Hastings 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 Hastings 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 waterways as a natural waterbody watercourse, an artificial waterbody, or a watercourse or connector watercourse. Details on the development of the updated spatial layer and the multi-criteria analysis can be found in Section 12 of the Methods report (Rayner et al., 2023). The updated waterways layer was used to calculate subcatchment drainage density during the subcatchment prioritisation assessment and will also be a valuable tool for informing management option implementation.

A2 Existing waterway data

Available information for the floodplain waterway network across the Hastings 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
Port Macquarie – Hastings Council	Shapefile	Yes	No	Local

A3 Waterway classification

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

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

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

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

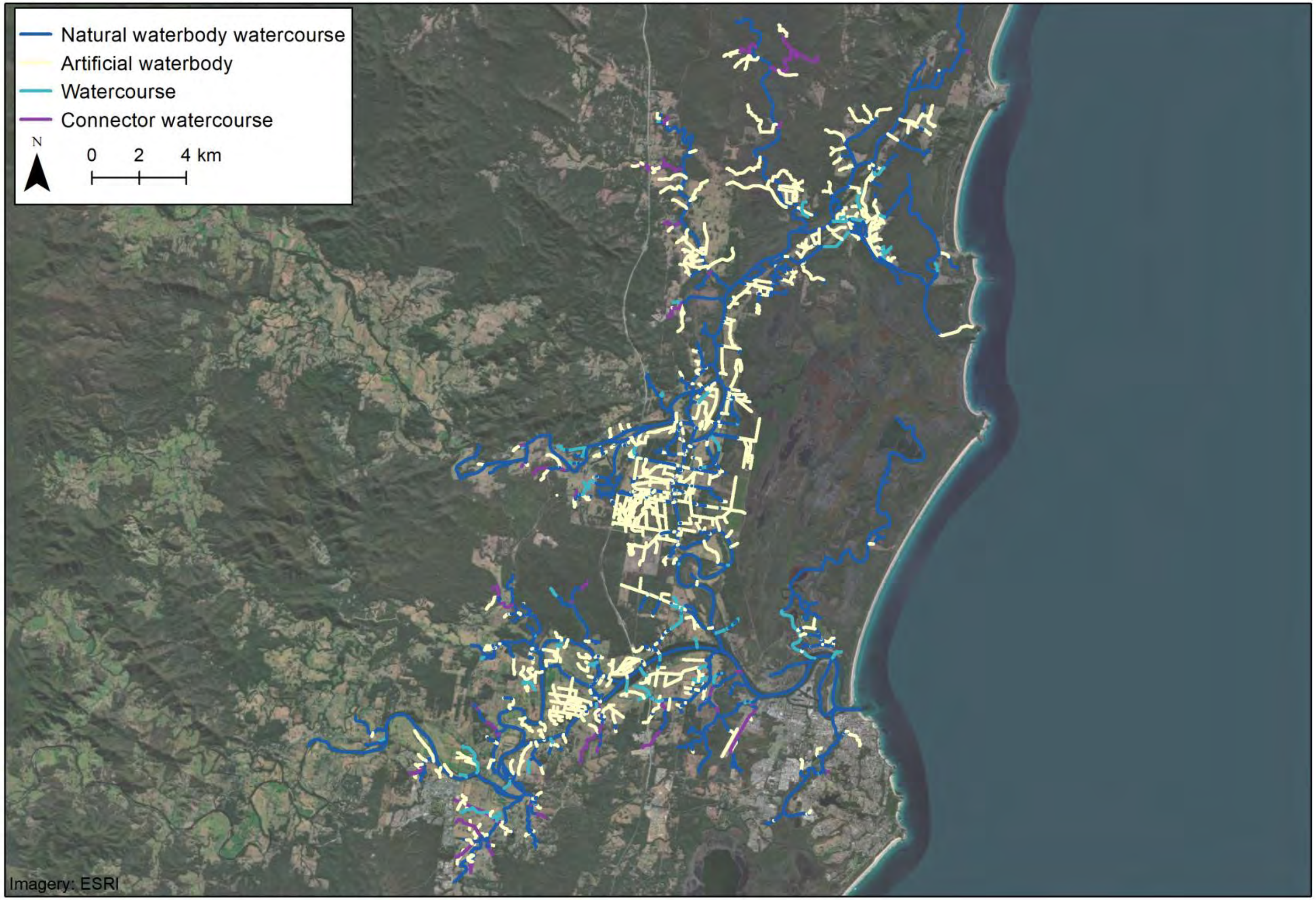

Figure A-1: Hastings River floodplain waterways

A4 Drainage density

The drainage density of each subcatchment is determined by the total waterway length across the subcatchment relative to the subcatchment area affected by acid sulfate soils (see Section 4.3.1 of the Methods report (Rayner et al., 2023)). When assessing the length of waterways that contribute to the drainage of an acid sulfate soil affected landscape, all waterways within the subcatchment boundaries were included in the priority assessment to provide a total waterway length for each subcatchment, as all waterways have the potential to impact acid sulfate soil oxidation and acid mobilisation. A summary of the floodplain drainage density analysis is provided in Table A-2 and the ranking of the drainage density factors for each subcatchment of the Hastings 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**
Connection Creek	61,610	39.92	1,543	10
Fernbank Creek	29,720	8.21	3,622	3
Kings Creek	14,650	2.81	5,221	1
Limeburners Creek	24,190	28.48	849	13
Lower Maria River East	46,700	22.47	2,078	8
Lower Maria River West	109,420	37.62	2,909	6
Partridge Creek	10,630	4.50	2,363	7
Pembrooke	20,540	5.99	3,429	4
Port Macquarie Airport	5,550	3.77	1,473	11
Rawdon Island	22,040	7.52	2,930	5
Redbank	2,630	1.85	1,421	12
Sarahs Creek/Sancrox	5,600	1.25	4,476	2
Upper Maria River	73,680	46.14	1,597	9

