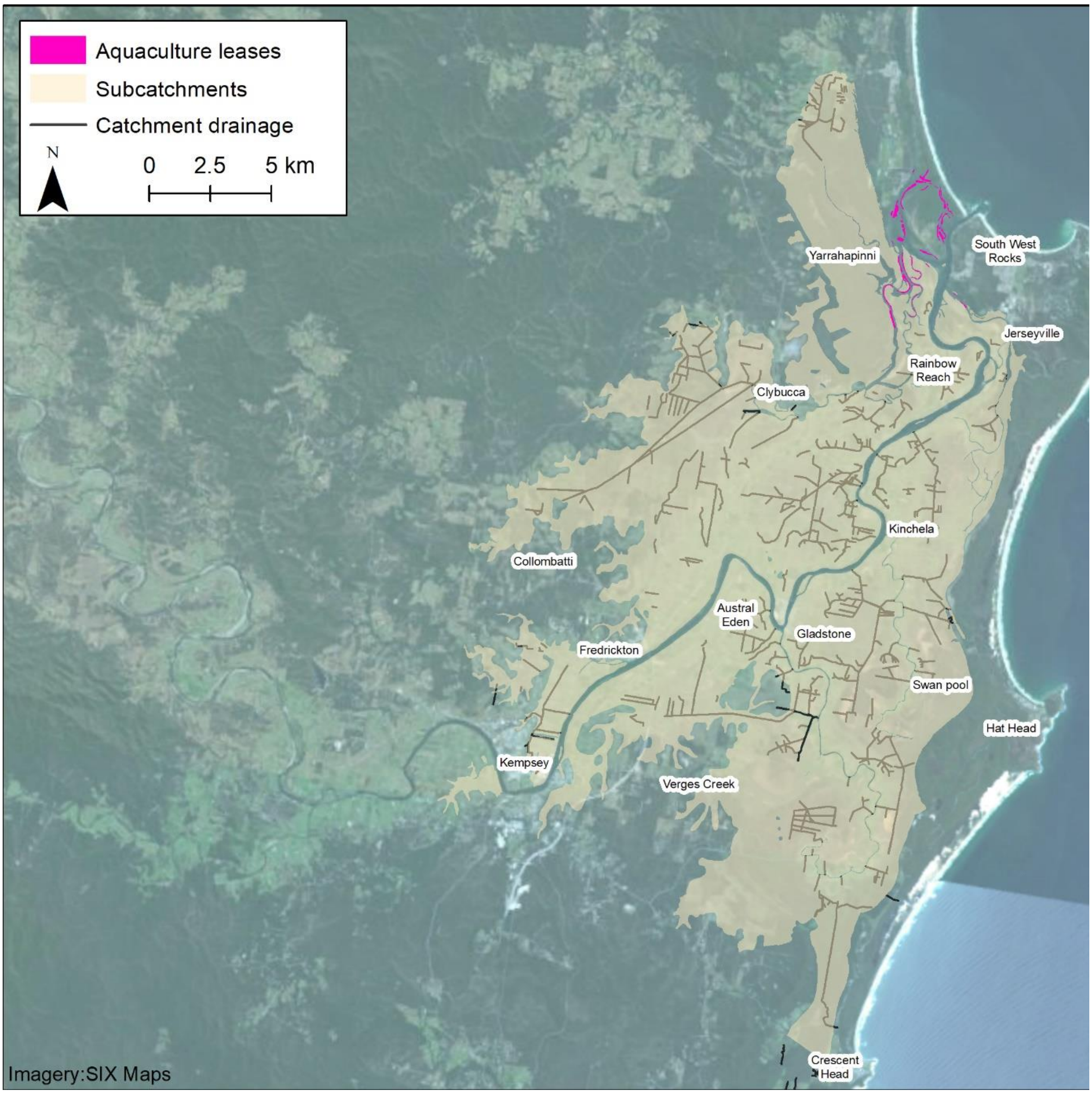

Figure J-2: Priority oyster leases (Source: NSW DPI Fisheries)

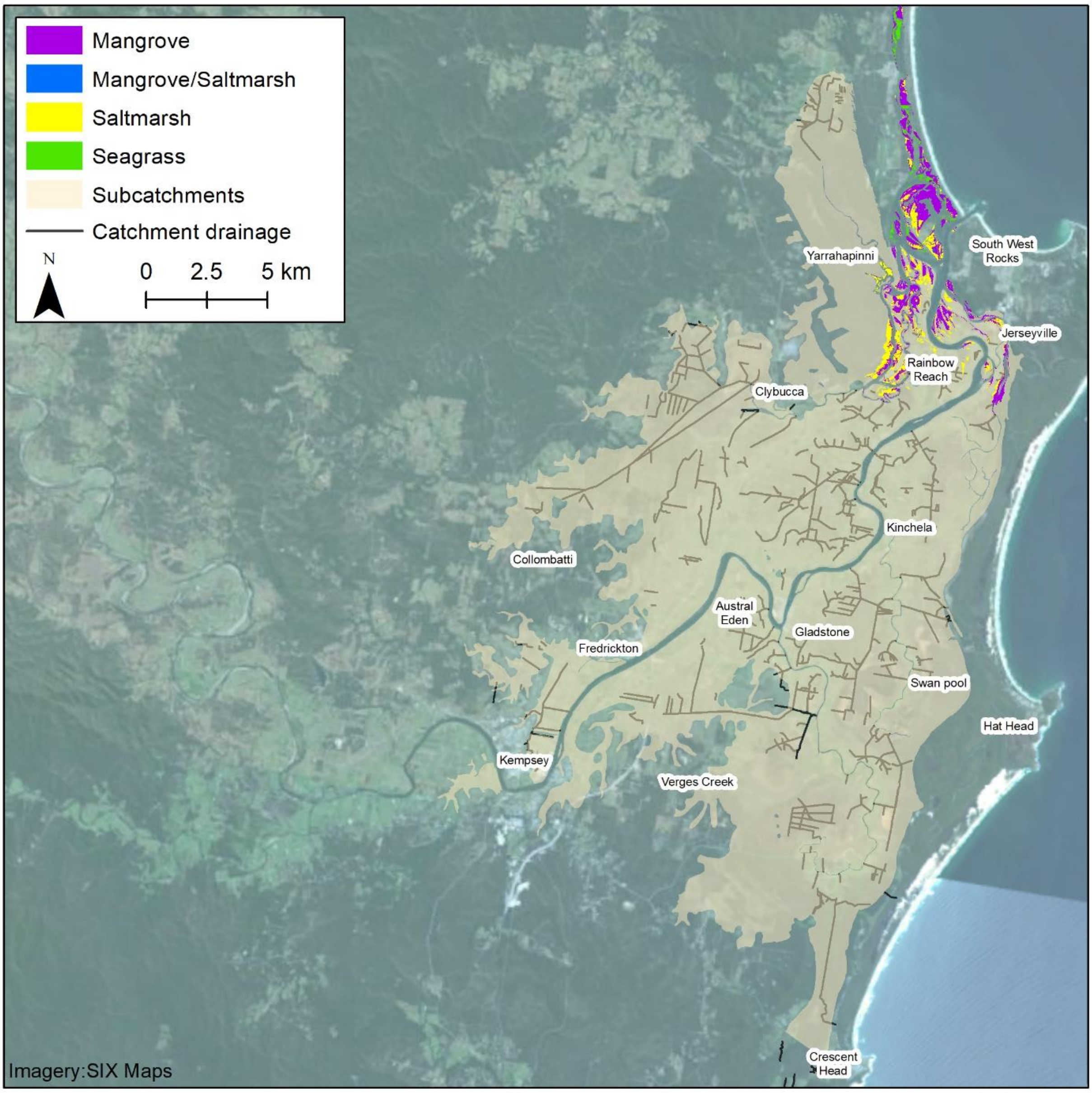

Figure J-3: Estuarine macrophytes (Source: NSW DPI Fisheries)

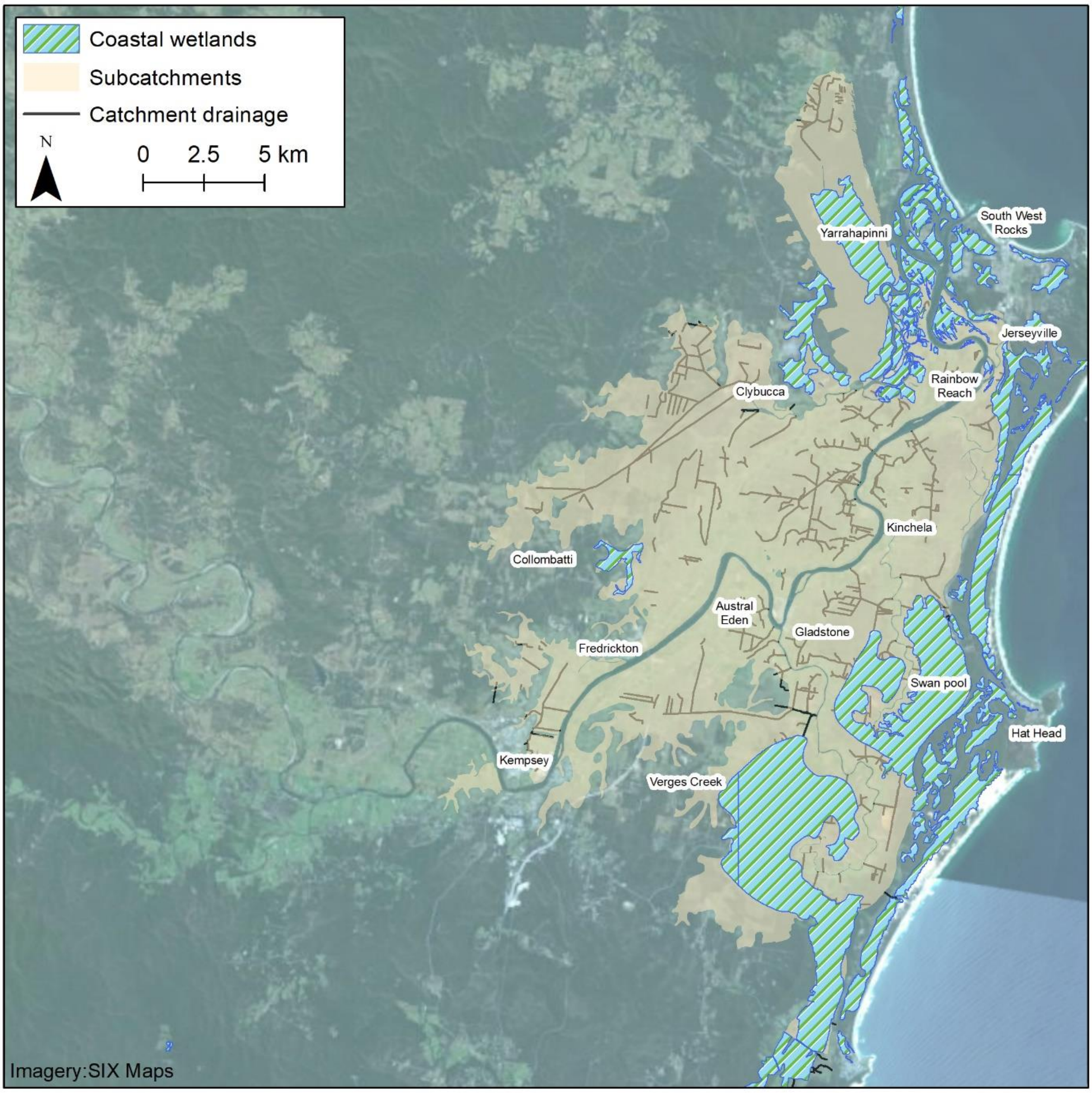

Figure J-4: Coastal Management SEPP coastal wetlands (Source: SEED NSW data portal)[1]

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[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 K Heritage

K1 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 significant 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 remediation. Heritage items fall under the category of implementation constraint in the prioritisation methodology (see Section 2 of the Methods Report (Rayner et al., 2020a)). 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.

K2 Aboriginal heritage

Aboriginal sites across the Macleay 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 K3).

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.

K3 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;
- Items listed on State Agency Heritage Registers; and
- Items listed on the Kempsey Shire Council LEP.

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

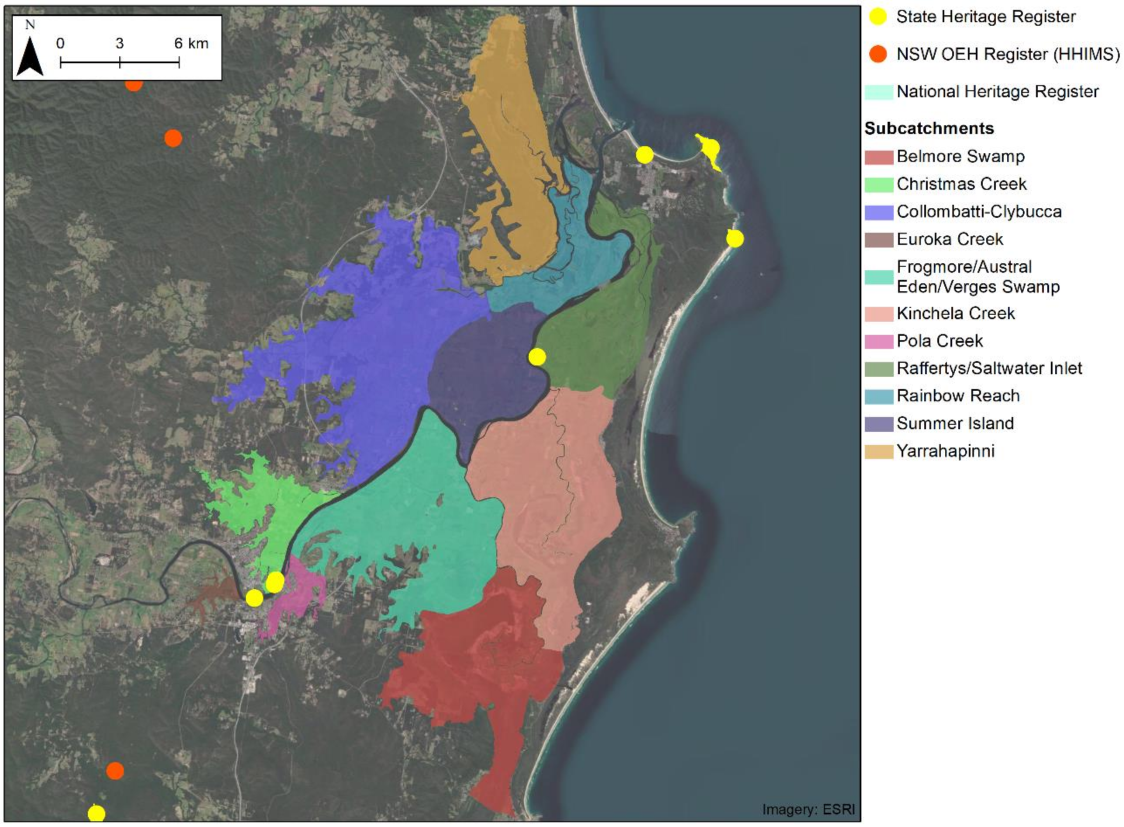


Figure K-1: Heritage items listed on Australian and NSW registers with location information

A total of 134 items were identified as listed on State Agency Registers and the Kempsey Shire Council LEP. For an up to date list of these items consult the NSW State Heritage Inventory.

K4 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 K-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.