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

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

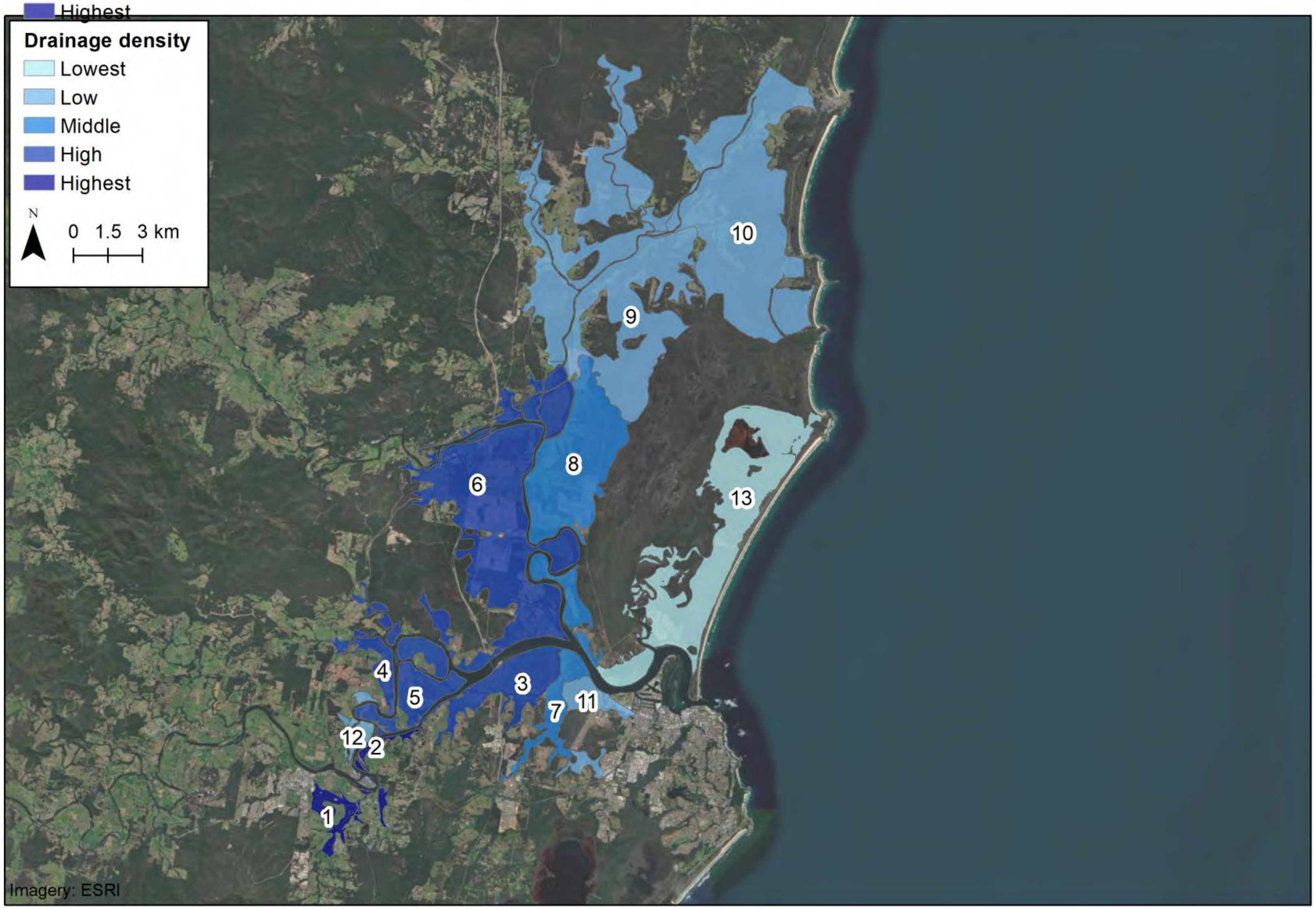

Figure A-2: Floodplain drainage density ranking

Appendix B Catchment hydrology

B1 Preamble

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

B2 Runoff coefficient

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

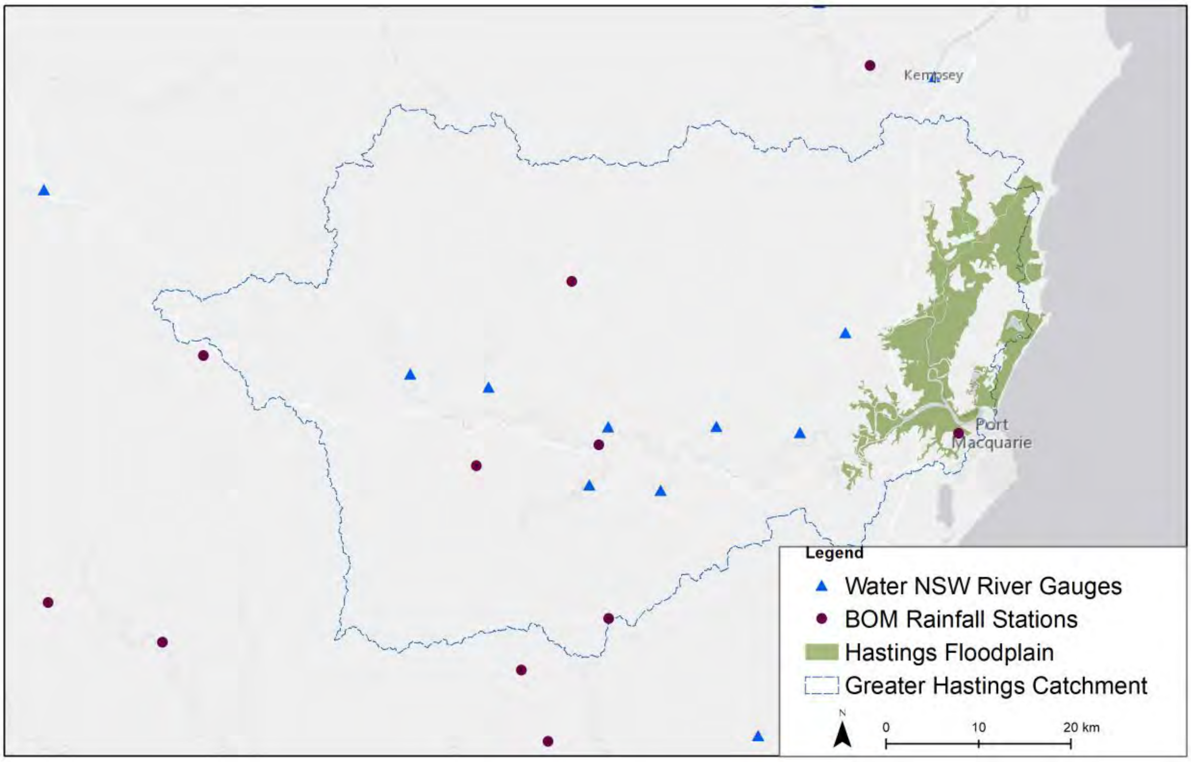

Figure B-1: Hastings River floodplain location of rainfall and runoff stations

Stream flow gauges upstream of the tidal confluence that are most representative of the lower catchment rainfall-runoff conditions were selected for the catchment hydrology analysis. WaterNSW gauging stations 207017, 207010 and 201014 were selected for the Hastings River floodplain assessment. The upstream contributing area for these sites 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 sites, upstream catchment area of the gauging sites, and the BOM rainfall contributions (shown in parenthesis) used in the analysis are summarised in Figure B-2.

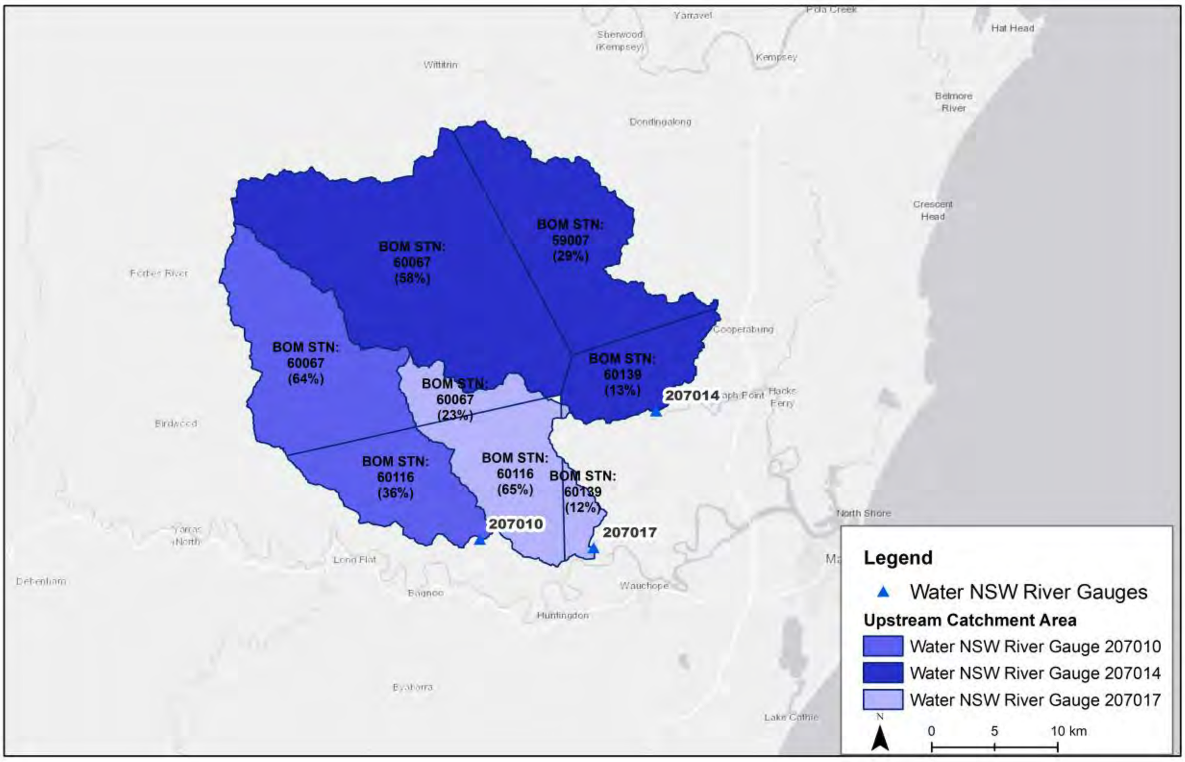

Figure B-2: Upstream catchment of selected flow sites

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

The runoff co-efficient was selected by comparing the annual time-series of streamflow data for the predicted runoff volume calculated for the selected gauging stations. Figure B-3 shows an example time-series of predicted and observed runoff for 2012. This analysis yielded an estimated runoff coefficient of 0.40 and 0.45, which was applied to Hastings floodplain subcatchments for the acid prioritisation assessment.