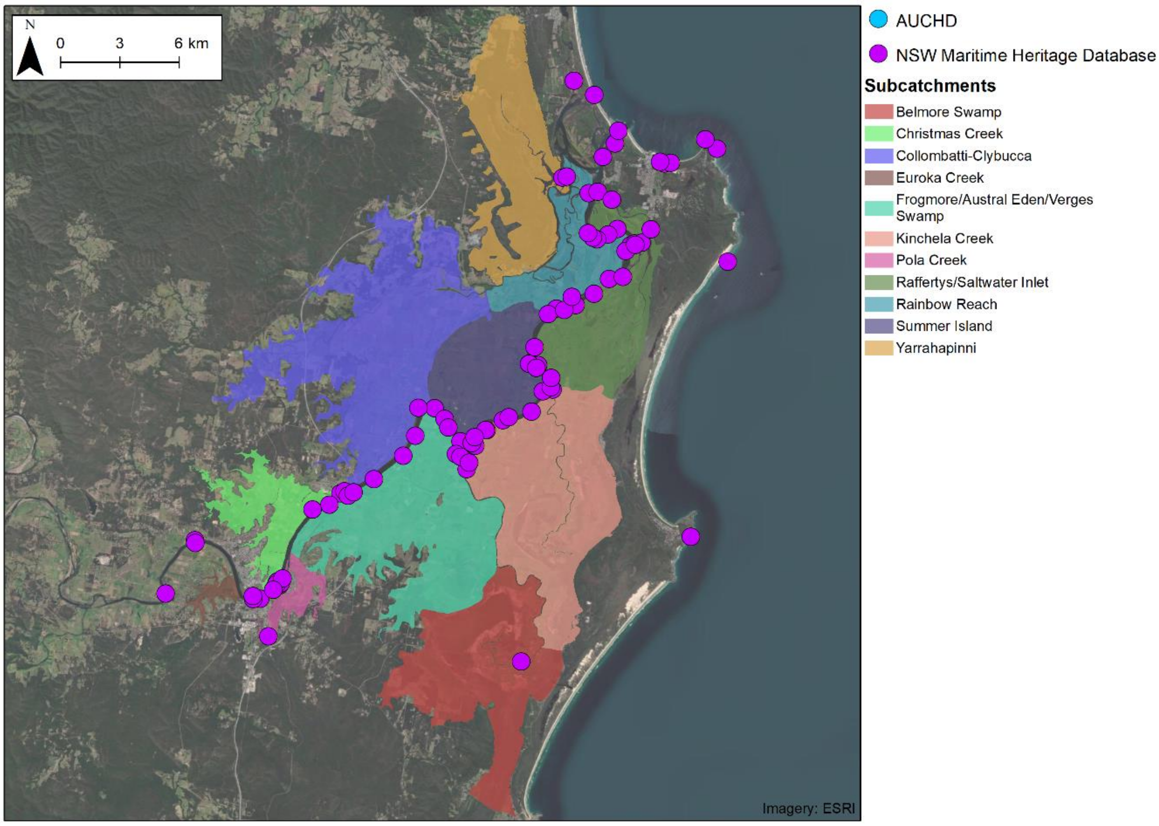


Figure K-2: Maritime heritage items listed on Australian and NSW registers

Appendix L Soil profile data sheets

Soil profile details:

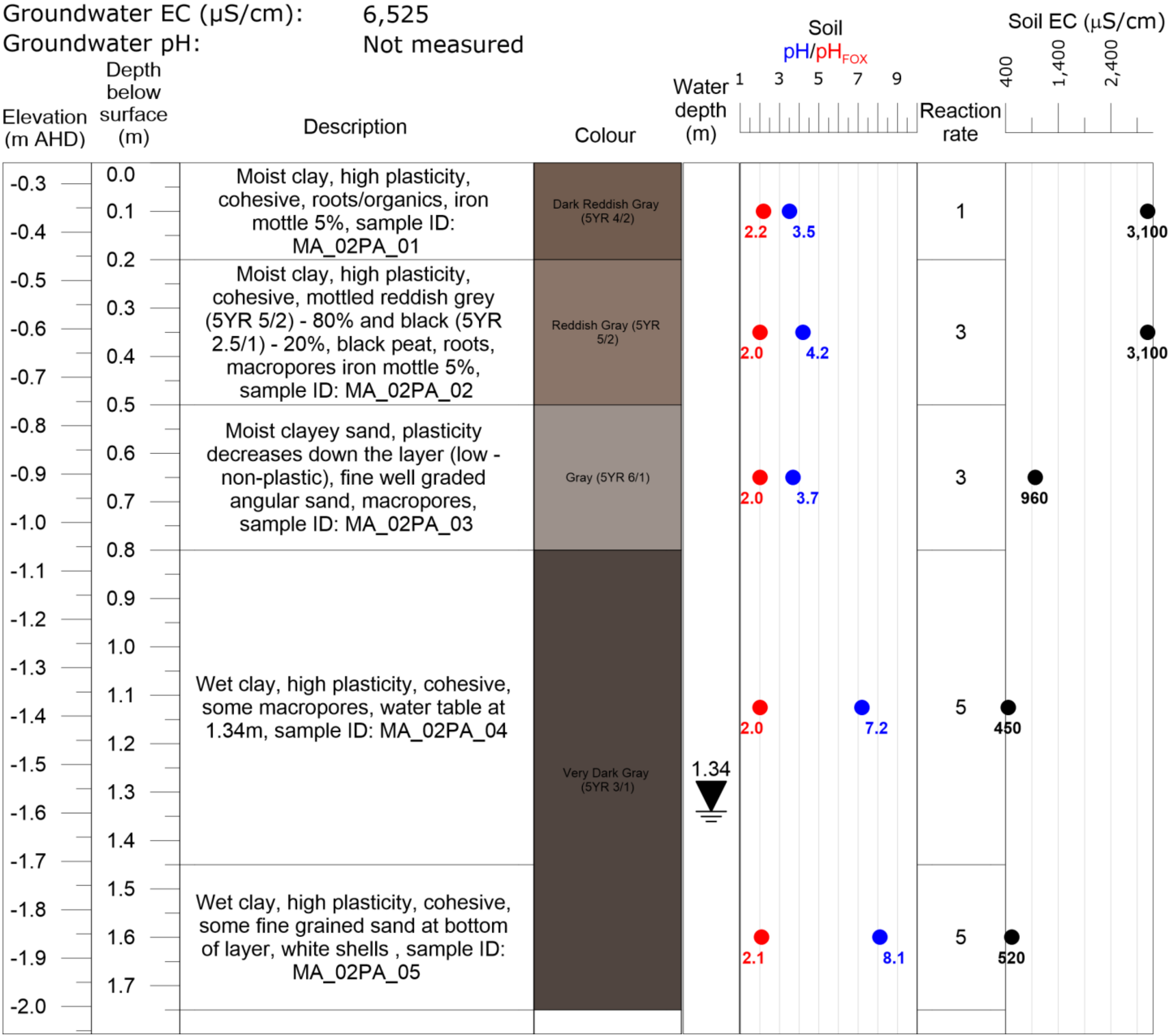
Project Number:	2018064	Profile ID:	MA_02_PA
River/estuary:	Macleay	Sample date:	30/01/20
Easting:	497314.3	Sampled by:	TAT DWJ
Northing:	6561083.3		

Water Research Laboratory
School of Civil and Environmental Engineering

Ground elevation (m AHD):	-0.26
Hydraulic conductivity (m/d):	0.08

Water quality:

Surface water EC (μS/cm):	24,388 (upstream floodgate), 20,827 (downstream floodgate)
Surface water pH:	Not measured
Groundwater EC (μS/cm):	6,525
Groundwater pH:	Not measured



0.0–0.2	Moist clay, high plasticity, cohesive, roots/organics, iron mottle 5%, sample ID: MA_02PA_01	Dark Reddish Gray (5YR 4/2)	2.2	3.5	1	3,100
0.2–0.5	Moist clay, high plasticity, cohesive, mottled reddish grey (5YR 5/2) - 80% and black (5YR 2.5/1) - 20%, black peat, roots, macropores iron mottle 5%, sample ID: MA_02PA_02	Reddish Gray (5YR 5/2)	2.0	4.2	3	3,100
0.5–0.8	Moist clayey sand, plasticity decreases down the layer (low - non-plastic), fine well graded angular sand, macropores, sample ID: MA_02PA_03	Gray (5YR 6/1)	2.0	3.7	3	960
0.8–1.45	Wet clay, high plasticity, cohesive, some macropores, water table at 1.34m, sample ID: MA_02PA_04	Very Dark Gray (5YR 3/1)	2.0	7.2	5	450
1.45–1.75	Wet clay, high plasticity, cohesive, some fine grained sand at bottom of layer, white shells , sample ID: MA_02PA_05		2.1	8.1	5	520

Soil profile details:

Project Number: 2018064
River/estuary: Macleay
Easting: 487335.6
Northing: 6561201.8
Profile ID: MA_08_P
Sample date: 27/09/19
Sampled by: TAT DWJ

Ground elevation (m AHD): 1.21
Hydraulic conductivity (m/d): 88.57

Water Research Laboratory
School of Civil and Environmental Engineering
UNSW SYDNEY

Water quality:

Surface water EC (µS/cm): Not measured
Surface water pH: Not measured
Groundwater EC (µS/cm): 1,402
Groundwater pH: 5.94

Water depth (m): 1.5

Description	Colour	Soil pH	Soil pH_{FOX}	Reaction rate	Soil EC (µS/cm)
Very dry hard dark clay, non cohesive, organic roots, iron mottle (<5%), sample ID: MA_08P_01	Reddish Brown (5YR 4/3)	5.2	3.2	2	35
Moist clay, high plasticity, cohesive, macropores, iron mottle (~20%), sample ID: MA_08P_02	Dark Reddish Brown (5YR 3/3)	5.0	3.8	1	38
Moist clay, high plasticity, cohesive, macropores, iron mottle (5%), sample ID: MA_08P_03	Reddish Gray (5YR 5/2)	5.0	3.8	1	32
Wet clay, high plasticity, cohesive, macropores, iron mottle (<40%), sample ID: MA_08P_04		5.6	3.4	5	40
Wet clay, sticky, medium plasticity, cohesive, sample ID: MA_08P_05		6.3	3.4	5	35

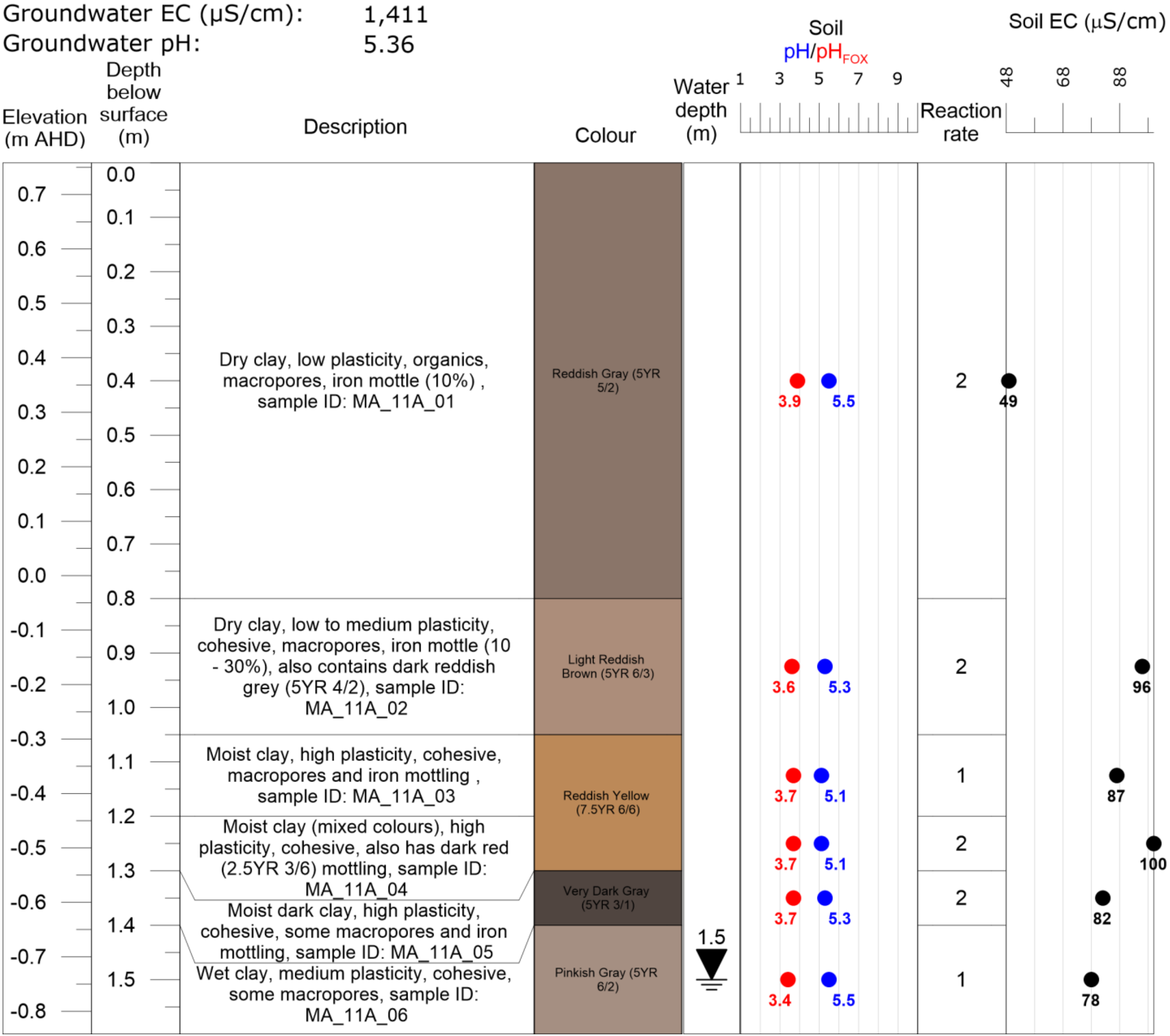
Soil profile details:

Project Number:	2018064	Profile ID:	MA_11_A
River/estuary:	Macleay	Sample date:	30/09/19
Easting:	481495.3	Sampled by:	TAT DWJ
Northing:	6561379.9		

Ground elevation (m AHD):	0.76
Hydraulic conductivity (m/d):	5.39

Water quality:

Surface water EC (μS/cm):	Not measured
Surface water pH:	Not measured
Groundwater EC (μS/cm):	1,411
Groundwater pH:	5.36



Depth below surface (m)	Description	Colour	pH_{FOX}	pH	Reaction rate	Soil EC (µS/cm)
0.0–0.8	Dry clay, low plasticity, organics, macropores, iron mottle (10%) , sample ID: MA_11A_01	Reddish Gray (5YR 5/2)	3.9	5.5	2	49
0.8–1.05	Dry clay, low to medium plasticity, cohesive, macropores, iron mottle (10 - 30%), also contains dark reddish grey (5YR 4/2), sample ID: MA_11A_02	Light Reddish Brown (5YR 6/3)	3.6	5.3	2	96
1.05–1.2	Moist clay, high plasticity, cohesive, macropores and iron mottling , sample ID: MA_11A_03	Reddish Yellow (7.5YR 6/6)	3.7	5.1	1	87
1.2–1.3	Moist clay (mixed colours), high plasticity, cohesive, also has dark red (2.5YR 3/6) mottling, sample ID: MA_11A_04		3.7	5.1	2	100
1.3–1.4	Moist dark clay, high plasticity, cohesive, some macropores and iron mottling, sample ID: MA_11A_05	Very Dark Gray (5YR 3/1)	3.7	5.3	2	82
1.4–1.6	Wet clay, medium plasticity, cohesive, some macropores, sample ID: MA_11A_06	Pinkish Gray (5YR 6/2)	3.4	5.5	1	78

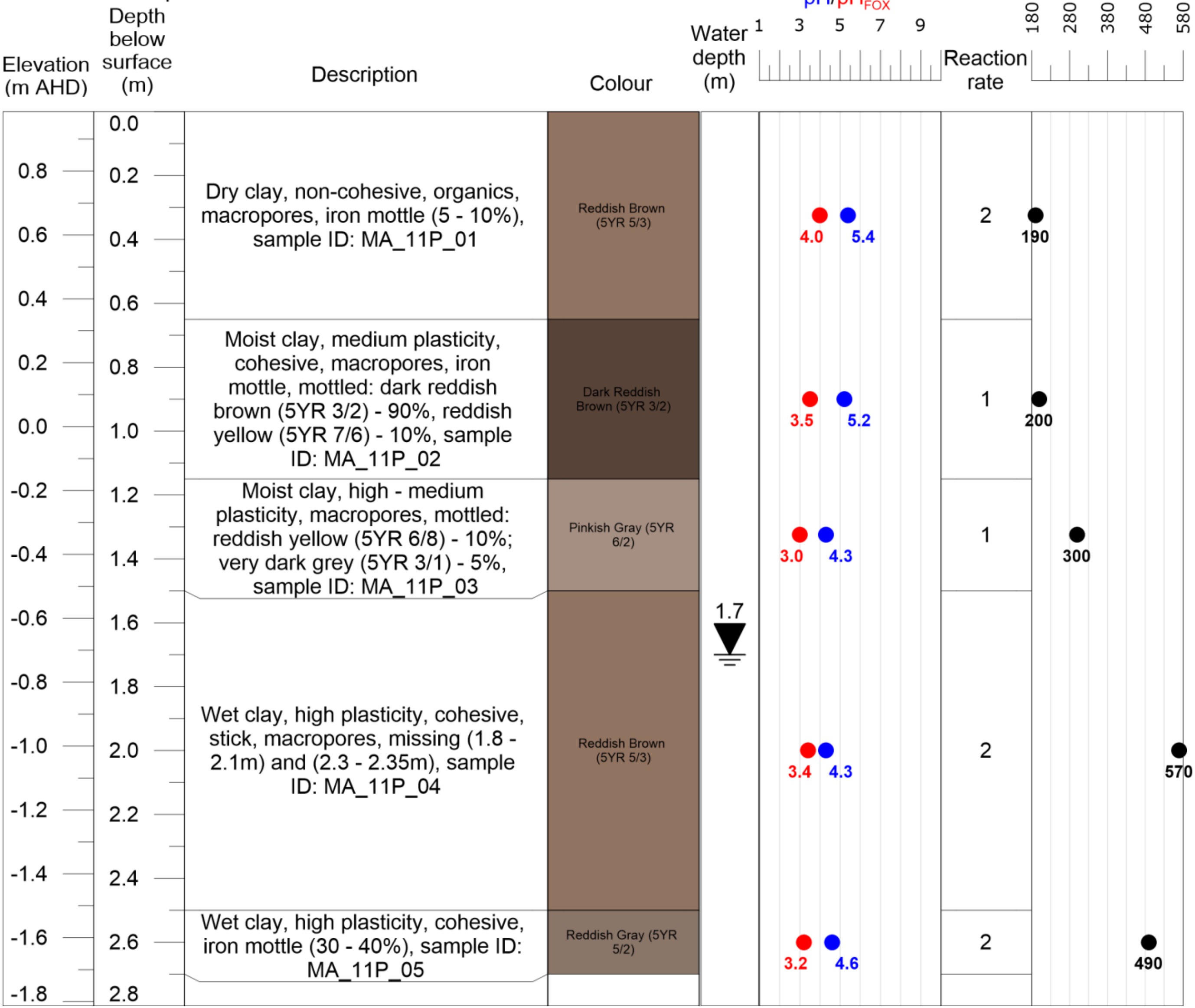
Soil profile details:

Project Number:	2018064	Profile ID:	MA_11_P
River/estuary:	Macleay	Sample date:	30/09/19
Easting:	481738	Sampled by:	TAT DWJ
Northing:	6560677.9		

Ground elevation (m AHD):	0.99
Hydraulic conductivity (m/d):	0.75

Water quality:

Surface water EC (µS/cm):	Not measured
Surface water pH:	Not measured
Groundwater EC (µS/cm):	5,659
Groundwater pH:	4.09