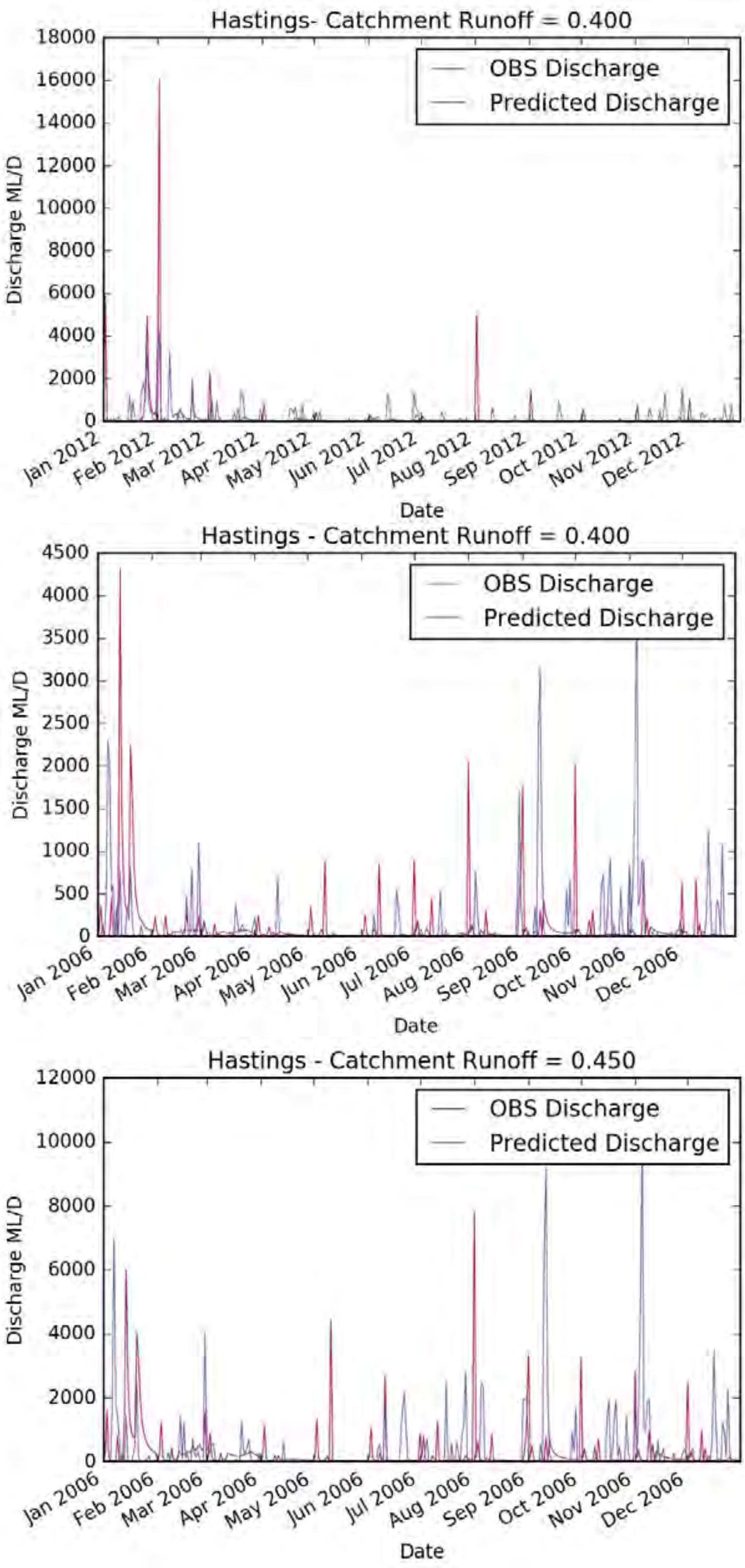

Figure B-3: Predicted and observed runoff for the catchment area upstream of river gauging station 207017 (top), station 207010 (middle) and station 207014 (bottom)

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.

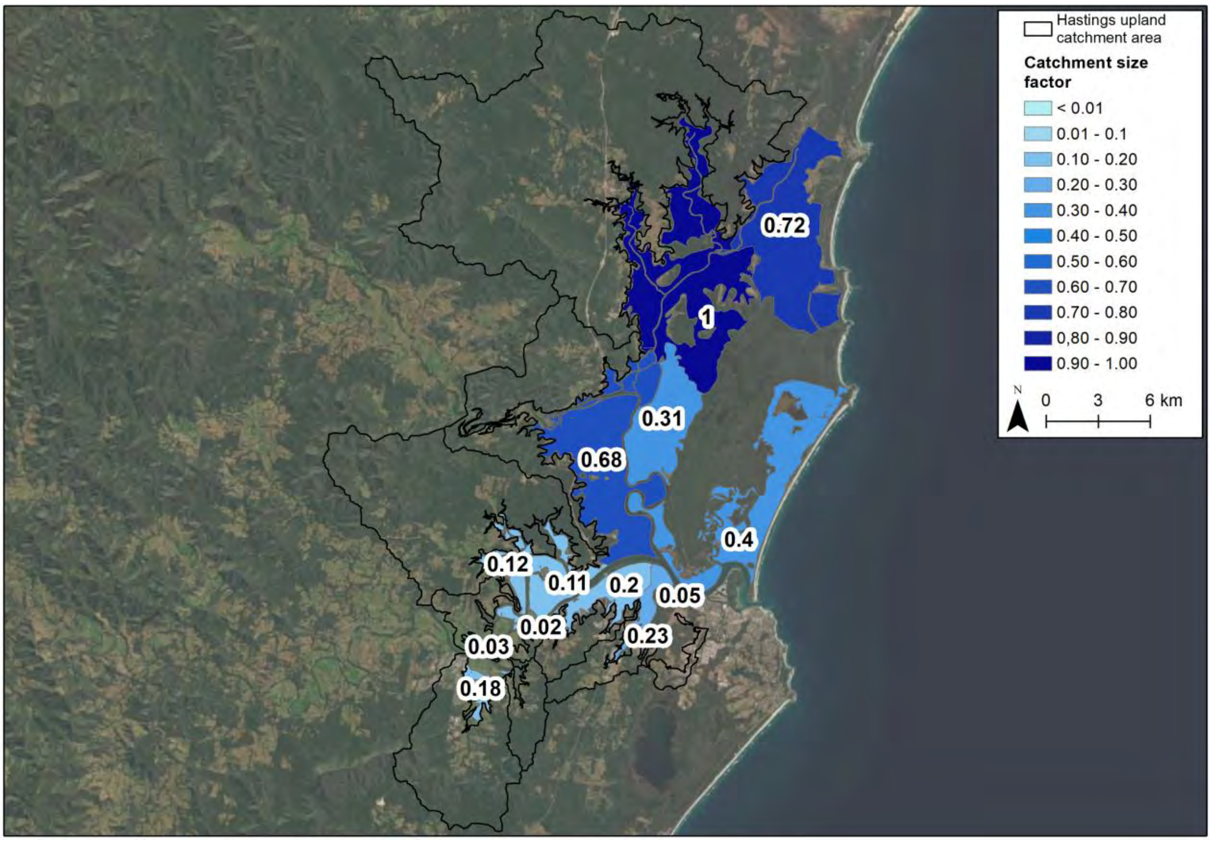

Figure B-4: Catchment size factor for each subcatchment in the Hastings River estuary

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

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 Hastings 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
Redbank	0.4	0	1,848,150	0.026	0.010
Port Macquarie Airport	0.4	0	3,765,600	0.053	0.021
Kings Creek	0.4	9,990,050	12,795,850	0.179	0.072
Pembrooke	0.45	2,247,500	8,238,550	0.115	0.052
Rawdon Island	0.4	0	7,522,300	0.105	0.042
Fernbank Creek	0.4	6,004,600	14,211,300	0.199	0.079
Partridge Creek	0.4	11,905,700	16,403,150	0.229	0.092
Lower Maria River West	0.45	10,859,190	48,475,250	0.677	0.305
Connection Creek	0.45	11,282,200	51,200,650	0.716	0.322
Upper Maria River	0.45	25,417,600	71,557,550	1.000	0.450
Sarahs Creek/Sancrox	0.4	0	1,251,600	0.017	0.007
Limeburners Creek	0.45	0	28,478,800	0.398	0.179
Lower Maria River East	0.45	0	22,471,350	0.314	0.141

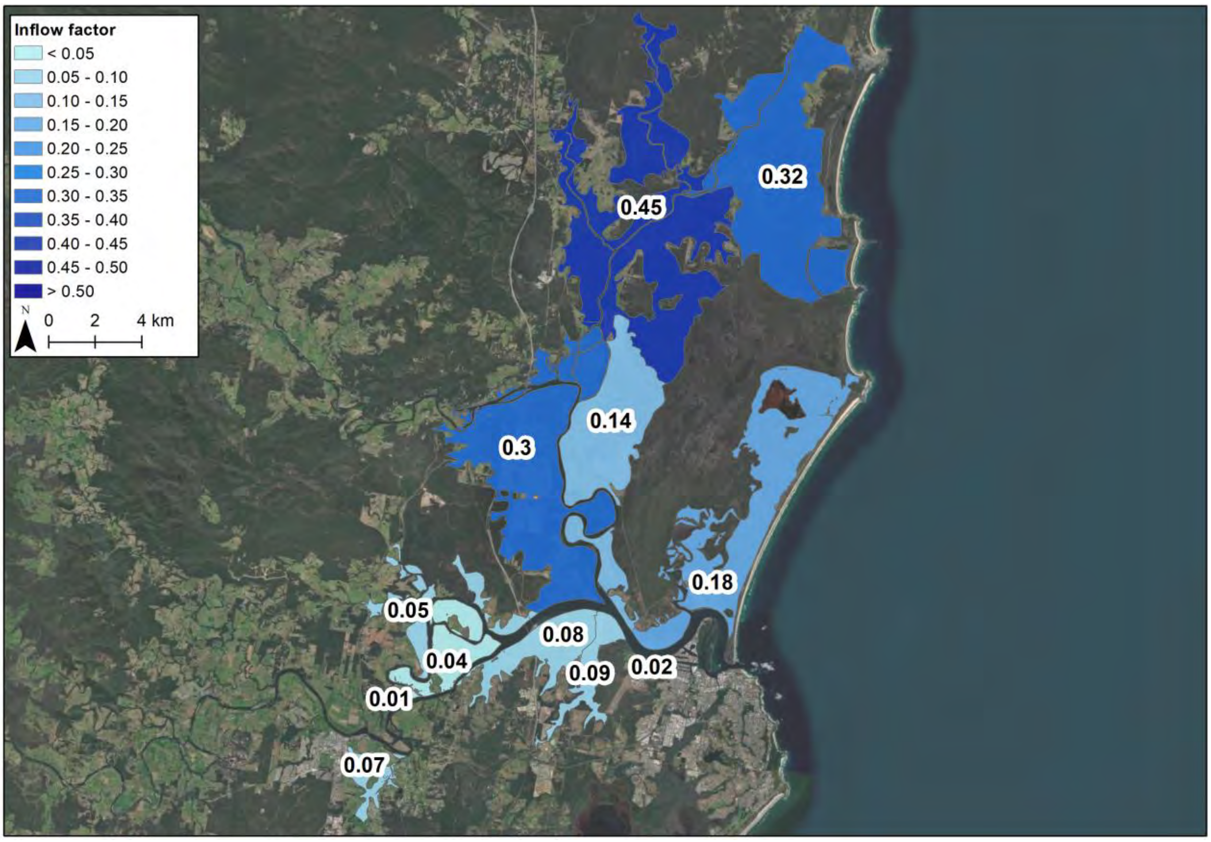

Figure B-5: Subcatchment inflow factors

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 Hastings River floodplain. A detailed discussion of the principles relating to hydraulic conductivity and data collection can be found in Appendix A of the Methods report (Rayner et al., 2023). Details on the techniques and methods used to collect the field data presented in this section can be found in Appendix B of the Methods report (Rayner et al., 2023).

C2 Existing saturated hydraulic conductivity data

A data gaps analysis was completed to identify existing hydraulic conductivity data within the Hastings 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:

- ERM Mitchell McCotter Pty Ltd (1997) measured the hydraulic conductivity at three (3) locations in the Partridge Creek subcatchment. Hydraulic conductivities were calculated using laboratory techniques from soil samples and it was noted that these samples were unlikely to represent the actual hydraulic conductivity of soil at Partridge Creek. For this reason this data has been excluded from the analysis.

- Aaso (2003) completed two pit bailing tests to determine the hydraulic conductivity within the Partridge Creek subcatchment. Hydraulic conductivity rates were estimated based on similar measurements.

- Johnston et al. (2003) calculated hydraulic conductivity of sulfuric horizons at selected sites within the Partridge Creek subcatchment using the pit bailing method and the auger hole slug test method. Discrete hydraulic conductivity values were determined for the pit bail method using three (3) different techniques (Boast and Langebartel, 1984; Bouwer and Rice, 1983; Lomen et al., 1987).

- 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 Hastings River floodplain, data was collected in the Lower Maria River East and Lower Maria River West 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 lower Maria River East, Lower Maria River West and Partridge Creek subcatchments. Close inspection indicated that the majority of this data is the same as was presented by Hirst et al. (2009). 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.

Table C-1 Summary of existing hydraulic conductivity data in the Hastings 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	4.2	4.0		Moderate	Hirst et al. (2009)	Pit bailing
2	4.8	6.2		Moderate	Hirst et al. (2009)	Pit bailing
3	6.1	5.3		Moderate	Hirst et al. (2009)	Pit bailing
4	55.1	77.9		High	Hirst et al. (2009)	Pit bailing
5	38.0	47.7		High	Hirst et al. (2009)	Pit bailing
6	55.0	52.0	58.0	High	Johnston et al. (2003)	Pit bailing
7	272.0	351.0	175.0	Extremely high	Johnston et al. (2003)	Pit bailing
8	210.0	263.0	165.0	Extremely high	Johnston et al. (2003)	Pit bailing
9	92.0	119.0	93.0	High - Extremely high	Johnston et al. (2003)	Pit bailing
10	91.0	76.0	71.0	High	Johnston et al. (2003)	Pit bailing
11	14.0	12.9	11.7	Moderate	Johnston et al. (2003)	Pit bailing
12	44.0	44.0	31.0	High	Johnston et al. (2003)	Pit bailing
13			20	High	Aaso (2003)	Pit bailing
14			80	High	Aaso (2003)	Pit bailing
15			84	High	Johnston et al. (2003)	Auger hole
16			19.3	High	Johnston et al. (2003)	Auger hole
17			85	High	Johnston et al. (2003)	Auger hole
18			14.1	Moderate	Johnston et al. (2003)	Auger hole
19			3.9	Moderate	Johnston et al. (2003)	Auger hole

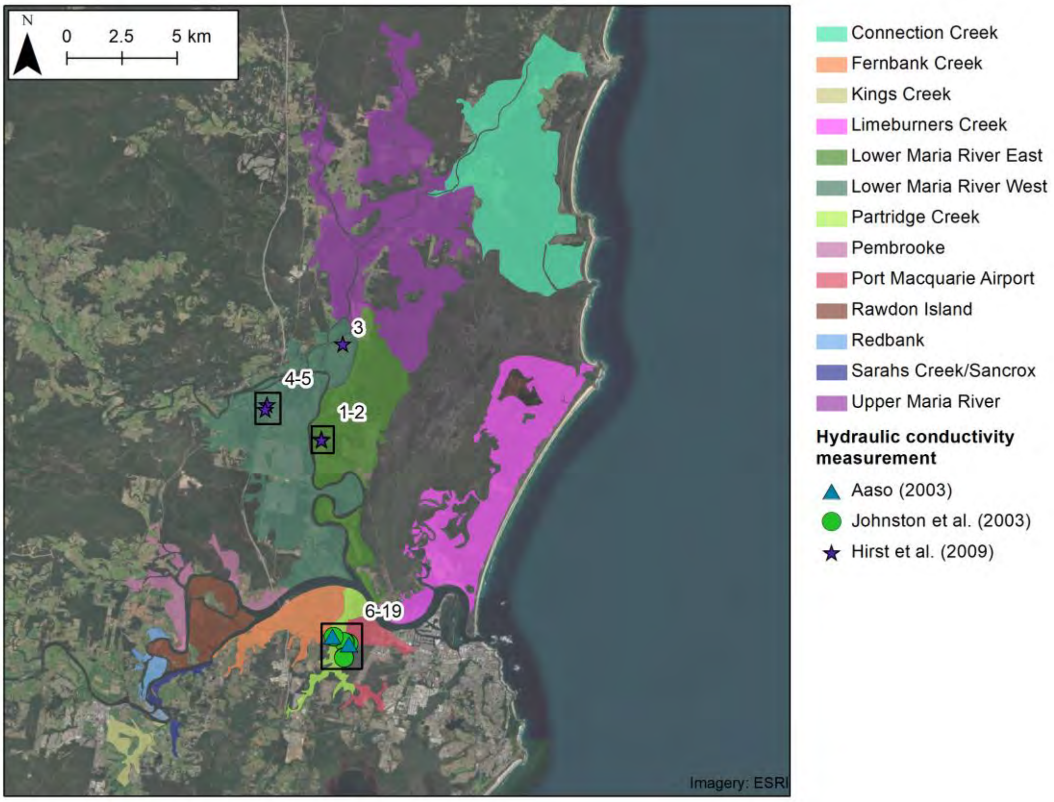

Figure C-1: Existing saturated hydraulic conductivity data available on the Hastings River floodplain