Description	Colour	Soil pH	Soil pH$_{FOX}$	Reaction rate	Soil EC (µS/cm)
Dry clay, non-cohesive, organics, macropores, iron mottle (5 - 10%), sample ID: MA_11P_01	Reddish Brown (5YR 5/3)	4.0	5.4	2	190
Moist clay, medium plasticity, cohesive, macropores, iron mottle, mottled: dark reddish brown (5YR 3/2) - 90%, reddish yellow (5YR 7/6) - 10%, sample ID: MA_11P_02	Dark Reddish Brown (5YR 3/2)	3.5	5.2	1	200
Moist clay, high - medium plasticity, macropores, mottled: reddish yellow (5YR 6/8) - 10%; very dark grey (5YR 3/1) - 5%, sample ID: MA_11P_03	Pinkish Gray (5YR 6/2)	3.0	4.3	1	300
Wet clay, high plasticity, cohesive, stick, macropores, missing (1.8 - 2.1m) and (2.3 - 2.35m), sample ID: MA_11P_04	Reddish Brown (5YR 5/3)	3.4	4.3	2	570
Wet clay, high plasticity, cohesive, iron mottle (30 - 40%), sample ID: MA_11P_05	Reddish Gray (5YR 5/2)	3.2	4.6	2	490

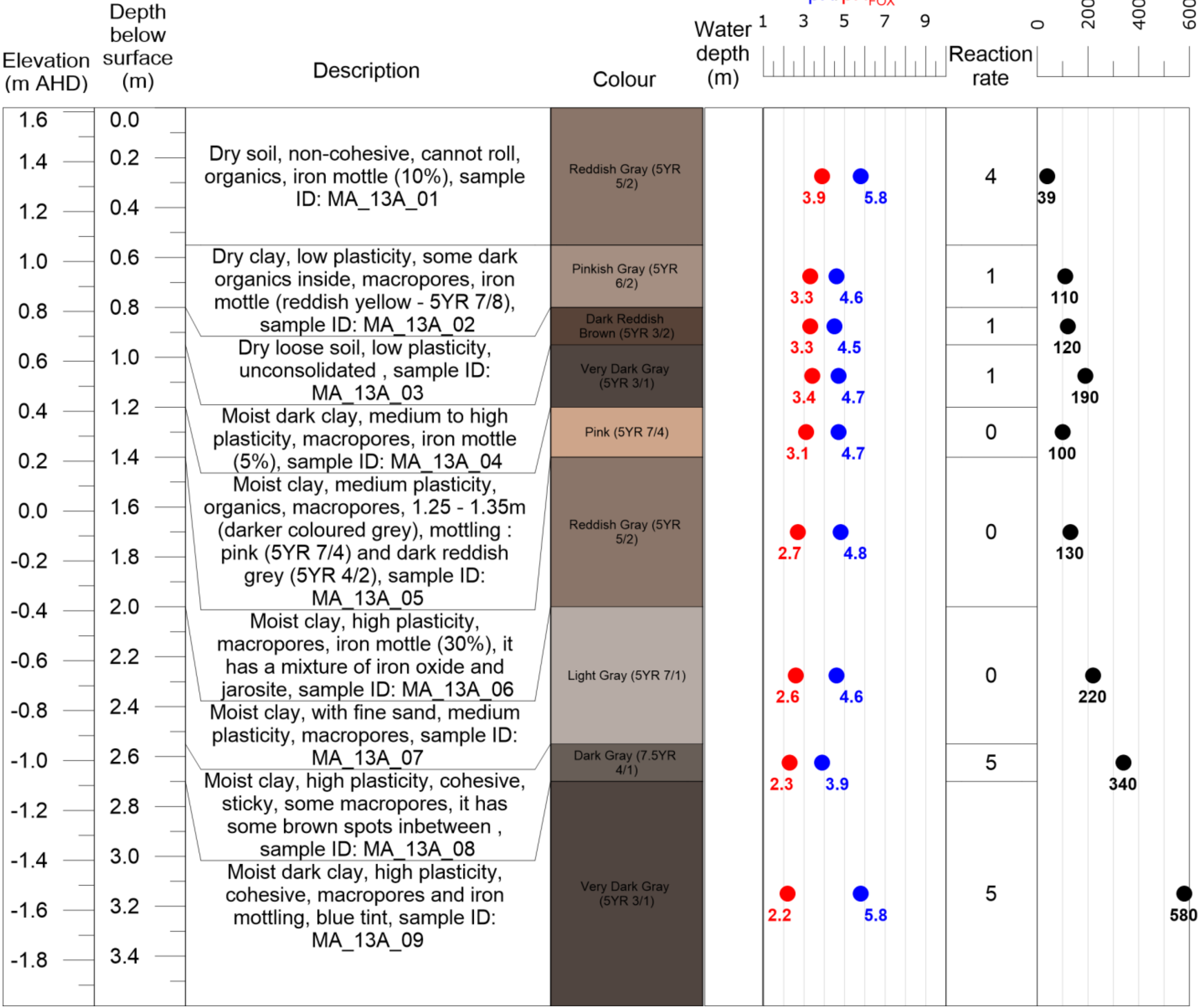
Soil profile details:

Project Number:	2018064	Profile ID:	MA_13_A
River/estuary:	Macleay	Sample date:	01/10/19
Easting:	484731.1	Sampled by:	TAT DWJ
Northing:	6563502.2		

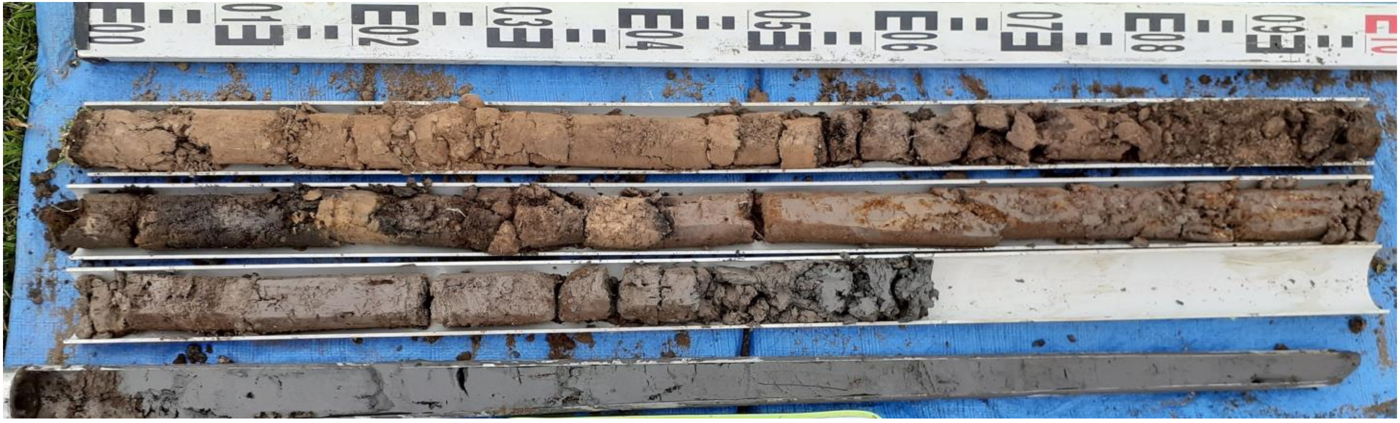
Ground elevation (m AHD):	1.62
Hydraulic conductivity (m/d):	Not measured

Water quality:

Surface water EC (μS/cm):	1,247
Surface water pH:	6.79
Groundwater EC (μS/cm):	Not measured
Groundwater pH:	Not measured



Description	pH_{FOX}	pH	Reaction rate	Soil EC (μS/cm)
Dry soil, non-cohesive, cannot roll, organics, iron mottle (10%), sample ID: MA_13A_01	3.9	5.8	4	39
Dry clay, low plasticity, some dark organics inside, macropores, iron mottle (reddish yellow - 5YR 7/8), sample ID: MA_13A_02	3.3	4.6	1	110
Dry loose soil, low plasticity, unconsolidated , sample ID: MA_13A_03	3.3	4.5	1	120
Moist dark clay, medium to high plasticity, macropores, iron mottle (5%), sample ID: MA_13A_04	3.4	4.7	1	190
Moist clay, medium plasticity, organics, macropores, 1.25 - 1.35m (darker coloured grey), mottling : pink (5YR 7/4) and dark reddish grey (5YR 4/2), sample ID: MA_13A_05	3.1	4.7	0	100
Moist clay, high plasticity, macropores, iron mottle (30%), it has a mixture of iron oxide and jarosite, sample ID: MA_13A_06	2.7	4.8	0	130
Moist clay, with fine sand, medium plasticity, macropores, sample ID: MA_13A_07	2.6	4.6	0	220
Moist clay, high plasticity, cohesive, sticky, some macropores, it has some brown spots inbetween , sample ID: MA_13A_08	2.3	3.9	5	340
Moist dark clay, high plasticity, cohesive, macropores and iron mottling, blue tint, sample ID: MA_13A_09	2.2	5.8	5	580



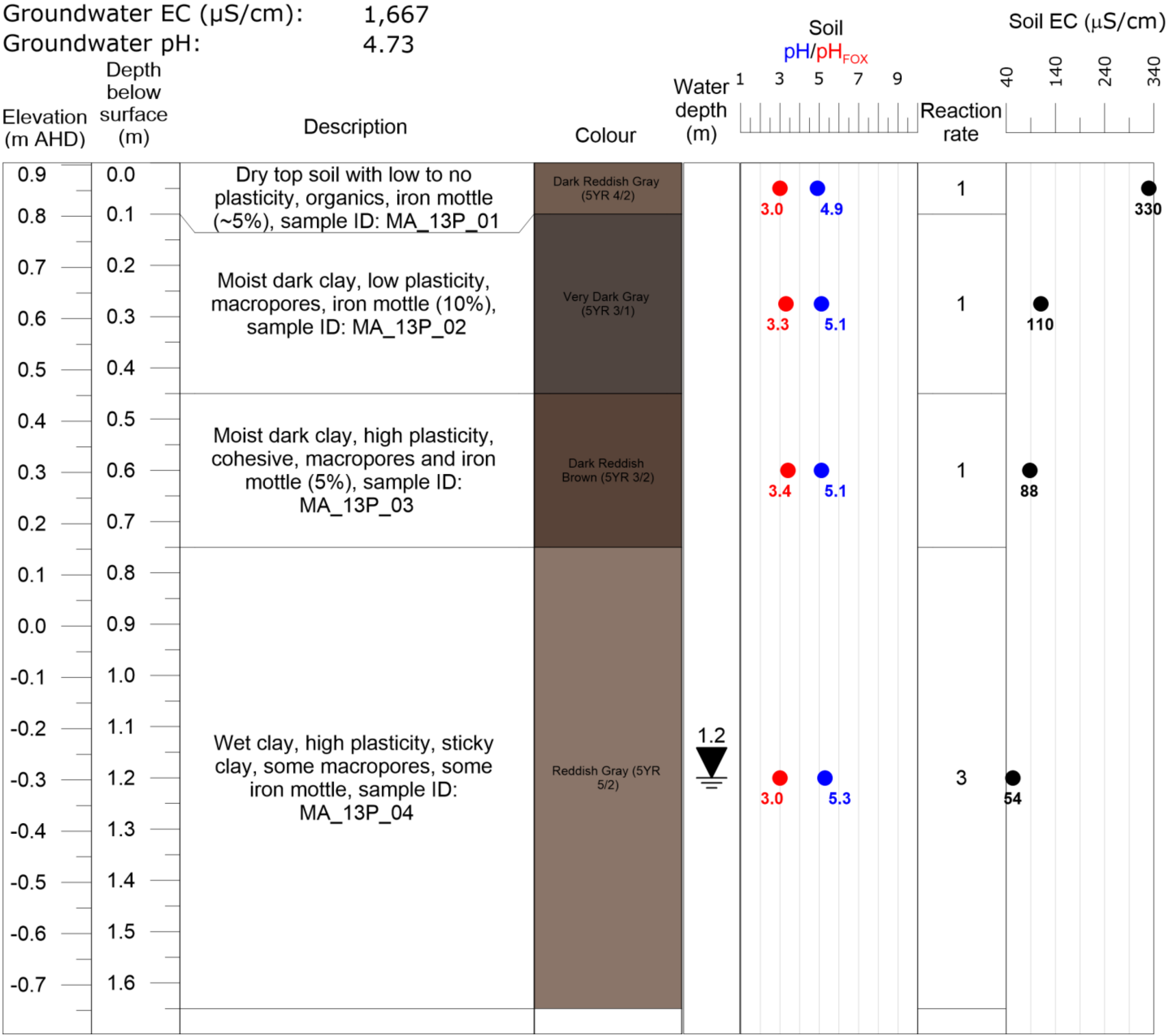
Soil profile details:

Project Number:	2018064	Profile ID:	MA_13_P
River/estuary:	Macleay	Sample date:	01/10/19
Easting:	484877.5	Sampled by:	TAT DWJ
Northing:	6566953.5		

Ground elevation (m AHD):	0.90
Hydraulic conductivity (m/d):	3.66

Water quality:

Surface water EC (μS/cm):	11,281
Surface water pH:	3.7
Groundwater EC (μS/cm):	1,667
Groundwater pH:	4.73



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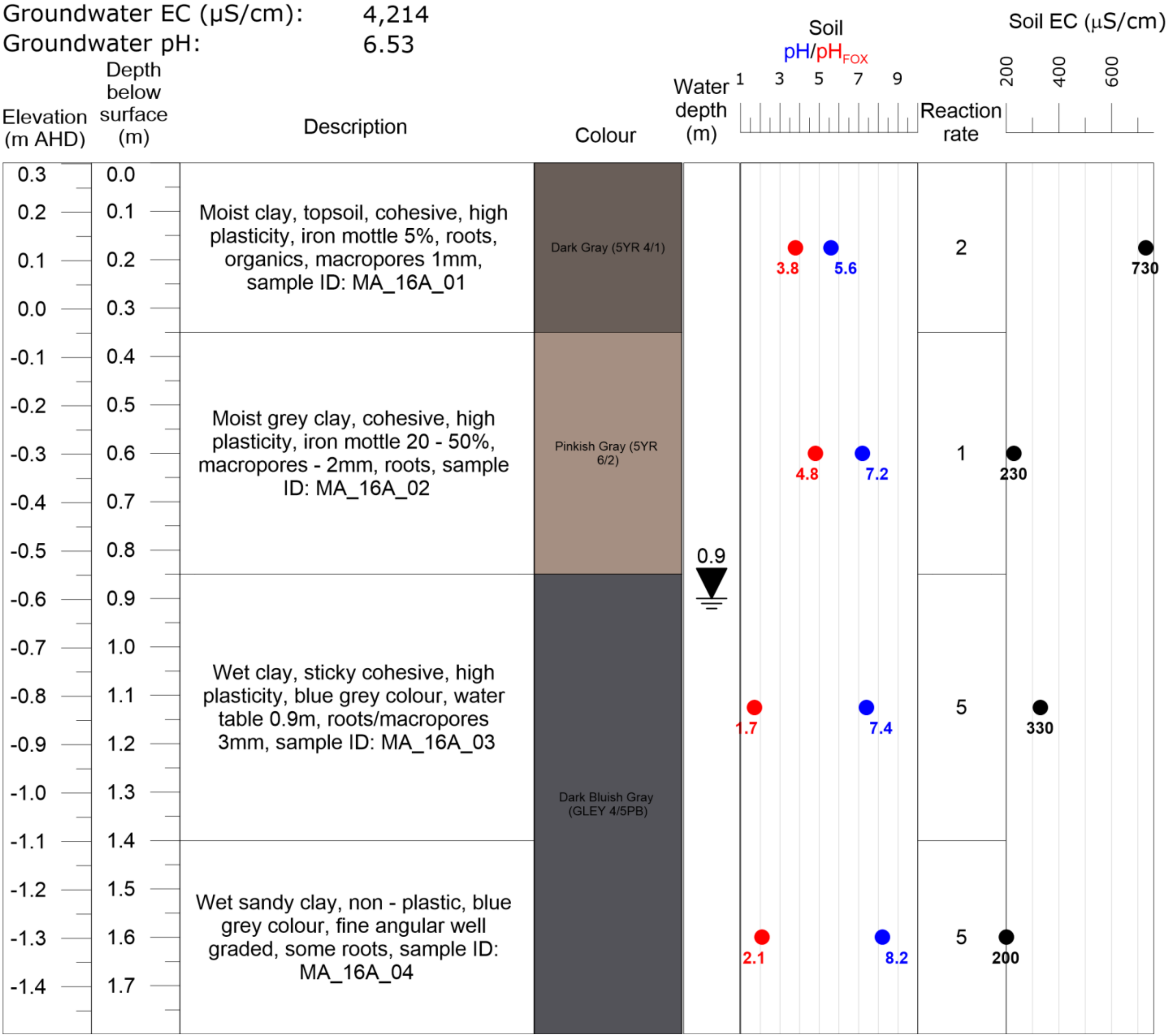
Soil profile details:

Project Number:	2018064	Profile ID:	MA_16_A
River/estuary:	Macleay	Sample date:	29/01/20
Easting:	501161.6	Sampled by:	TAT DWJ
Northing:	6577247.4		

Ground elevation (m AHD):	0.30
Hydraulic conductivity (m/d):	0.44

Water quality:

Surface water EC (µS/cm):	Not measured
Surface water pH:	Not measured
Groundwater EC (µS/cm):	4,214
Groundwater pH:	6.53



Description	Colour	pH$_{FOX}$	pH	Reaction rate	Soil EC (µS/cm)
Moist clay, topsoil, cohesive, high plasticity, iron mottle 5%, roots, organics, macropores 1mm, sample ID: MA_16A_01	Dark Gray (5YR 4/1)	3.8	5.6	2	730
Moist grey clay, cohesive, high plasticity, iron mottle 20 - 50%, macropores - 2mm, roots, sample ID: MA_16A_02	Pinkish Gray (5YR 6/2)	4.8	7.2	1	230
Wet clay, sticky cohesive, high plasticity, blue grey colour, water table 0.9m, roots/macropores 3mm, sample ID: MA_16A_03	Dark Bluish Gray (GLEY 4/5PB)	1.7	7.4	5	330
Wet sandy clay, non - plastic, blue grey colour, fine angular well graded, some roots, sample ID: MA_16A_04		2.1	8.2	5	200