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 method was 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 (2) methodologies. 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., 2023). The hydraulic conductivity measurements obtained across the Hastings 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 to 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 Hastings 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?*
HA_01_P	478201.8	6524665.8	24.5	High	Pit bailing	Yes
HA_01_P	478201.8	6524665.8	0.5	Low	Auger hole	Below MLWS
HA_02_A	491864.9	6544698.9	0.9	Low	Auger hole	Below MLWS
HA_03_A	487606.6	6547304.4	10.3	Moderate	Auger hole	Below MLWS
HA_04_PA	494274.4	6548234.4	0.4	Low	Auger hole	Below MLWS
HA_06_P	489483.2	6545293.3	4.7	Moderate	Auger hole	Below MLWS
HA_07_P	484605.0	6540164.9	2.7	Moderate	Auger hole	Below MLWS
HA_10_P	486049.9	6536298.7	>100	Extremely high	Auger hole	Yes
HA_13_P	489990.4	6526655.9	0.2	Low	Auger hole	Yes
HA_14_P	482496.1	6523954.3	0.1	Low	Auger hole	Below MLWS
HA_19_P	478183.4	6518799.5	2.1	Moderate	Auger hole	Yes
HA_20_P	475869.0	6518358.0	4.6	Moderate	Auger hole	Below MLWS
HA_21_P	480493.9	6524799.8	3.5	Moderate	Auger hole	Yes
HA_24_A	479170.4	6523079.4	0.1	Low	Auger hole	Yes
HA_24_P	485547.9	6524685.0	4.0	Moderate	Auger hole	Yes
HA_25_P	484935.4	6523852.7	3.7	Moderate	Auger hole	Yes
HA_29_AA	476496.5	6522196.8	0.4	Low	Auger hole	Yes
HA_29_PA	483540.1	6532060.1	0.4	Low	Auger hole	Below MLWS
HA_33_P	475859.0	6517570.0	10.5	Moderate	Auger hole	Below MLWS
HA_34_P	476518.5	6518424.0	0.5	Low	Auger hole	Yes
HA_35_A	480540.3	6525580.3	0.1	Low	Auger hole	Below MLWS
HA_35_P	479088.2	6525549.9	0.3	Low	Auger hole	Yes
HA_37_X	481711.5	6525300.6	2.9	Moderate	Auger hole	Yes
HA_38_C	487710.4	6541316.6	10.9	Moderate	Auger hole	Below MLWS
HA_40_P	485362.6	6525339.3	2.8	Moderate	Auger hole	Yes
HA_45_P	483853.7	6523322.0	0.3	Low	Auger hole	Yes
HA_46_P	483783.0	6526230.7	0.4	Low	Auger hole	Below MLWS
HP_11_C	487046.4	6534686.1	3.0	Moderate	Auger hole	Yes

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

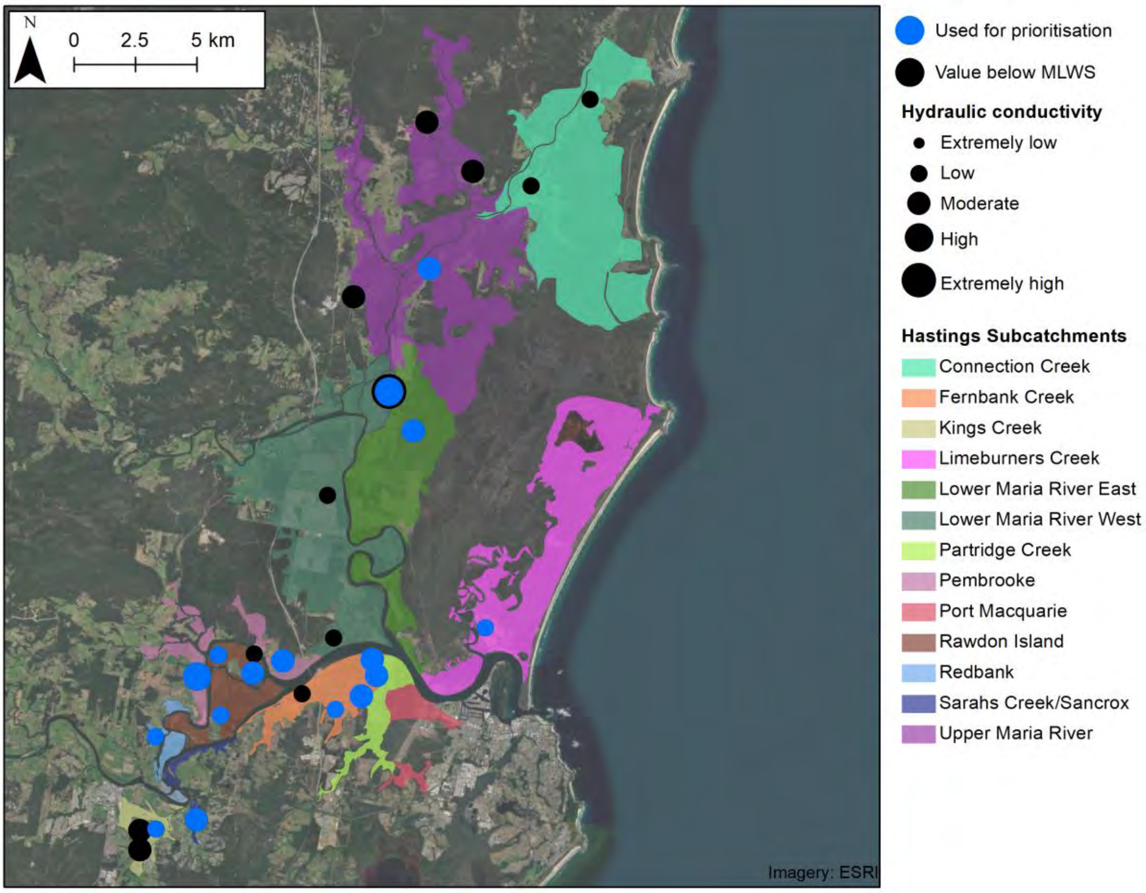

Figure C-2: Location of saturated hydraulic conductivity data collected by WRL and data used during the subcatchment prioritisation

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 Section 4 of the Methods report (Rayner et al., 2023)). The risk rating applies on a scale of one (1) to five (5) corresponding to the risk classifications with extremely low equating to a risk rating of one (1) and extremely high equating to a risk rating or five (5). This results in subcatchments with larger hydraulic conductivities having an increased risk as they are able to transport larger volumes of acidic groundwater to the estuary.

Note that the spatial coverage of hydraulic conductivity data across certain subcatchments of the Hastings 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:

- Connection Creek has been assumed to have the same hydraulic conductivity as Upper Maria River; and
- Port Macquarie Airport has been assumed to have the same hydraulic conductivity as Partridge 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 Hastings River floodplain

Subcatchment	Hydraulic conductivity classification	Hydraulic conductivity risk rating	Number of data points per area*
Connection Creek*	Moderate	3	0
Fernbank Creek	Moderate	3	4
Kings Creek	Low	2	1
Limeburners Creek	Low	2	1
Lower Maria River East	Moderate	3	3
Lower Maria River West	High	4	4
Partridge Creek	High	4	14
Pembrooke	High	4	2
Port Macquarie Airport*	High	4	0
Rawdon Island	Low	2	3
Redbank	Low	2	1
Sarahs Creek/Sancrox	Moderate	3	1
Upper Maria River	Moderate	3	1

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

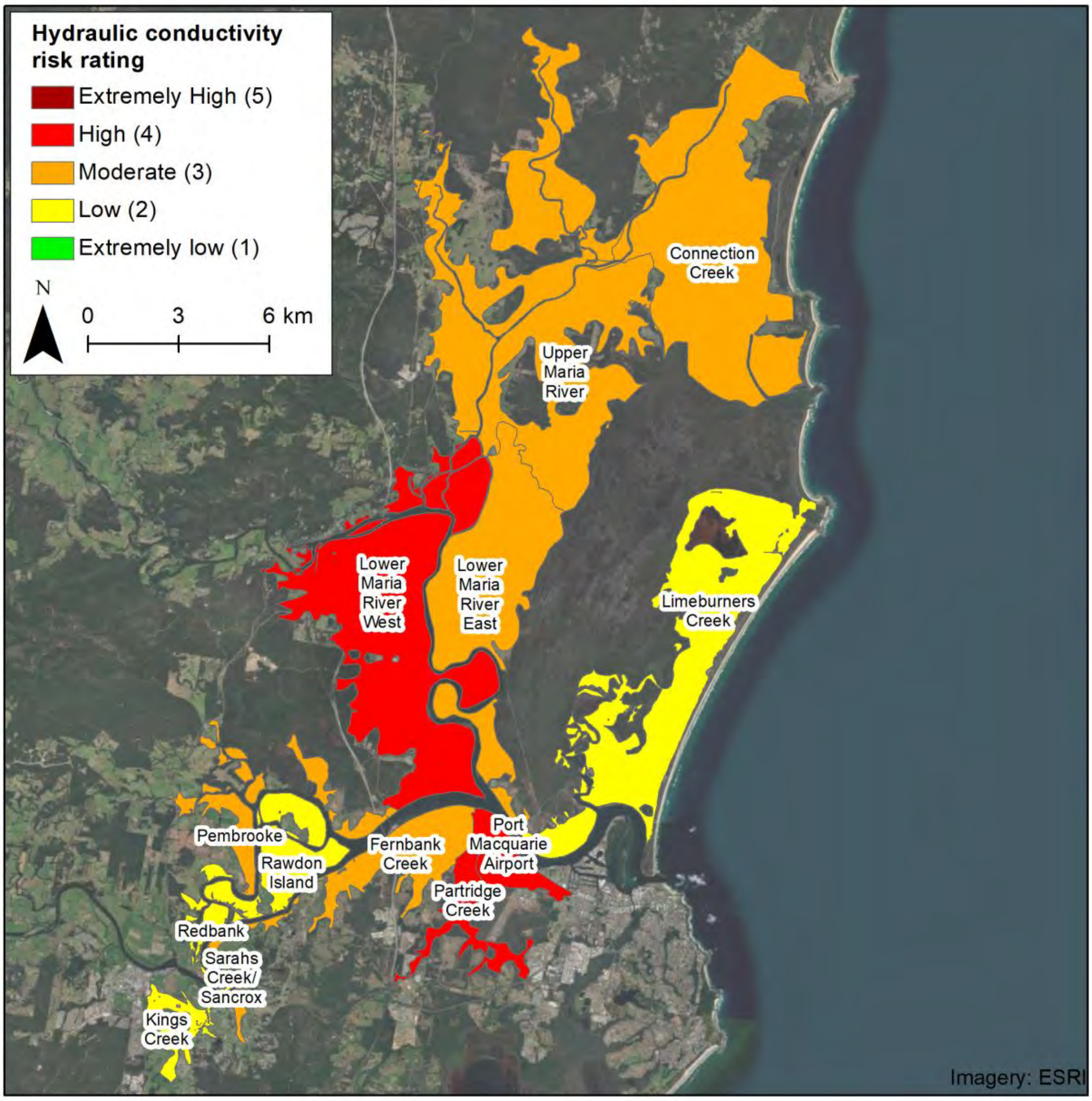

Figure C-3: Risk ratings for saturated hydraulic conductivity for each subcatchment in the Hastings River floodplain

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 Hastings 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 Hastings River floodplain that was available prior to the commencement of this study was sourced from:

- eSPADE Database (DPIE, 2020);
- Johnston et al. (2014); and
- Claff et al. (2010).

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 Hastings River floodplain 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 Hastings 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.

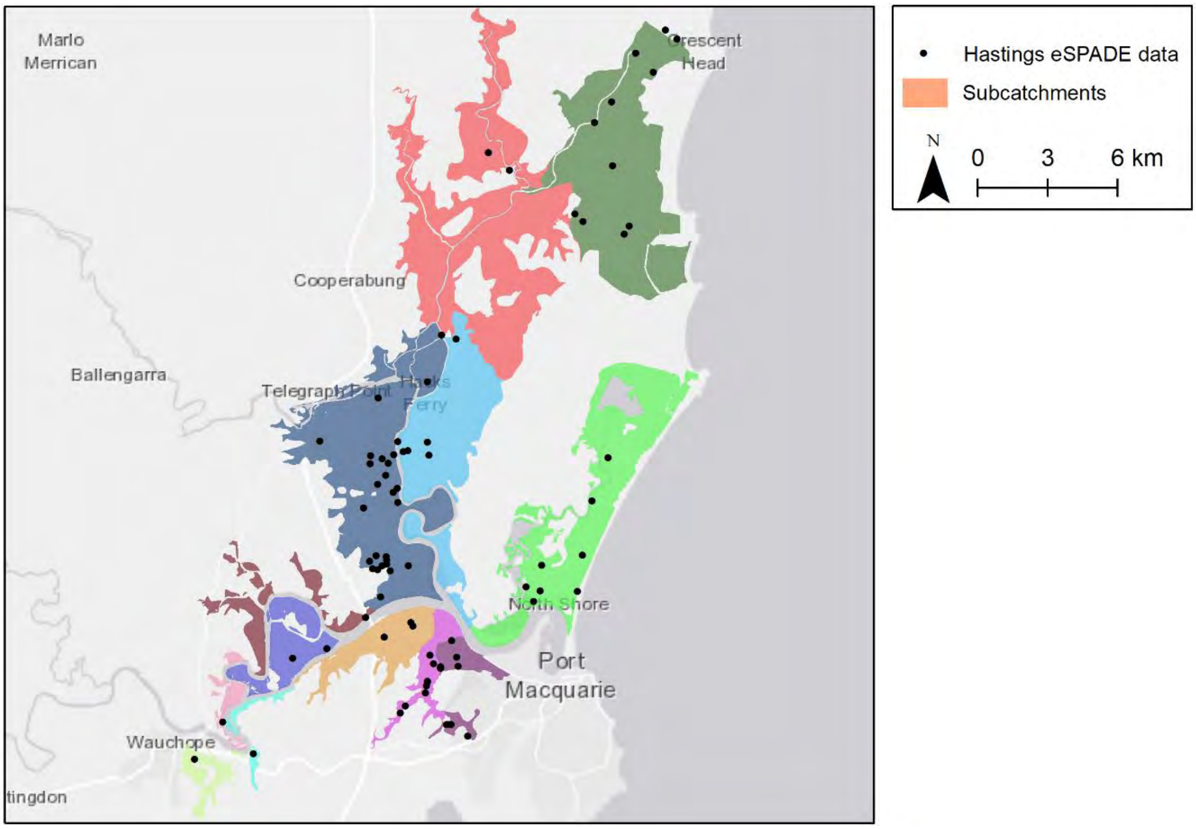

Figure D-1: Location of applicable eSPADE soil profiles in the study region

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**
15728	Connection Creek	495224	6548588	0.4	2.2	6
15729	Connection Creek	493444	6547308	1.2	2.3	4.5
15730	Connection Creek	491864	6542509	1.3	1.5	5.5
15746	Connection Creek	496244	6550008	0.7	2	5
4851	Connection Creek	495754	6550388	0.1	1.1	3.5
4907	Connection Creek	492204	6542179	1.4	0.75	5.5
5015	Connection Creek	492704	6546428	1.4	0.7	5
5016	Connection Creek	494484	6549408	0.8	0.9	5.5
5074	Connection Creek	493484	6544578	0.5	2.3	4.5
5090	Connection Creek	494194	6541978	0.8	1.8	5
5091	Connection Creek	493974	6541648	0.4	0.7	4.5
15737	Fernbank Creek	484929	6524814	0.8	2	4.5
15738	Fernbank Creek	483684	6524339	1.3	2	5
22548	Fernbank Creek	484824	6524969	1.0	0.9	5
4846	Kings Creek	475554	6519089	2.1	2.4	5.5
15741	Limeburners Creek	490374	6526328	0.6	2	5.5