Soil profile details:

Project Number:	2018064	Profile ID:	MA_16_PA
River/estuary:	Macleay	Sample date:	28/01/20
Easting:	500487.5	Sampled by:	TAT DWJ
Northing:	6577535.9		

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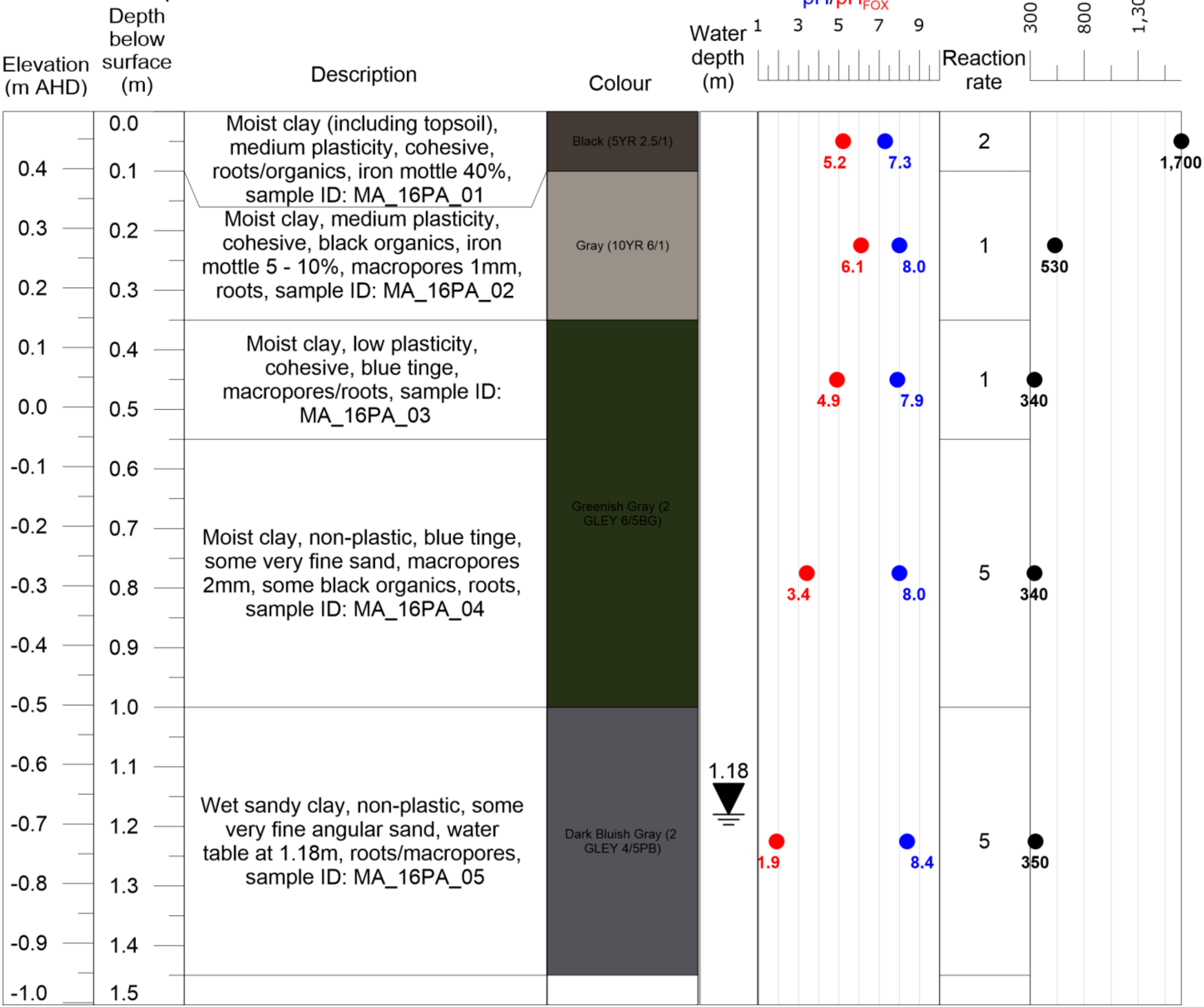
Ground elevation (m AHD):	0.50
Hydraulic conductivity (m/d):	1.43

Water quality:

Surface water EC (µS/cm):	45,974
Surface water pH:	6.98
Groundwater EC (µS/cm):	5,690
Groundwater pH:	7.38



Description	Colour	Soil pH	Soil pH_FOX	Reaction rate	Soil EC (µS/cm)
Moist clay (including topsoil), medium plasticity, cohesive, roots/organics, iron mottle 40%, sample ID: MA_16PA_01	Black (5YR 2.5/1)	7.3	5.2	2	1,700
Moist clay, medium plasticity, cohesive, black organics, iron mottle 5 - 10%, macropores 1mm, roots, sample ID: MA_16PA_02	Gray (10YR 6/1)	8.0	6.1	1	530
Moist clay, low plasticity, cohesive, blue tinge, macropores/roots, sample ID: MA_16PA_03	Greenish Gray (2 GLEY 6/5BG)	7.9	4.9	1	340
Moist clay, non-plastic, blue tinge, some very fine sand, macropores 2mm, some black organics, roots, sample ID: MA_16PA_04		8.0	3.4	5	340
Wet sandy clay, non-plastic, some very fine angular sand, water table at 1.18m, roots/macropores, sample ID: MA_16PA_05	Dark Bluish Gray (2 GLEY 4/5PB)	8.4	1.9	5	350

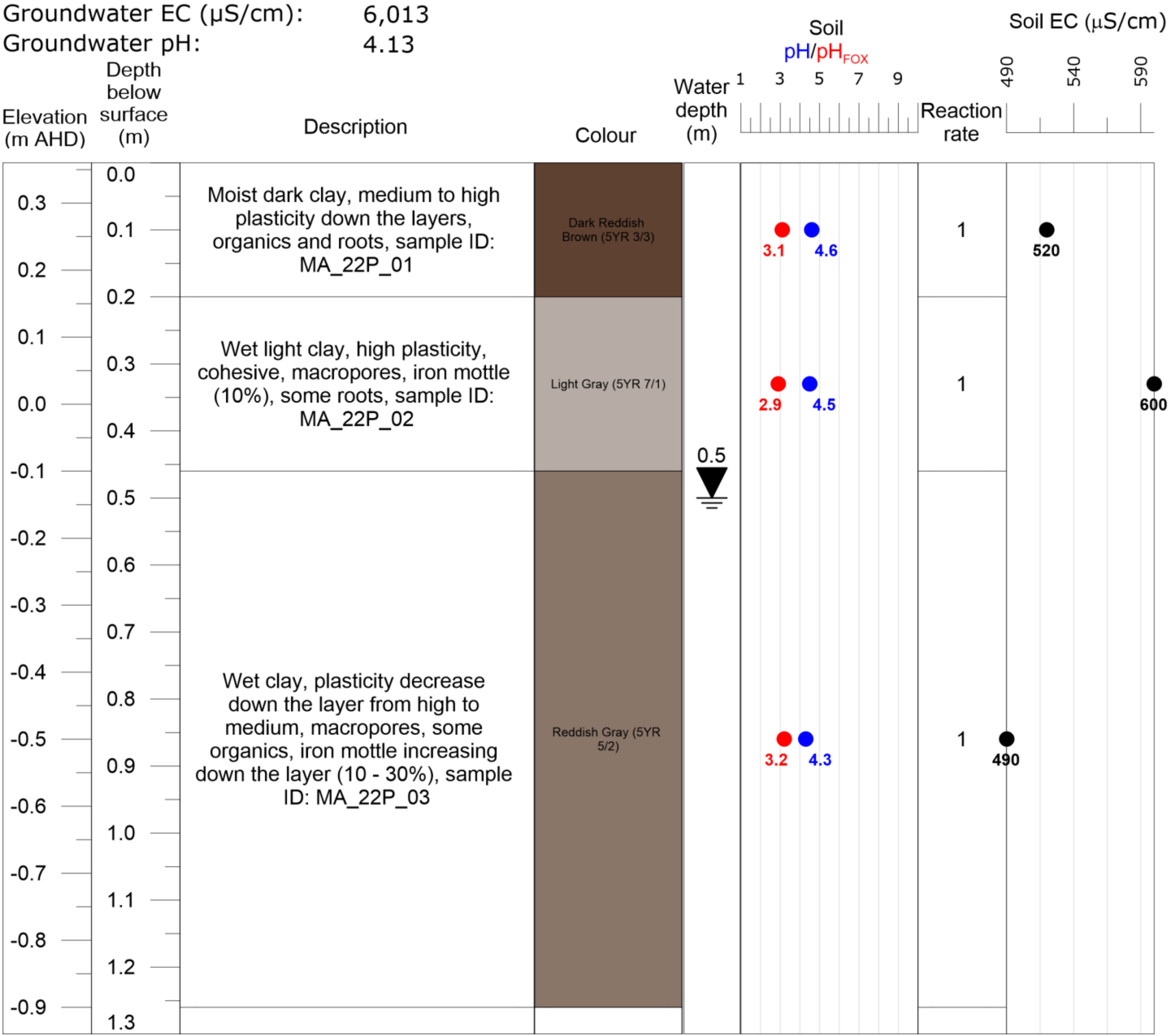
Soil profile details:

Project Number:	2018064	Profile ID:	MA_22_P
River/estuary:	Macleay	Sample date:	03/10/19
Easting:	500839.7	Sampled by:	TAT DWJ
Northing:	6571885.9		

Ground elevation (m AHD): 0.36
Hydraulic conductivity (m/d): 152.80

Water quality:

Surface water EC (μS/cm):	8,180
Surface water pH:	3.27
Groundwater EC (μS/cm):	6,013
Groundwater pH:	4.13



Description	Colour	Soil pH$_{FOX}$	Soil pH	Reaction rate	Soil EC (μS/cm)
Moist dark clay, medium to high plasticity down the layers, organics and roots, sample ID: MA_22P_01	Dark Reddish Brown (5YR 3/3)	3.1	4.6	1	520
Wet light clay, high plasticity, cohesive, macropores, iron mottle (10%), some roots, sample ID: MA_22P_02	Light Gray (5YR 7/1)	2.9	4.5	1	600
Wet clay, plasticity decrease down the layer from high to medium, macropores, some organics, iron mottle increasing down the layer (10 - 30%), sample ID: MA_22P_03	Reddish Gray (5YR 5/2)	3.2	4.3	1	490

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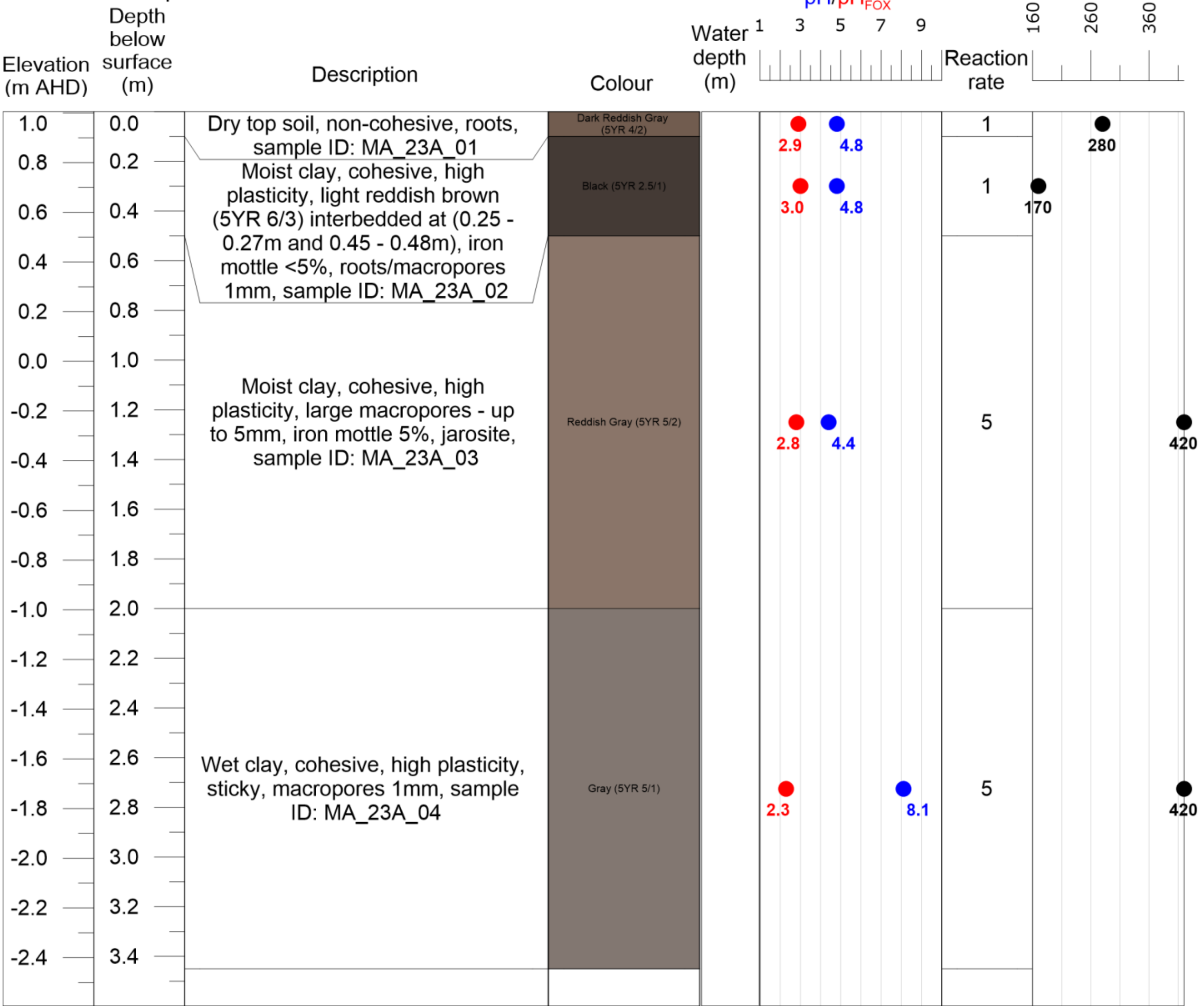
Soil profile details:

Project Number:	2018064	Profile ID:	MA_23_A
River/estuary:	Macleay	Sample date:	30/01/20
Easting:	489837.1	Sampled by:	TAT DWJ
Northing:	6562910.8		

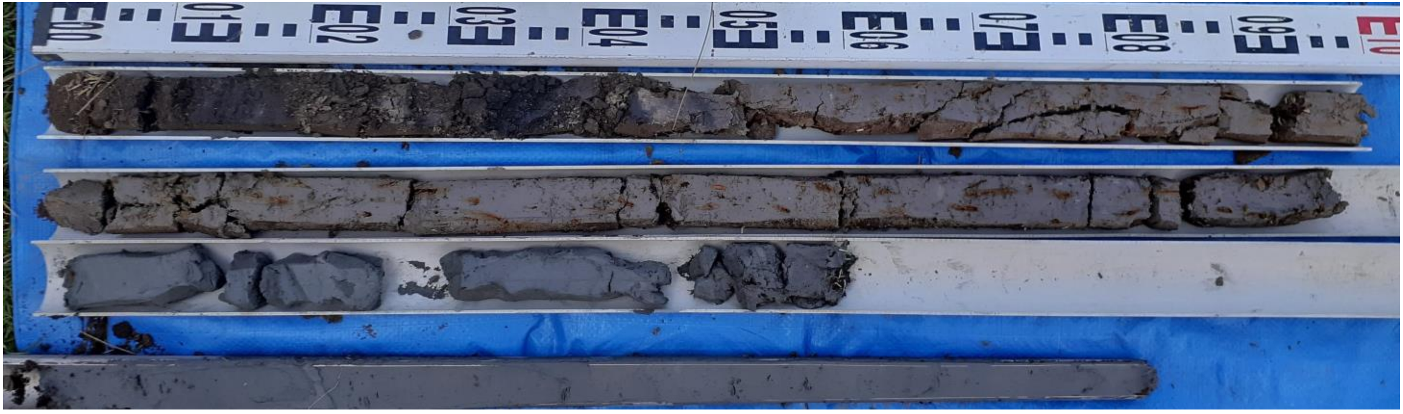
Ground elevation (m AHD):	1.00
Hydraulic conductivity (m/d):	105.66

Water quality:

Surface water EC (µS/cm):	Not measured
Surface water pH:	Not measured
Groundwater EC (µS/cm):	Not measured
Groundwater pH:	Not measured



Description	Colour	pH$_{FOX}$	pH	Reaction rate	Soil EC (µS/cm)
Dry top soil, non-cohesive, roots, sample ID: MA_23A_01	Dark Reddish Gray (5YR 4/2)	2.9	4.8	1	280
Moist clay, cohesive, high plasticity, light reddish brown (5YR 6/3) interbedded at (0.25 - 0.27m and 0.45 - 0.48m), iron mottle <5%, roots/macropores 1mm, sample ID: MA_23A_02	Black (5YR 2.5/1)	3.0	4.8	1	170
Moist clay, cohesive, high plasticity, large macropores - up to 5mm, iron mottle 5%, jarosite, sample ID: MA_23A_03	Reddish Gray (5YR 5/2)	2.8	4.4	5	420
Wet clay, cohesive, high plasticity, sticky, macropores 1mm, sample ID: MA_23A_04	Gray (5YR 5/1)	2.3	8.1	5	420



Soil profile details:

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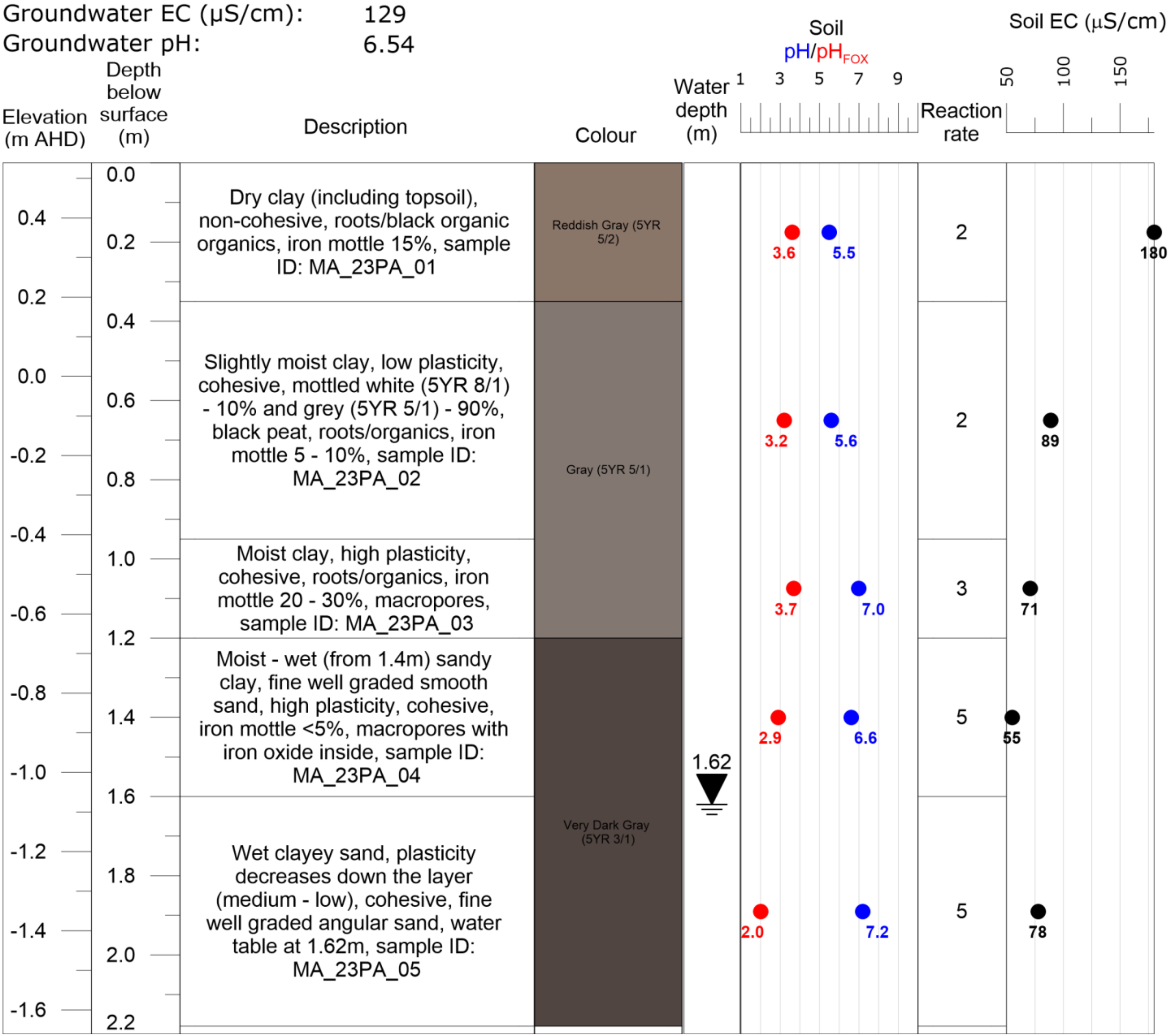
Project Number:	2018064	Profile ID:	MA_23_PA
River/estuary:	Macleay	Sample date:	29/01/20
Easting:	500194.3	Sampled by:	TAT DWJ
Northing:	6575287.3		

Ground elevation (m AHD):	0.54
Hydraulic conductivity (m/d):	0.27

Water quality:

Surface water EC (µS/cm):	9,842
Surface water pH:	8.85
Groundwater EC (µS/cm):	129
Groundwater pH:	6.54



Description	Colour	Water depth (m)	Soil pH/pH$_{FOX}$	Reaction rate	Soil EC (µS/cm)
Dry clay (including topsoil), non-cohesive, roots/black organic organics, iron mottle 15%, sample ID: MA_23PA_01	Reddish Gray (5YR 5/2)		5.5/3.6	2	180
Slightly moist clay, low plasticity, cohesive, mottled white (5YR 8/1) - 10% and grey (5YR 5/1) - 90%, black peat, roots/organics, iron mottle 5 - 10%, sample ID: MA_23PA_02	Gray (5YR 5/1)		5.6/3.2	2	89
Moist clay, high plasticity, cohesive, roots/organics, iron mottle 20 - 30%, macropores, sample ID: MA_23PA_03			7.0/3.7	3	71
Moist - wet (from 1.4m) sandy clay, fine well graded smooth sand, high plasticity, cohesive, iron mottle <5%, macropores with iron oxide inside, sample ID: MA_23PA_04	Very Dark Gray (5YR 3/1)		6.6/2.9	5	55
Wet clayey sand, plasticity decreases down the layer (medium - low), cohesive, fine well graded angular sand, water table at 1.62m, sample ID: MA_23PA_05		1.62	7.2/2.0	5	78

Soil profile details:

Project Number: 2018064
River/estuary: Macleay
Easting: 499196.8
Northing: 6558683.5
Profile ID: MA_26_P
Sample date: 02/10/19
Sampled by: TAT DWJ

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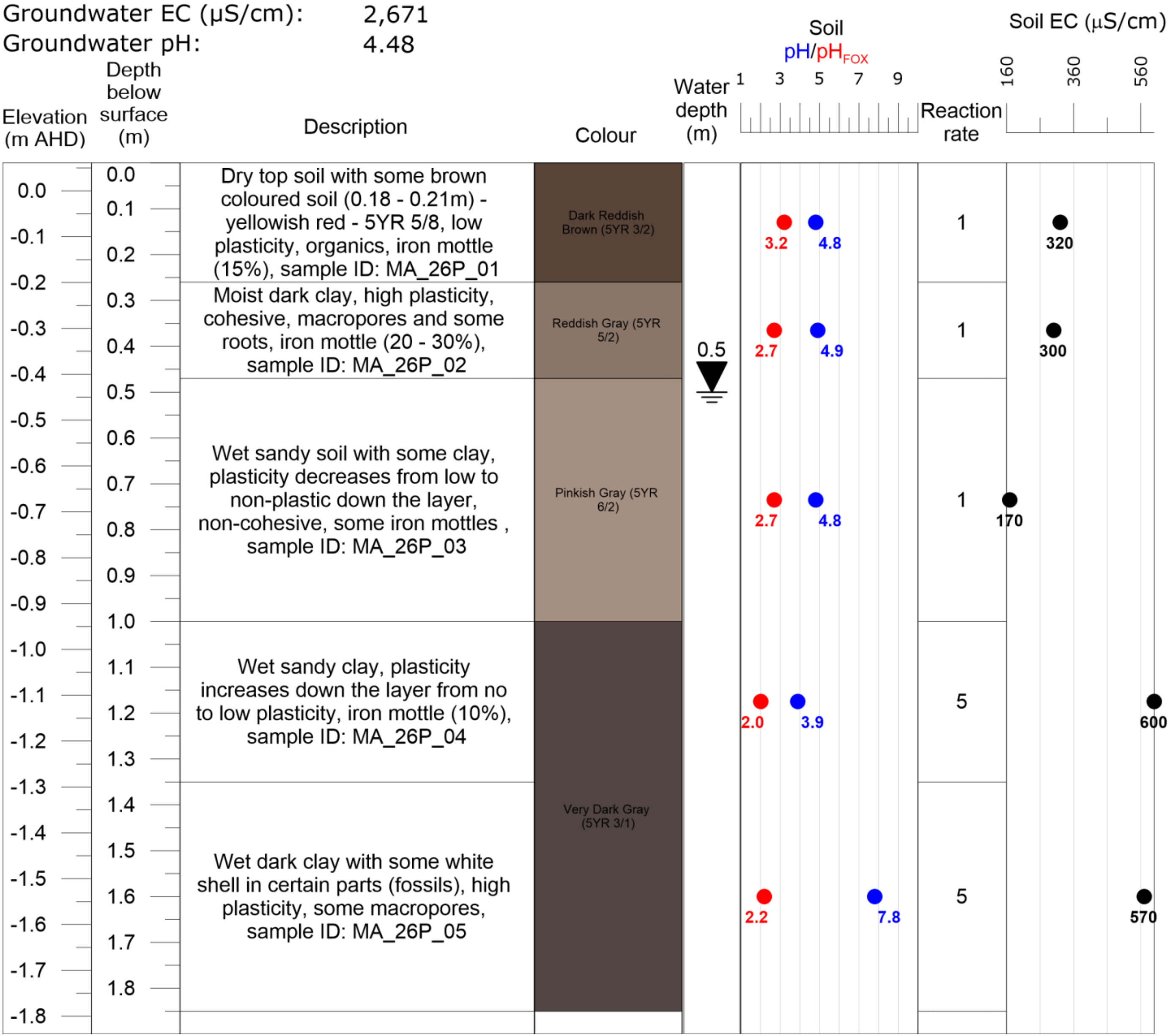
Ground elevation (m AHD): 0.06
Hydraulic conductivity (m/d): ~200

Water quality:

Surface water EC (µS/cm): Not measured
Surface water pH: Not measured
Groundwater EC (µS/cm): 2,671
Groundwater pH: 4.48



Description	Colour	pH_{FOX}	pH	Reaction rate	Soil EC (µS/cm)
Dry top soil with some brown coloured soil (0.18 - 0.21m) - yellowish red - 5YR 5/8, low plasticity, organics, iron mottle (15%), sample ID: MA_26P_01	Dark Reddish Brown (5YR 3/2)	3.2	4.8	1	320
Moist dark clay, high plasticity, cohesive, macropores and some roots, iron mottle (20 - 30%), sample ID: MA_26P_02	Reddish Gray (5YR 5/2)	2.7	4.9	1	300
Wet sandy soil with some clay, plasticity decreases from low to non-plastic down the layer, non-cohesive, some iron mottles , sample ID: MA_26P_03	Pinkish Gray (5YR 6/2)	2.7	4.8	1	170
Wet sandy clay, plasticity increases down the layer from no to low plasticity, iron mottle (10%), sample ID: MA_26P_04	Very Dark Gray (5YR 3/1)	2.0	3.9	5	600
Wet dark clay with some white shell in certain parts (fossils), high plasticity, some macropores, sample ID: MA_26P_05		2.2	7.8	5	570

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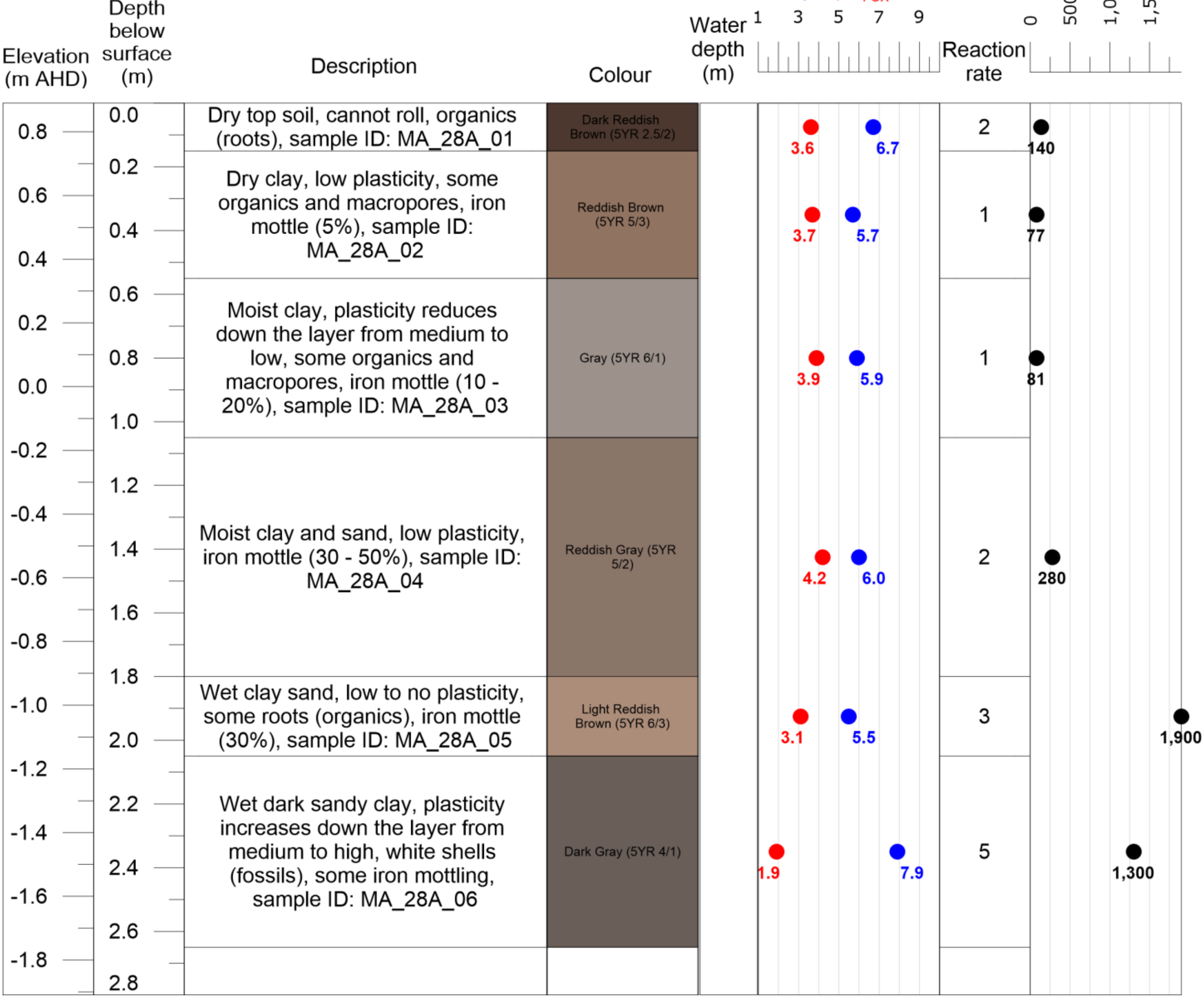
Soil profile details:

Project Number:	2018064	Profile ID:	MA_28_A
River/estuary:	Macleay	Sample date:	04/10/19
Easting:	495850.8	Sampled by:	TAT DWJ
Northing:	6570710.2		

Ground elevation (m AHD): 0.89
Hydraulic conductivity (m/d): Not measured

Water quality:

Surface water EC (µS/cm): Not measured
Surface water pH: Not measured
Groundwater EC (µS/cm): Not measured
Groundwater pH: Not measured



Description	Colour	Soil pH	Soil pH_FOX	Reaction rate	Soil EC (µS/cm)
Dry top soil, cannot roll, organics (roots), sample ID: MA_28A_01	Dark Reddish Brown (5YR 2.5/2)	3.6	6.7	2	140
Dry clay, low plasticity, some organics and macropores, iron mottle (5%), sample ID: MA_28A_02	Reddish Brown (5YR 5/3)	3.7	5.7	1	77
Moist clay, plasticity reduces down the layer from medium to low, some organics and macropores, iron mottle (10 - 20%), sample ID: MA_28A_03	Gray (5YR 6/1)	3.9	5.9	1	81
Moist clay and sand, low plasticity, iron mottle (30 - 50%), sample ID: MA_28A_04	Reddish Gray (5YR 5/2)	4.2	6.0	2	280
Wet clay sand, low to no plasticity, some roots (organics), iron mottle (30%), sample ID: MA_28A_05	Light Reddish Brown (5YR 6/3)	3.1	5.5	3	1,900
Wet dark sandy clay, plasticity increases down the layer from medium to high, white shells (fossils), some iron mottling, sample ID: MA_28A_06	Dark Gray (5YR 4/1)	1.9	7.9	5	1,300