eSPADE profile ID	Subcatchment	Easting	Northing	Surface elevation* (m AHD)	Total profile depth (m)	Minimum pH**
15743	Limeburners Creek	490434	6527419	1.1	1.5	4.5
4890	Limeburners Creek	490104	6525868	1.2	1.5	5
4893	Limeburners Creek	489764	6526488	1.4	1.3	5
4908	Limeburners Creek	492604	6530188	1.5	1	5.5
4923	Limeburners Creek	492184	6527849	1.3	2.4	5.5
5093	Limeburners Creek	493294	6532038	1.4	1.28	6.5
5115	Limeburners Creek	491974	6526288	2.0	1.8	6
15744	Lower Maria River East	484264	6532729	0.9	1.8	4.5
15745	Lower Maria River East	485544	6532711	0.8	1.8	4
4894	Lower Maria River East	484504	6532288	0.6	1.1	4.5
4895	Lower Maria River East	484704	6532339	1.5	0.8	5.5
4897	Lower Maria River East	485604	6532139	0.6	2	4.5
5012	Lower Maria River East	486784	6537128	1.2	0.9	4.5
16439	Lower Maria River West	482804	6529889	1.0	1.5	5
15720	Lower Maria River West	484084	6530549	1.8	1.5	4
15721	Lower Maria River West	483404	6530889	0.9	1.5	4
15722	Lower Maria River West	483854	6531808	0.9	2	4.5
15723	Lower Maria River West	483744	6531289	0.8	1.5	4.5
15724	Lower Maria River West	483084	6531789	0.8	2	4
15725	Lower Maria River West	483604	6531989	1.0	2.5	4
15726	Lower Maria River West	483104	6532128	1.3	2.5	4
15750	Lower Maria River West	483424	6534608	1.5	2	4
15751	Lower Maria River West	480929	6532739	1.4	2.1	4.5
15752	Lower Maria River West	483544	6526069	1.5	2.2	4.5
4903	Lower Maria River West	485554	6535289	1.6	1.4	4.5
4910	Lower Maria River West	484724	6527389	2.6	2.5	6
4911	Lower Maria River West	484264	6530109	1.2	1.5	5

eSPADE profile ID	Subcatchment	Easting	Northing	Surface elevation* (m AHD)	Total profile depth (m)	Minimum pH**
4912	Lower Maria River West	484244	6530729	0.0	1.5	4.5
4913	Lower Maria River West	484104	6532169	2.3	2	6
4966	Lower Maria River West	483404	6527229	2.8	3	5.5
4967	Lower Maria River West	483184	6527269	2.3	2	6
4968	Lower Maria River West	483954	6527189	2.8	3.8	5
4969	Lower Maria River West	483784	6527788	2.5	3.5	8.5
4970	Lower Maria River West	483804	6527639	2.3	3	8
4971	Lower Maria River West	483804	6527469	3.5	3	9.5
4972	Lower Maria River West	483604	6527389	3.1	2.5	5
4974	Lower Maria River West	483054	6527588	1.9	2.85	5
4975	Lower Maria River West	483354	6527839	2.0	4.2	5.5
15733	Partridge Creek	485454	6521949	1.7	2	4
15734	Partridge Creek	484373	6521079	2.0	2	4.5
66706	Partridge Creek	485647	6523567	1.0	0.78	5
21066	Partridge Creek	486099	6522989	0.8	1.6	4.5
21067	Partridge Creek	486099	6523014	0.9	1.8	5
21068	Partridge Creek	486099	6523064	0.9	1.13	4.5
21070	Partridge Creek	485804	6523189	1.7	1.7	5
21071	Partridge Creek	485554	6522439	1.5	1.37	5
21072	Partridge Creek	485554	6522413	1.2	1.7	5
21076	Partridge Creek	484604	6521389	1.6	1.8	5
4926	Partridge Creek	485504	6522239	1.5	1.4	4.5
4928	Pembrooke	482884	6525169	1.9	1.7	4.5
15735	Port Macquarie Airport	487279	6520089	2.0	2	6.5
15739	Port Macquarie Airport	486804	6523469	1.0	2	4
21081	Port Macquarie Airport	486554	6520589	1.8	1.7	6
21082	Port Macquarie Airport	486504	6520589	1.7	1.8	6
21083	Port Macquarie Airport	486454	6520589	1.8	1.8	6
21084	Port Macquarie Airport	486354	6520589	1.9	1.8	6
4867	Port Macquarie Airport	486854	6523089	0.9	0.7	4.5
4927	Port Macquarie Airport	486584	6524189	0.9	1	6
4835	Rawdon Island	481224	6523829	1.1	1.7	5.5

eSPADE profile ID	Subcatchment	Easting	Northing	Surface elevation* (m AHD)	Total profile depth (m)	Minimum pH**
4840	Rawdon Island	479754	6523439	1.1	0.9	3.5
4836	Redbank	476754	6520689	0.5	5	6
15736	Sarahs Creek/Sancrox	478084	6519339	0.8	1.8	4.5
15748	Upper Maria River	489054	6544388	1.3	0.65	5.5
15749	Upper Maria River	488154	6545138	0.6	2	4.5
5011	Upper Maria River	486154	6537308	0.5	0.7	4.5

D2.2 Other literature

Published and grey literature was investigated for other soil profiles within the Hastings River floodplain, which included data from journal articles (Claff et al. (2010) and Johnston et al. (2014)). 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 Hastings River 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.

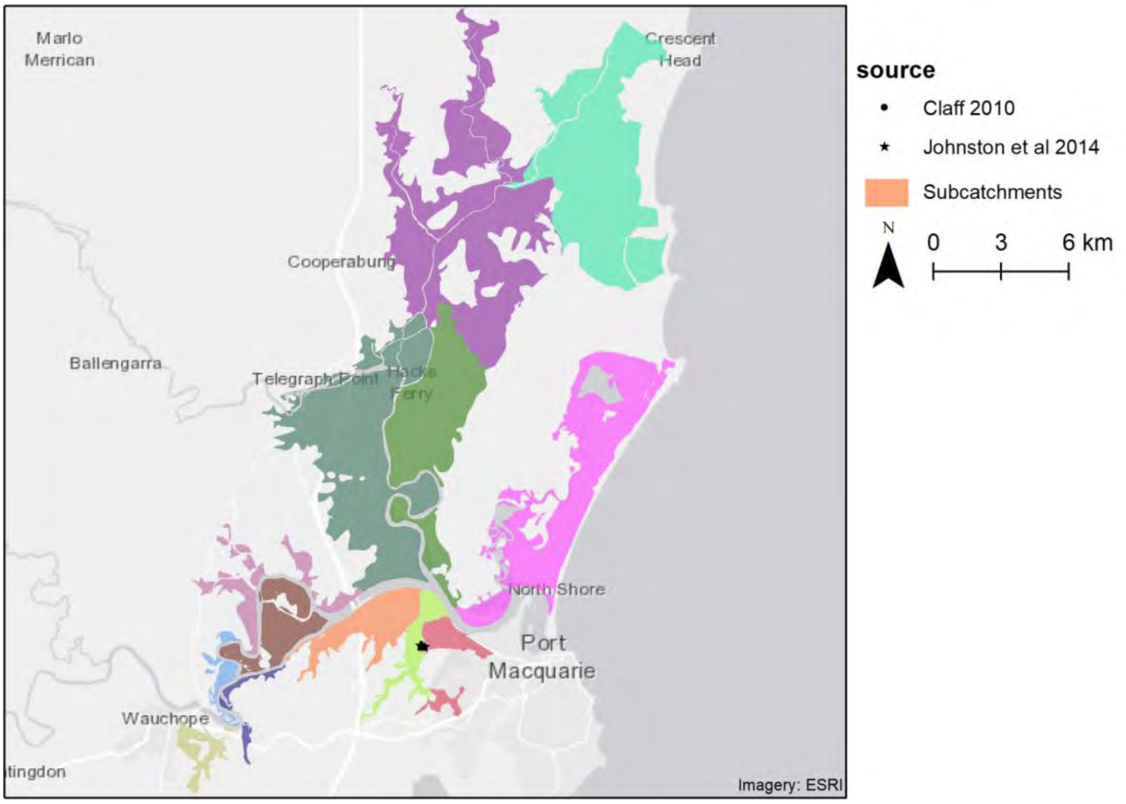

Figure D-2: Location of applicable soil profiles from literature in the study region