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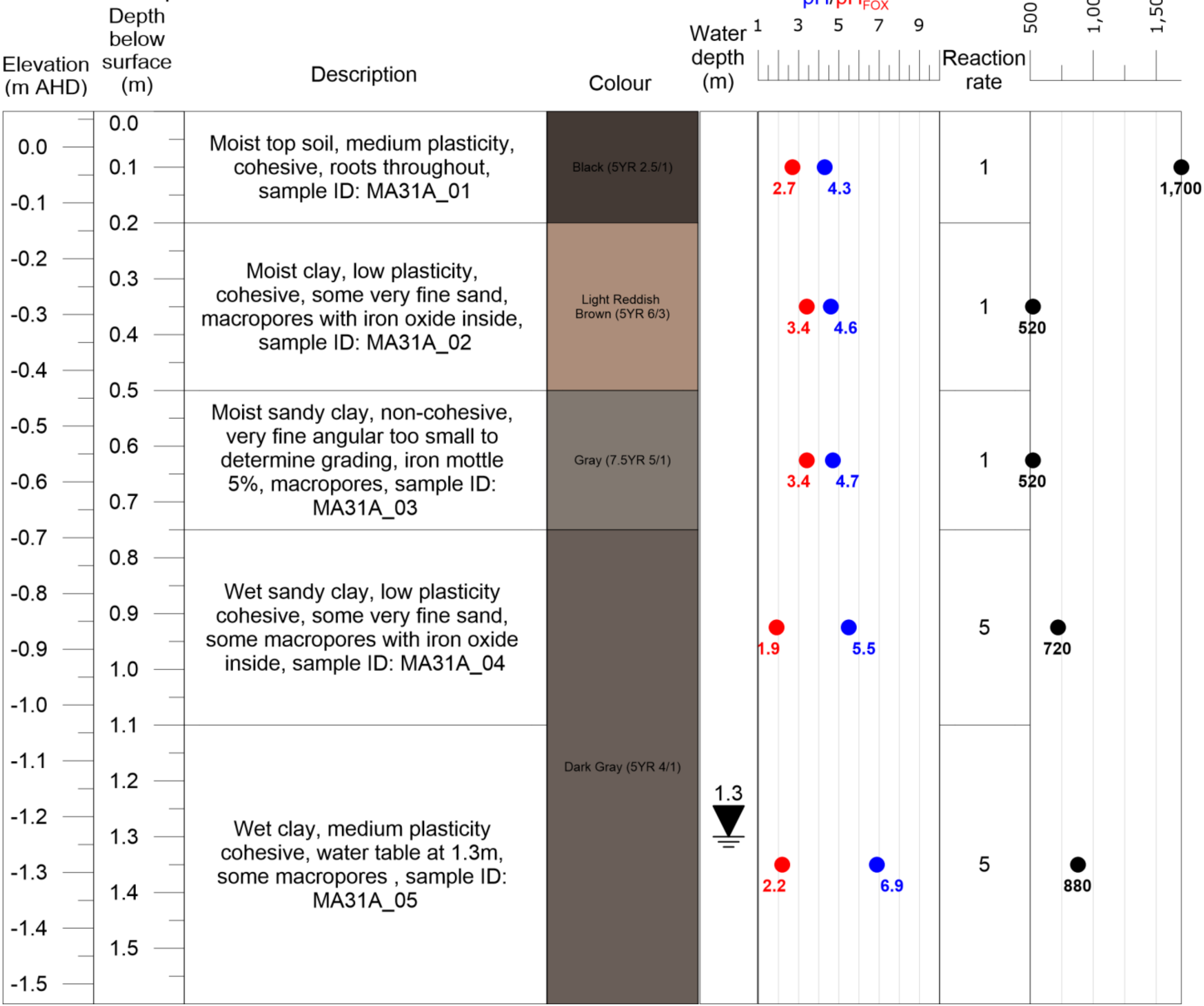
Soil profile details:

Project Number:	2018064	Profile ID:	MA_31_A
River/estuary:	Macleay	Sample date:	20/11/19
Easting:	498294.4	Sampled by:	TAT DWJ
Northing:	6566463.1		

Ground elevation (m AHD):	0.06
Hydraulic conductivity (m/d):	1.40

Water quality:

Surface water EC (μS/cm):	11,692
Surface water pH:	2.93
Groundwater EC (μS/cm):	11,864
Groundwater pH:	6.22



Description	Colour	Soil pH$_{FOX}$	Soil pH	Reaction rate	Soil EC (μS/cm)
Moist top soil, medium plasticity, cohesive, roots throughout, sample ID: MA31A_01	Black (5YR 2.5/1)	2.7	4.3	1	1,700
Moist clay, low plasticity, cohesive, some very fine sand, macropores with iron oxide inside, sample ID: MA31A_02	Light Reddish Brown (5YR 6/3)	3.4	4.6	1	520
Moist sandy clay, non-cohesive, very fine angular too small to determine grading, iron mottle 5%, macropores, sample ID: MA31A_03	Gray (7.5YR 5/1)	3.4	4.7	1	520
Wet sandy clay, low plasticity cohesive, some very fine sand, some macropores with iron oxide inside, sample ID: MA31A_04	Dark Gray (5YR 4/1)	1.9	5.5	5	720
Wet clay, medium plasticity cohesive, water table at 1.3m, some macropores , sample ID: MA31A_05		2.2	6.9	5	880

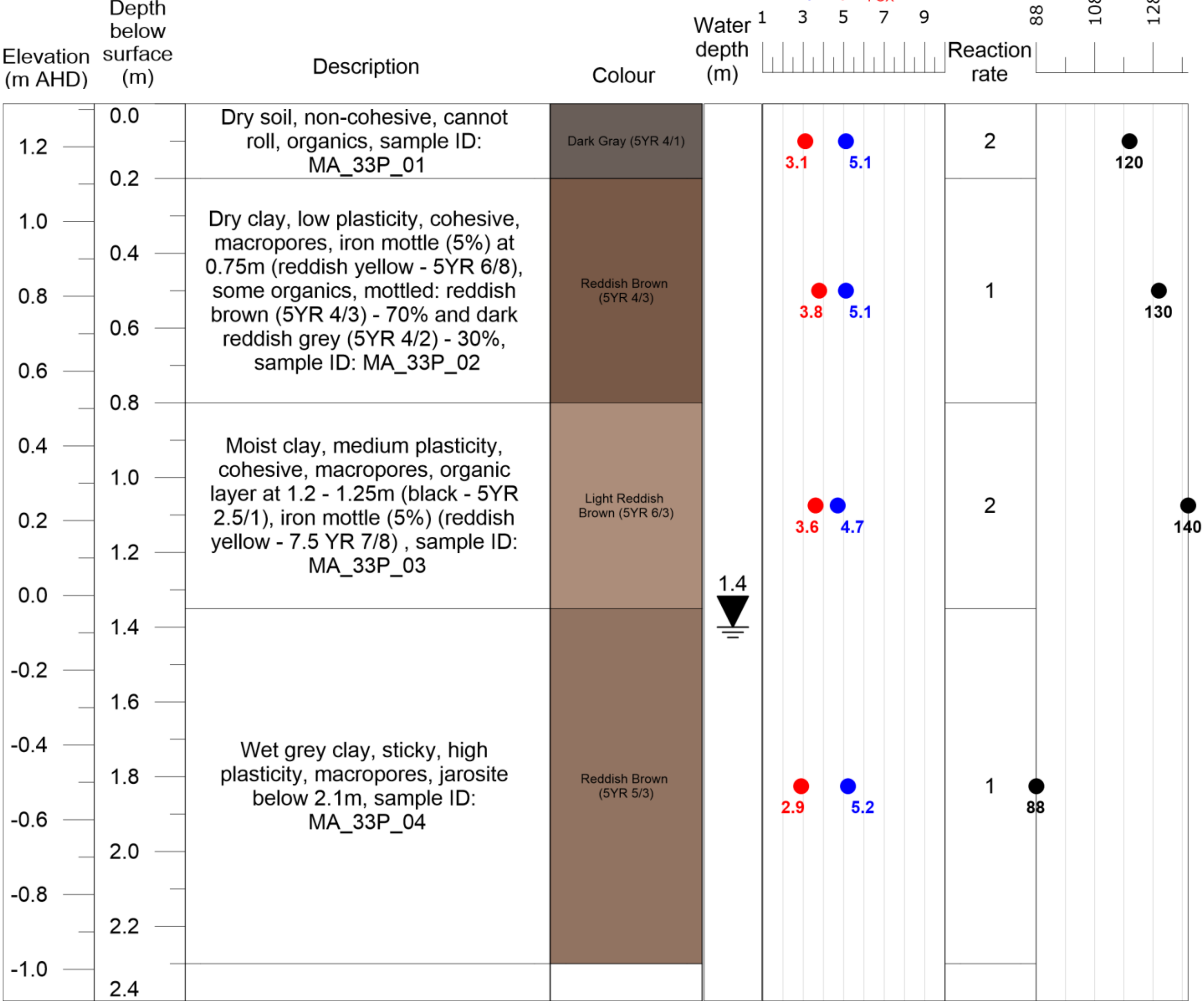
Soil profile details:

Project Number:	2018064	Profile ID:	MA_33_P
River/estuary:	Macleay	Sample date:	01/10/19
Easting:	485307	Sampled by:	TAT DWJ
Northing:	6565076.5		

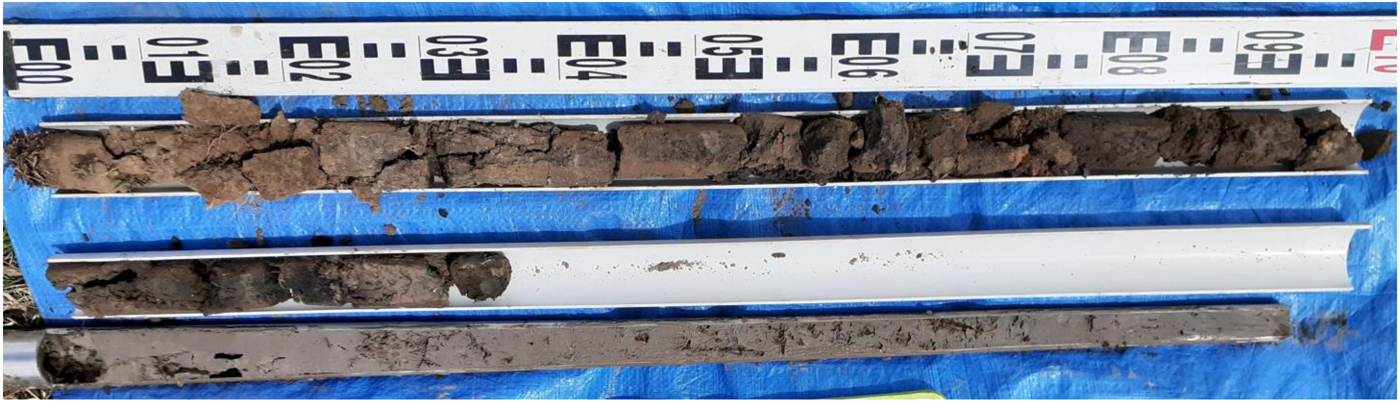
Ground elevation (m AHD):	1.31
Hydraulic conductivity (m/d):	0.90

Water quality:

Surface water EC (µS/cm):	9,737
Surface water pH:	6.56
Groundwater EC (µS/cm):	1,553
Groundwater pH:	4.67



Dry soil, non-cohesive, cannot roll, organics, sample ID: MA_33P_01	Dark Gray (5YR 4/1)	3.1	5.1	2	120
Dry clay, low plasticity, cohesive, macropores, iron mottle (5%) at 0.75m (reddish yellow - 5YR 6/8), some organics, mottled: reddish brown (5YR 4/3) - 70% and dark reddish grey (5YR 4/2) - 30%, sample ID: MA_33P_02	Reddish Brown (5YR 4/3)	3.8	5.1	1	130
Moist clay, medium plasticity, cohesive, macropores, organic layer at 1.2 - 1.25m (black - 5YR 2.5/1), iron mottle (5%) (reddish yellow - 7.5 YR 7/8) , sample ID: MA_33P_03	Light Reddish Brown (5YR 6/3)	3.6	4.7	2	140
Wet grey clay, sticky, high plasticity, macropores, jarosite below 2.1m, sample ID: MA_33P_04	Reddish Brown (5YR 5/3)	2.9	5.2	1	88



Soil profile details:

Project Number: 2018064
River/estuary: Macleay
Easting: 493372.5
Northing: 6561523.9

Profile ID: MA_34_A
Sample date: 01/10/19
Sampled by: TAT DWJ

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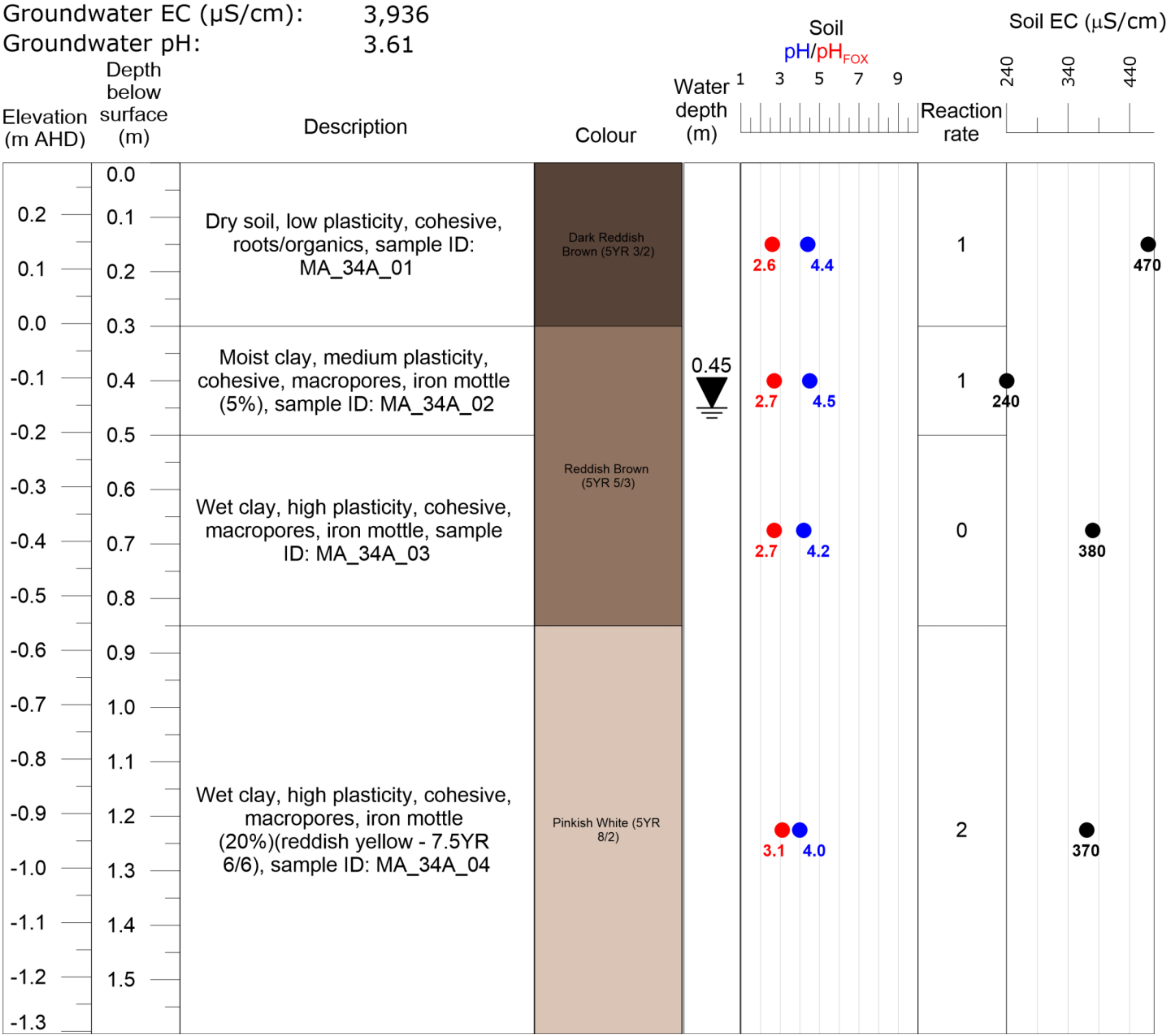
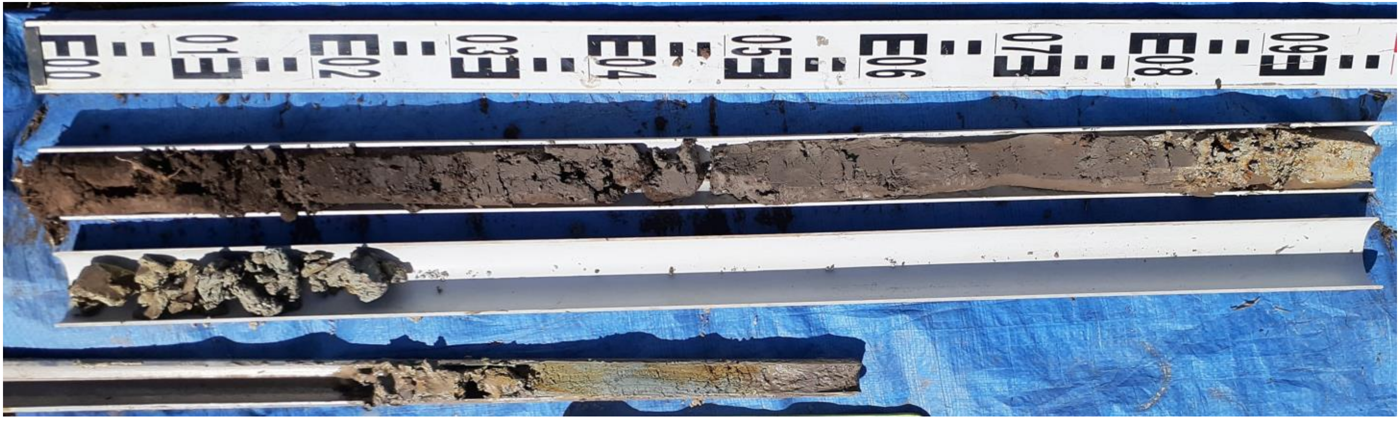
Ground elevation (m AHD): 0.29
Hydraulic conductivity (m/d): 1.22

Water quality:

Surface water EC (µS/cm): 751
Surface water pH: 4.95
Groundwater EC (µS/cm): 3,936
Groundwater pH: 3.61



Description	Colour	Soil pH/pH$_{FOX}$	Reaction rate	Soil EC (µS/cm)
Dry soil, low plasticity, cohesive, roots/organics, sample ID: MA_34A_01	Dark Reddish Brown (5YR 3/2)	2.6 / 4.4	1	470
Moist clay, medium plasticity, cohesive, macropores, iron mottle (5%), sample ID: MA_34A_02	Reddish Brown (5YR 5/3)	2.7 / 4.5	1	240
Wet clay, high plasticity, cohesive, macropores, iron mottle, sample ID: MA_34A_03		2.7 / 4.2	0	380
Wet clay, high plasticity, cohesive, macropores, iron mottle (20%)(reddish yellow - 7.5YR 6/6), sample ID: MA_34A_04	Pinkish White (5YR 8/2)	3.1 / 4.0	2	370



Soil profile details:

Project Number:	2018064	Profile ID:	MA_36_A
River/estuary:	Macleay	Sample date:	03/10/19
Easting:	499549.9	Sampled by:	TAT DWJ
Northing:	6564149.5		

Ground elevation (m AHD):	0.10
Hydraulic conductivity (m/d):	11.61

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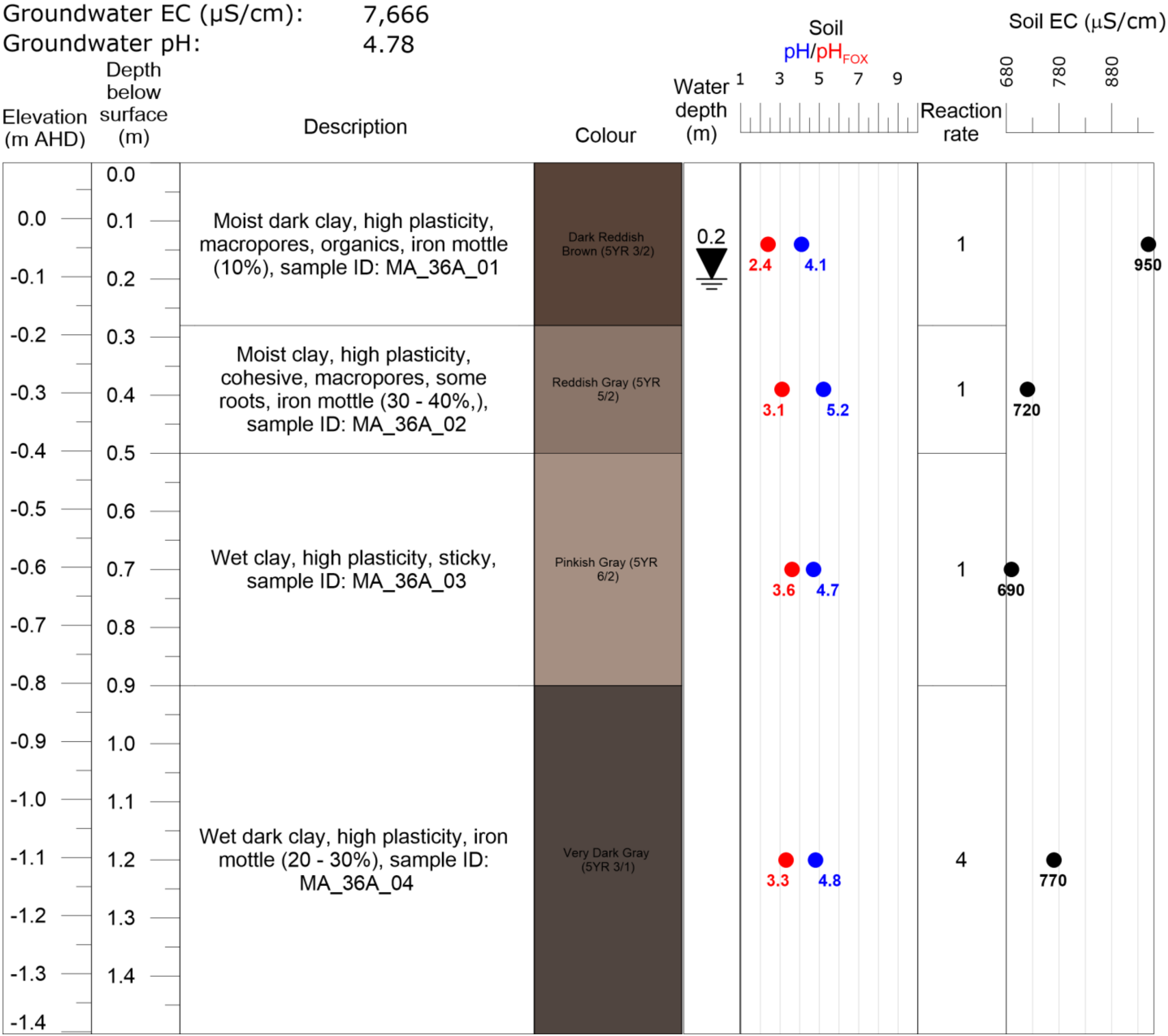
Water quality:

Surface water EC (µS/cm):	21,431
Surface water pH:	6.43
Groundwater EC (µS/cm):	7,666
Groundwater pH:	4.78



Description	Colour	Soil pH_{FOX}	Soil pH	Reaction rate	Soil EC (µS/cm)
Moist dark clay, high plasticity, macropores, organics, iron mottle (10%), sample ID: MA_36A_01	Dark Reddish Brown (5YR 3/2)	2.4	4.1	1	950
Moist clay, high plasticity, cohesive, macropores, some roots, iron mottle (30 - 40%,), sample ID: MA_36A_02	Reddish Gray (5YR 5/2)	3.1	5.2	1	720
Wet clay, high plasticity, sticky, sample ID: MA_36A_03	Pinkish Gray (5YR 6/2)	3.6	4.7	1	690
Wet dark clay, high plasticity, iron mottle (20 - 30%), sample ID: MA_36A_04	Very Dark Gray (5YR 3/1)	3.3	4.8	4	770

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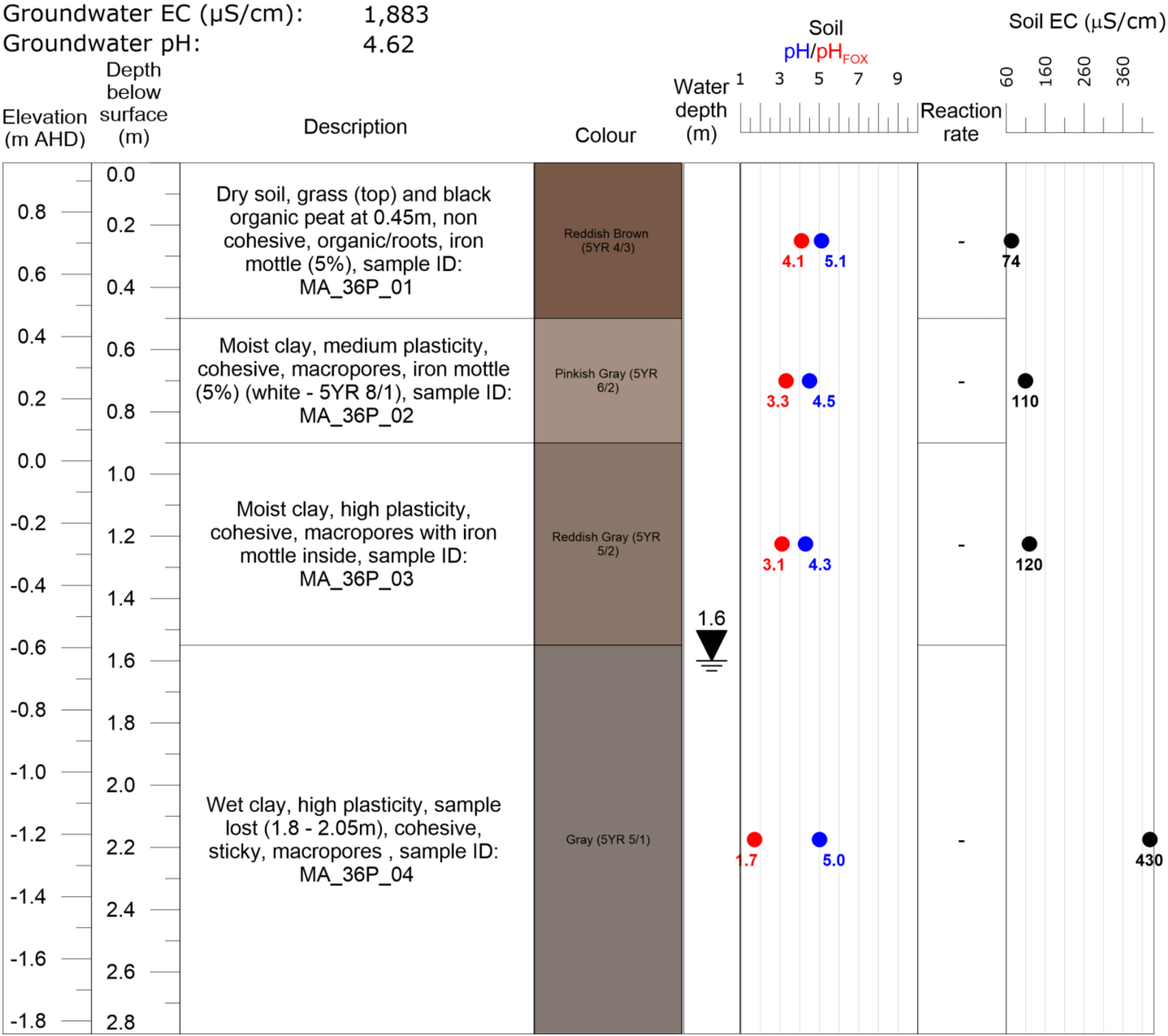
Soil profile details:

Project Number: 2018064
River/estuary: Macleay
Easting: 492761.3
Northing: 6563912.7
Profile ID: MA_36_P
Sample date: 02/10/19
Sampled by: TAT DWJ

Ground elevation (m AHD): 0.96
Hydraulic conductivity (m/d): 26.77

Water quality:

Surface water EC (µS/cm): 12,194
Surface water pH: 7.42
Groundwater EC (µS/cm): 1,883
Groundwater pH: 4.62



Description	Colour	pH$_{FOX}$	pH	Reaction rate	Soil EC (µS/cm)
Dry soil, grass (top) and black organic peat at 0.45m, non cohesive, organic/roots, iron mottle (5%), sample ID: MA_36P_01	Reddish Brown (5YR 4/3)	4.1	5.1	-	74
Moist clay, medium plasticity, cohesive, macropores, iron mottle (5%) (white - 5YR 8/1), sample ID: MA_36P_02	Pinkish Gray (5YR 6/2)	3.3	4.5	-	110
Moist clay, high plasticity, cohesive, macropores with iron mottle inside, sample ID: MA_36P_03	Reddish Gray (5YR 5/2)	3.1	4.3	-	120
Wet clay, high plasticity, sample lost (1.8 - 2.05m), cohesive, sticky, macropores , sample ID: MA_36P_04	Gray (5YR 5/1)	1.7	5.0	-	430

Soil profile details:

Project Number:	2018064	Profile ID:	MA_37_A
River/estuary:	Macleay	Sample date:	03/10/19
Easting:	499608.3	Sampled by:	TAT DWJ
Northing:	6569673.2		

Ground elevation (m AHD):	1.48
Hydraulic conductivity (m/d):	0.25

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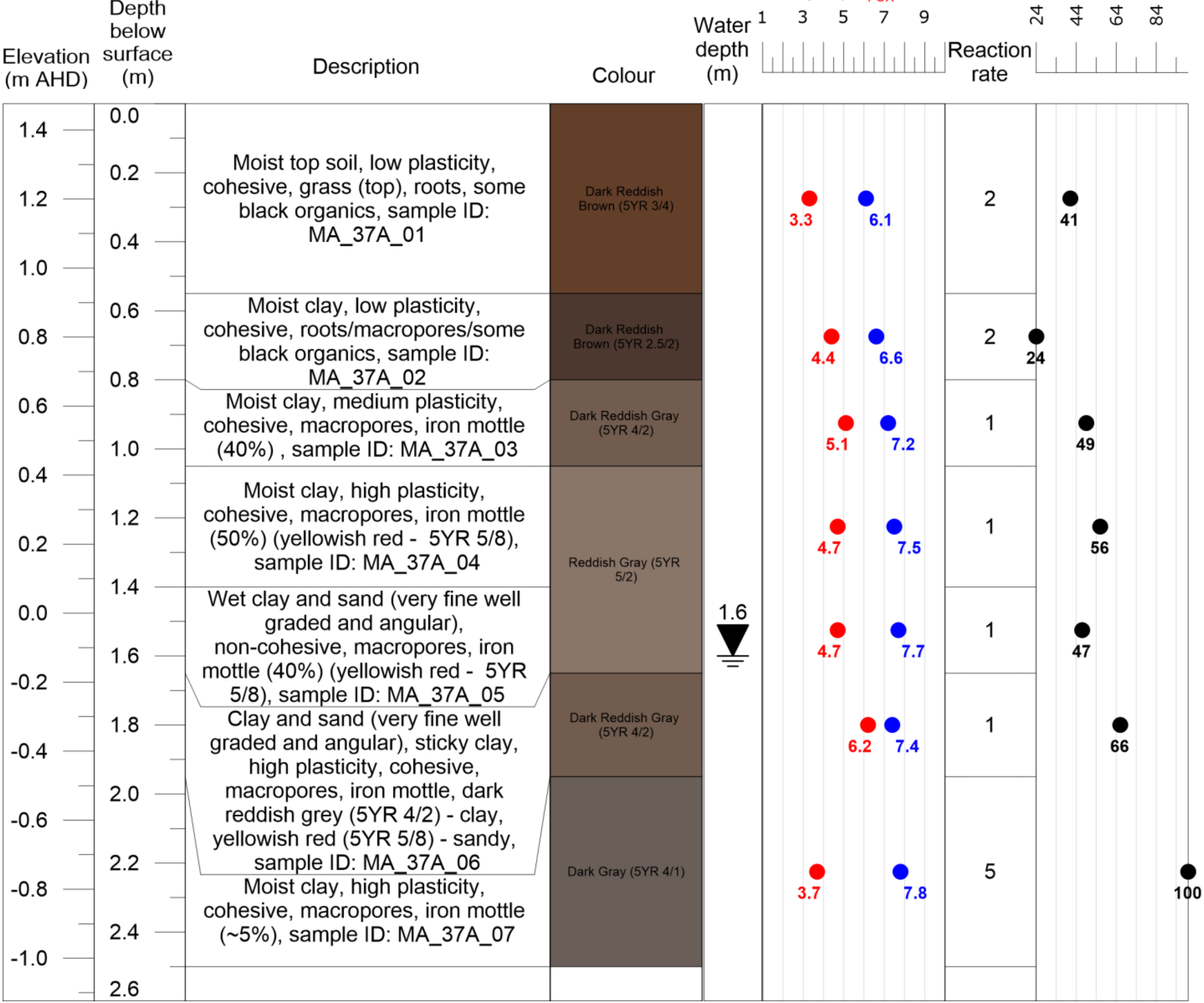
Water quality:

Surface water EC (µS/cm):	26,217
Surface water pH:	8.39
Groundwater EC (µS/cm):	2,203
Groundwater pH:	6.76



Description	Colour	Soil pH$_{FOX}$	Soil pH	Reaction rate	Soil EC (µS/cm)
Moist top soil, low plasticity, cohesive, grass (top), roots, some black organics, sample ID: MA_37A_01	Dark Reddish Brown (5YR 3/4)	3.3	6.1	2	41
Moist clay, low plasticity, cohesive, roots/macropores/some black organics, sample ID: MA_37A_02	Dark Reddish Brown (5YR 2.5/2)	4.4	6.6	2	24
Moist clay, medium plasticity, cohesive, macropores, iron mottle (40%) , sample ID: MA_37A_03	Dark Reddish Gray (5YR 4/2)	5.1	7.2	1	49
Moist clay, high plasticity, cohesive, macropores, iron mottle (50%) (yellowish red - 5YR 5/8), sample ID: MA_37A_04	Reddish Gray (5YR 5/2)	4.7	7.5	1	56
Wet clay and sand (very fine well graded and angular), non-cohesive, macropores, iron mottle (40%) (yellowish red - 5YR 5/8), sample ID: MA_37A_05		4.7	7.7	1	47
Clay and sand (very fine well graded and angular), sticky clay, high plasticity, cohesive, macropores, iron mottle, dark reddish grey (5YR 4/2) - clay, yellowish red (5YR 5/8) - sandy, sample ID: MA_37A_06	Dark Reddish Gray (5YR 4/2)	6.2	7.4	1	66
Moist clay, high plasticity, cohesive, macropores, iron mottle (~5%), sample ID: MA_37A_07	Dark Gray (5YR 4/1)	3.7	7.8	5	100

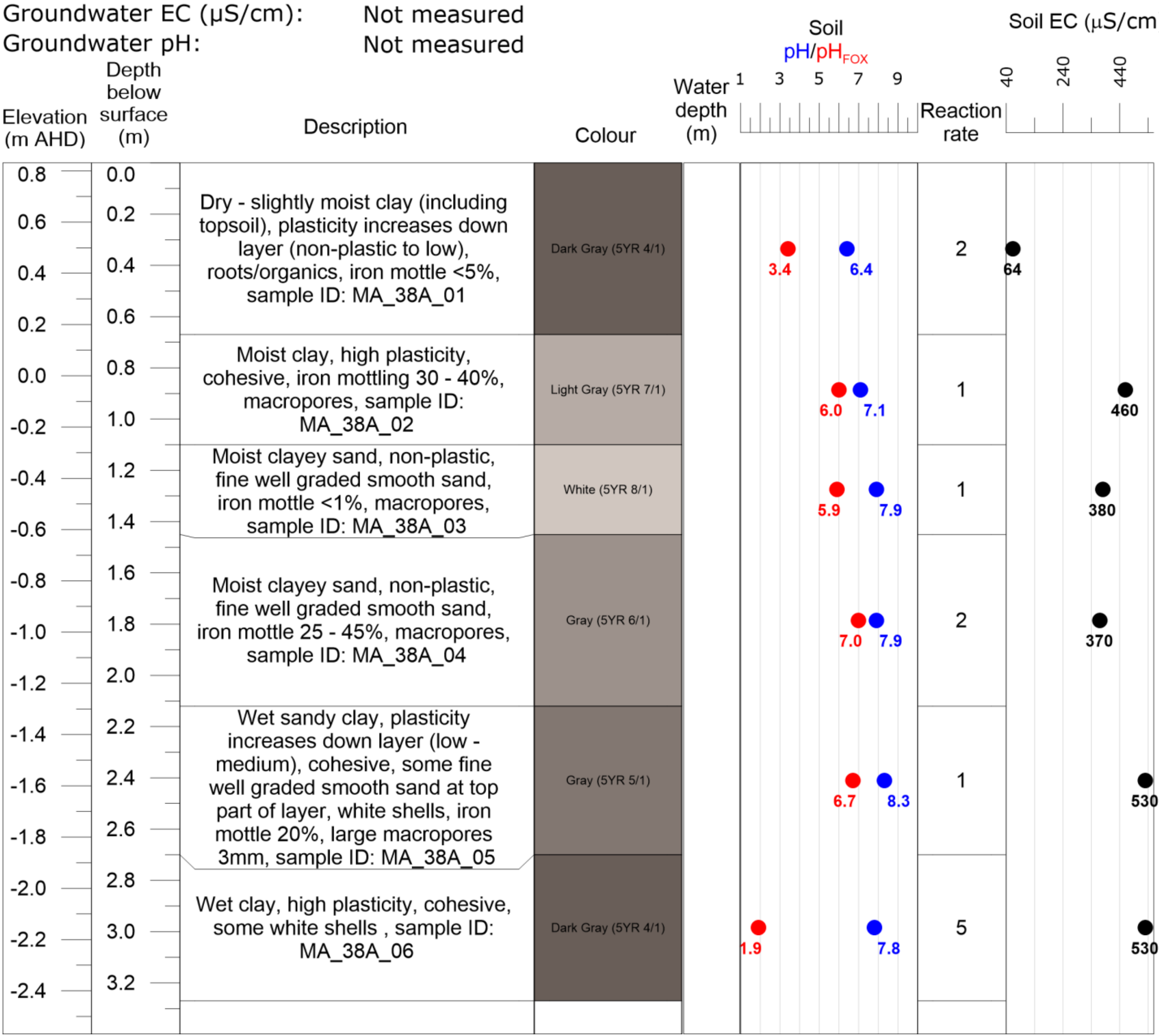
Soil profile details:

Project Number:	2018064	Profile ID:	MA_38_A
River/estuary:	Macleay	Sample date:	29/01/20
Easting:	498958	Sampled by:	TAT DWJ
Northing:	6574451.7		

Ground elevation (m AHD):	0.83
Hydraulic conductivity (m/d):	9.47

Water quality:

Surface water EC (µS/cm):	33,970
Surface water pH:	8.11
Groundwater EC (µS/cm):	Not measured
Groundwater pH:	Not measured



Description	Colour	Soil pH	Soil pH_{FOX}	Reaction rate	Soil EC (µS/cm)
Dry - slightly moist clay (including topsoil), plasticity increases down layer (non-plastic to low), roots/organics, iron mottle <5%, sample ID: MA_38A_01	Dark Gray (5YR 4/1)	6.4	3.4	2	64
Moist clay, high plasticity, cohesive, iron mottling 30 - 40%, macropores, sample ID: MA_38A_02	Light Gray (5YR 7/1)	7.1	6.0	1	460
Moist clayey sand, non-plastic, fine well graded smooth sand, iron mottle <1%, macropores, sample ID: MA_38A_03	White (5YR 8/1)	7.9	5.9	1	380
Moist clayey sand, non-plastic, fine well graded smooth sand, iron mottle 25 - 45%, macropores, sample ID: MA_38A_04	Gray (5YR 6/1)	7.9	7.0	2	370
Wet sandy clay, plasticity increases down layer (low - medium), cohesive, some fine well graded smooth sand at top part of layer, white shells, iron mottle 20%, large macropores 3mm, sample ID: MA_38A_05	Gray (5YR 5/1)	8.3	6.7	1	530
Wet clay, high plasticity, cohesive, some white shells , sample ID: MA_38A_06	Dark Gray (5YR 4/1)	7.8	1.9	5	530

Soil profile details:

Project Number:	2018064	Profile ID:	MA_39_A
River/estuary:	Macleay	Sample date:	04/10/19
Easting:	502951.1	Sampled by:	TAT DWJ
Northing:	6579962.2		

Ground elevation (m AHD): 1.02
Hydraulic conductivity (m/d): 1.11

Water quality:

Surface water EC (µS/cm):	48,807 (river), 4,189 (freshwater wetland)
Surface water pH:	7.53 (river), 7.39 (freshwater wetland)
Groundwater EC (µS/cm):	2,825
Groundwater pH:	5.74

Description	Colour	Water depth (m)	Soil pH_{FOX}	Soil pH	Reaction rate	Soil EC (µS/cm)
Dry soil, non-cohesive, organics/roots, sample ID: MA_39A_01	Reddish Brown (5YR 5/4)		3.4	6.2	2	62
Moist clay, high plasticity, cohesive, macropores, iron mottle (10 - 15%), sample ID: MA_39A_02	Reddish Brown (5YR 5/3)		3.5	5.8	0	84
Moist clay and sand (medium to fine, well graded and angular), lenses of medium plasticity clay, macropores, iron mottle (10%), mottling of reddish brown (5YR 5/4) and dark reddish grey (5YR 4/2), sample ID: MA_39A_03	Reddish Brown (5YR 5/4)		3.2	5.7	1	100
Very wet sand (medium to fine, well graded, angular), presence of particles white in colour, macropores/organics, sample ID: MA_39A_04	Reddish Gray (5YR 5/2)	1	2.3	5.3	5	190
Very grey clay and sand (medium to fine, well graded, angular), macropores, sample ID: MA_39A_05	Dark Reddish Gray (5YR 4/2)		2.0	5.1	5	250

Soil profile details:

Project Number:	2018064	Profile ID:	MA_41_A
River/estuary:	Macleay	Sample date:	20/11/19
Easting:	484178.9	Sampled by:	TAT DWJ
Northing:	6566135.2		

Ground elevation (m AHD):	0.80
Hydraulic conductivity (m/d):	0.18

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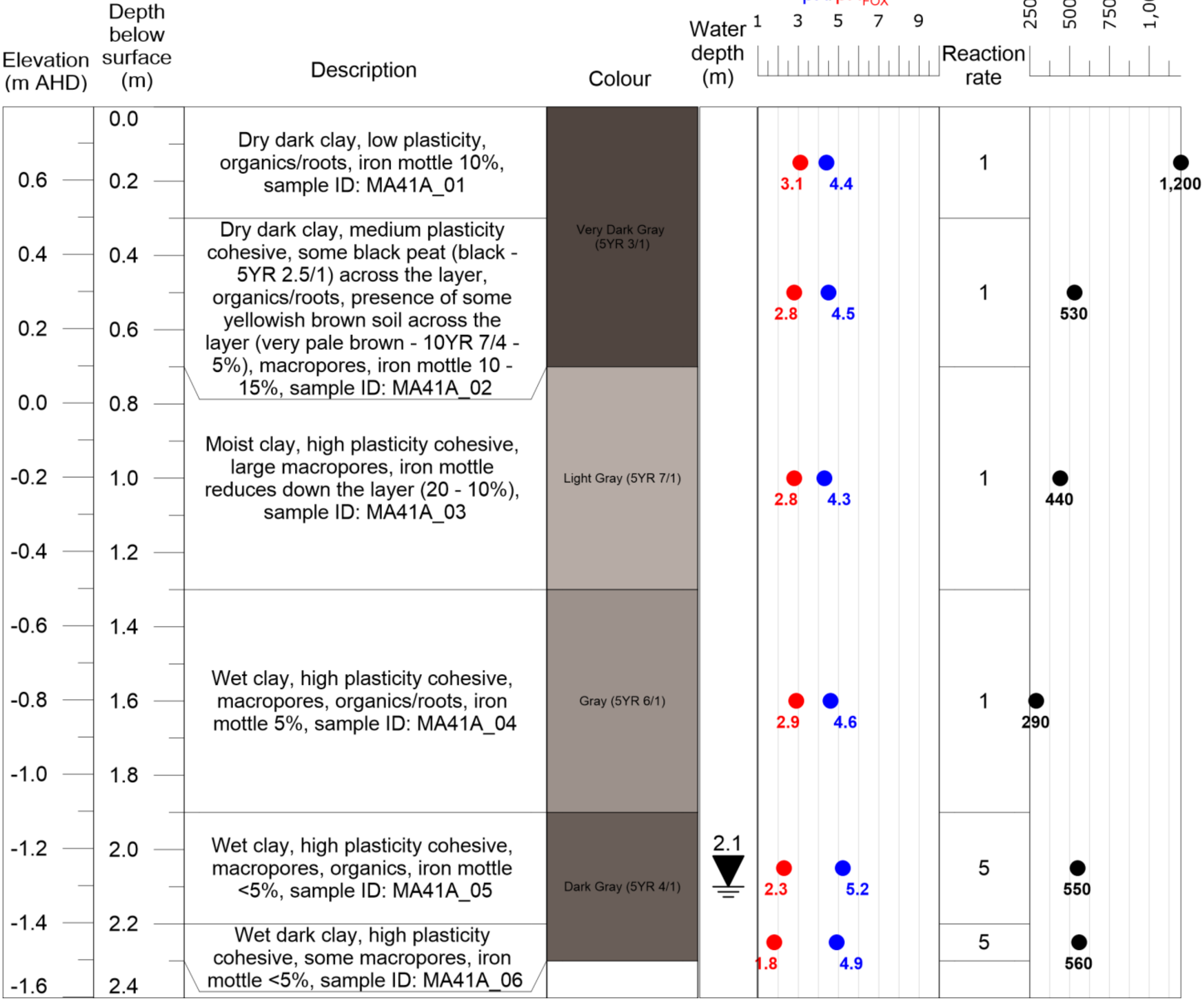
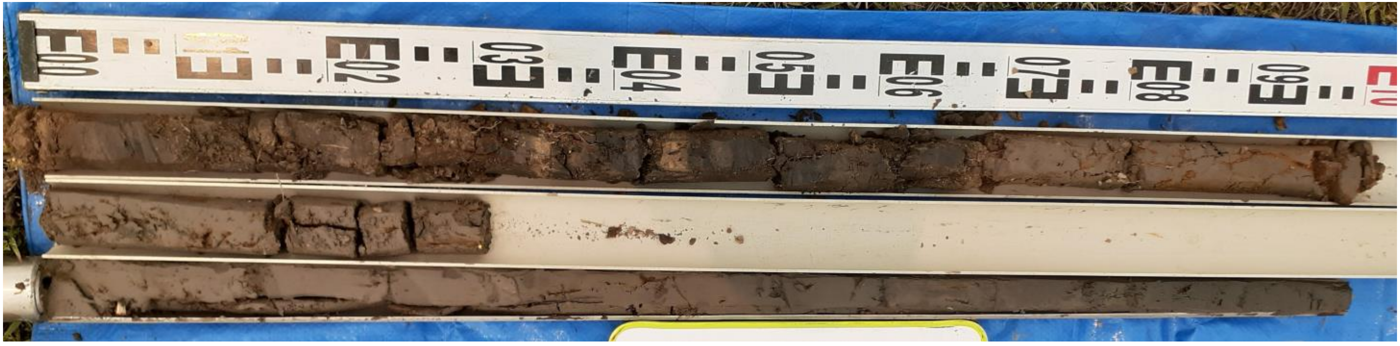
Water quality:

Surface water EC (µS/cm):	Not measured
Surface water pH:	Not measured
Groundwater EC (µS/cm):	Not measured
Groundwater pH:	Not measured



Description	Colour	pH_FOX	pH	Reaction rate	Soil EC (µS/cm)
Dry dark clay, low plasticity, organics/roots, iron mottle 10%, sample ID: MA41A_01	Very Dark Gray (5YR 3/1)	3.1	4.4	1	1,200
Dry dark clay, medium plasticity cohesive, some black peat (black - 5YR 2.5/1) across the layer, organics/roots, presence of some yellowish brown soil across the layer (very pale brown - 10YR 7/4 - 5%), macropores, iron mottle 10 - 15%, sample ID: MA41A_02		2.8	4.5	1	530
Moist clay, high plasticity cohesive, large macropores, iron mottle reduces down the layer (20 - 10%), sample ID: MA41A_03	Light Gray (5YR 7/1)	2.8	4.3	1	440
Wet clay, high plasticity cohesive, macropores, organics/roots, iron mottle 5%, sample ID: MA41A_04	Gray (5YR 6/1)	2.9	4.6	1	290
Wet clay, high plasticity cohesive, macropores, organics, iron mottle <5%, sample ID: MA41A_05	Dark Gray (5YR 4/1)	2.3	5.2	5	550
Wet dark clay, high plasticity cohesive, some macropores, iron mottle <5%, sample ID: MA41A_06		1.8	4.9	5	560



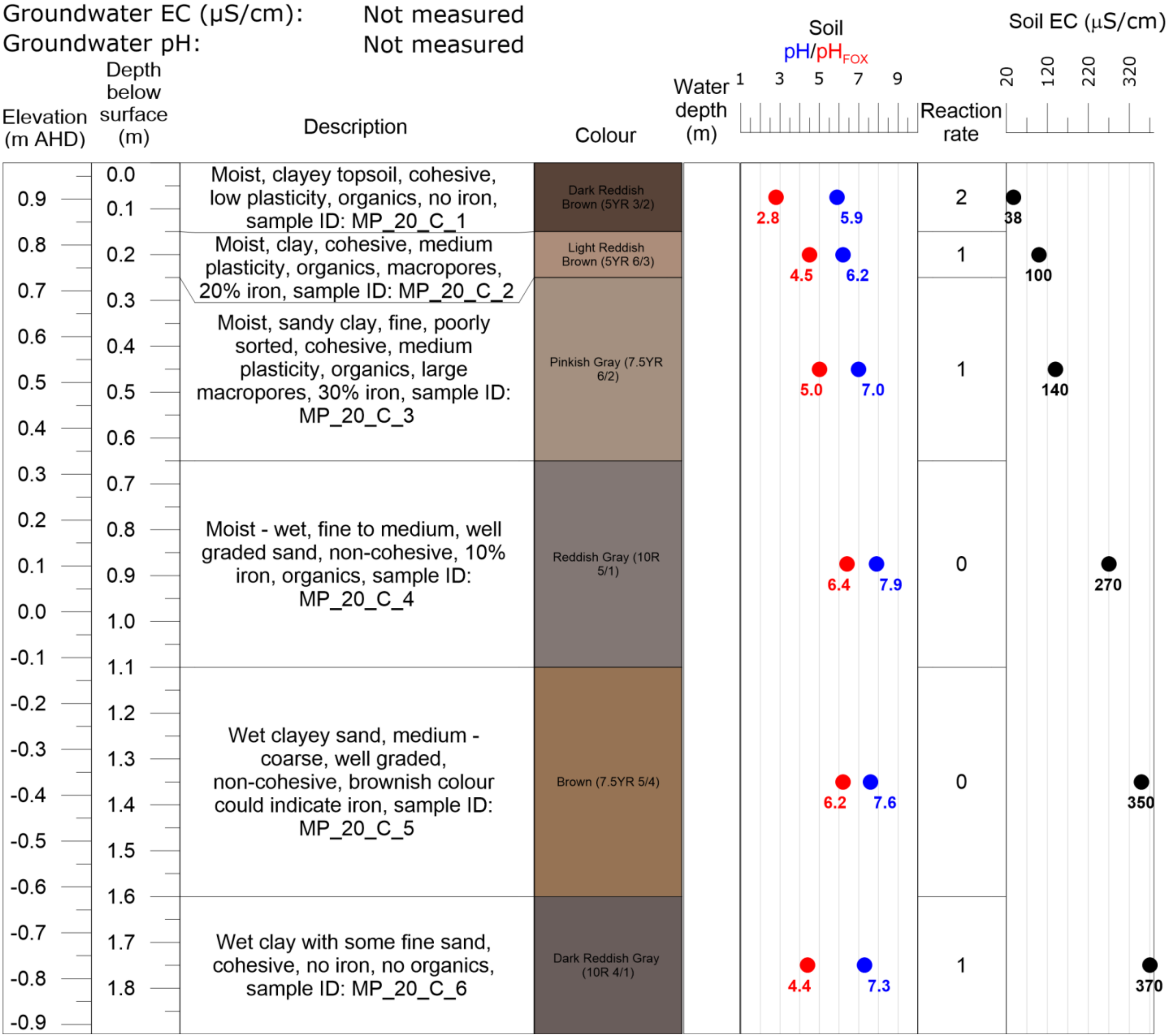
Soil profile details:

Project Number:	2018064	Profile ID:	MP_20_C
River/estuary:	Macleay	Sample date:	04/03/20
Easting:	494704.1	Sampled by:	AJH KW
Northing:	6573976.1		

Ground elevation (m AHD):	0.98
Hydraulic conductivity (m/d):	Not measured

Water quality:

Surface water EC (µS/cm):	Not measured
Surface water pH:	Not measured
Groundwater EC (µS/cm):	Not measured
Groundwater pH:	Not measured



Description	Colour	pH	pH FOX	Reaction rate	Soil EC (µS/cm)
Moist, clayey topsoil, cohesive, low plasticity, organics, no iron, sample ID: MP_20_C_1	Dark Reddish Brown (5YR 3/2)	5.9	2.8	2	38
Moist, clay, cohesive, medium plasticity, organics, macropores, 20% iron, sample ID: MP_20_C_2	Light Reddish Brown (5YR 6/3)	6.2	4.5	1	100
Moist, sandy clay, fine, poorly sorted, cohesive, medium plasticity, organics, large macropores, 30% iron, sample ID: MP_20_C_3	Pinkish Gray (7.5YR 6/2)	7.0	5.0	1	140
Moist - wet, fine to medium, well graded sand, non-cohesive, 10% iron, organics, sample ID: MP_20_C_4	Reddish Gray (10R 5/1)	7.9	6.4	0	270
Wet clayey sand, medium - coarse, well graded, non-cohesive, brownish colour could indicate iron, sample ID: MP_20_C_5	Brown (7.5YR 5/4)	7.6	6.2	0	350
Wet clay with some fine sand, cohesive, no iron, no organics, sample ID: MP_20_C_6	Dark Reddish Gray (10R 4/1)	7.3	4.4	1	370

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