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

Profile	Subcatchment	Easting	Northing	Surface elevation (m AHD)	Total profile depth (m)	Minimum pH
Claff_2010_1	Partridge Creek	485876	6523040	1.5	2.5	3.6
Johnston_2014_PC6	Partridge Creek	485819	6523074	1	0.89	5.2
Johnston_2014_PC7	Partridge Creek	485858	6523063	0.9	0.91	5
Johnston_2014_PC8	Partridge Creek	485895	6523054	0.85	0.9	5.4
Johnston_2014_PC9	Partridge Creek	485942	6523038	0.8	0.9	4.8
Johnston_2014_PC10	Partridge Creek	486013	6523020	0.75	0.89	4.8

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., 2023). The location of an additional 35 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-2. Detailed data logs of each of soil profile is provided in Appendix K .

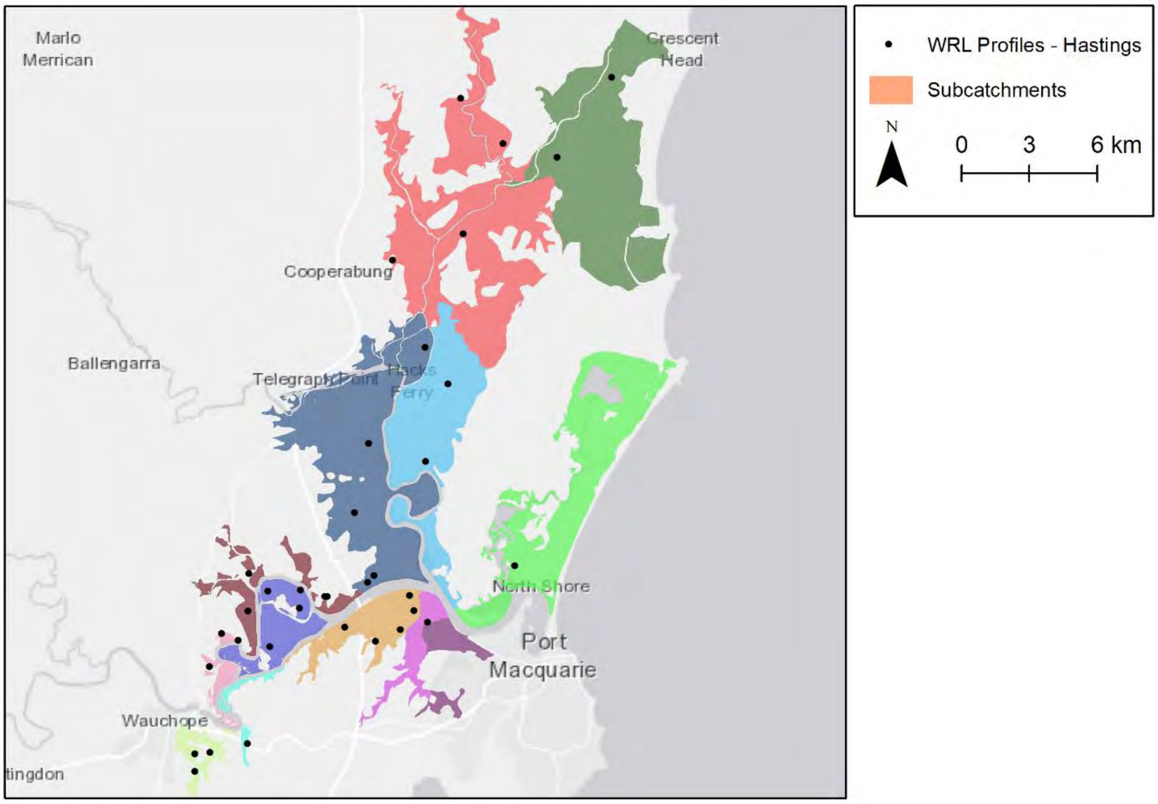

Figure D-3: Location of soil profiles from WRL field investigations

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
HA_01_P	Pembrooke	478202	6524666	0.67	2	4.3
HA_02_A	Connection Creek	491865	6544699	0.49	1.8	5.4
HA_03_A	Upper Maria River	487607	6547304	0.42	2.3	4.7
HA_04_PA	Connection Creek	494274	6548234	0.43	2	5.7
HA_06_P	Upper Maria River	489483	6545293	0.40	2.3	5.1
HA_07_P	Upper Maria River	484605	6540165	0.34	1.45	4.6
HA_10_P	Lower Maria River West	486050	6536299	0.48	1.3	4.7
HA_13_P	Limeburners Creek	489990	6526656	0.75	1.65	4.7
HA_14_P	Fernbank Creek	482496	6523954	0.69	2.1	4.7
HA_16_A	Lower Maria River West	483502	6525932	1.21	1.9	4.4
HA_17_A	Partridge Creek	486145	6524157	1.25	1.5	4.5
HA_17_P	Redbank	477053	6523672	1.87	3.35	5.8
HA_19_P	Sarahs Creek/Sancrox	478183	6518800	0.95	1.7	4.2
HA_20_P	Kings Creek	475869	6518358	0.72	2.1	4.7
HA_21_P	Rawdon Island	480494	6524800	0.89	1.7	3.7
HA_24_A	Rawdon Island	479170	6523079	0.86	2.4	4.3
HA_24_P	Fernbank Creek	485548	6524685	0.71	2	4.7
HA_25_P	Fernbank Creek	484935	6523853	0.47	1.6	5.2
HA_29_AA	Redbank	476496	6522197	1.15	1.9	4.8
HA_29_PA	Lower Maria River West	483540	6532060	0.87	2.1	4
HA_30_A	Redbank	477782	6523377	0.24	1.7	4.7
HA_31_P	Lower Maria River West	482912	6529005	0.35	1.95	4.4
HA_33_P	Kings Creek	475859	6517570	1.12	3	4.4
HA_34_P	Kings Creek	476519	6518424	1.73	2.8	5.7
HA_35_A	Rawdon Island	480540	6525580	1.72	3.8	6.2
HA_35_P	Rawdon Island	479088	6525550	0.65	1.85	4.4
HA_36_P	Pembrooke	478246	6526322	1.07	1.65	4
HA_37_C	Pembrooke	481617	6525311	1.85	1.1	5.5
HA_37_X	Pembrooke	481712	6525301	0.93	1.9	5.2
HA_38_C	Upper Maria River	487710	6541317	0.63	1.65	4
HA_40_P	Fernbank Creek	485363	6525339	0.51	2	5.2
HA_43_P	Lower Maria River East	486057	6531276	0.58	2	4.6
HA_45_P	Fernbank Creek	483854	6523322	0.71	1.7	4
HA_46_P	Lower Maria River West	483783	6526231	0.48	1.95	4.4
HP_11_C	Lower Maria River East	487046	6534686	0.70	1.5	4.3

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 of the Methods report (Rayner et al., 2023). These are multiplied together to get the pH factor which forms part of the final prioritisation. Table D-4 summarises the information per subcatchment in the Hastings 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
Connection Creek	11.8	1.3	15.4	13
Fernbank Creek	13.6	1.5	20.5	8
Kings Creek	10.4	1.5	15.6	4
Limeburners Creek	2.7	1.5	4.1	9
Lower Maria River East	19.0	1.3	24.7	8
Lower Maria River West	26.7	1.3	34.7	30
Partridge Creek	18.4	1.5	27.6	18
Pembrooke	27.8	1.5	41.7	5
Port Macquarie Airport	16.2	1.5	24.2	8
Rawdon Island	50.4	1.5	75.6	6
Redbank	5.3	1.5	8.0	4
Sarahs Creek/Sancrox	21.4	1.4	30.0	2
Upper Maria River	22.4	1.3	29.1	7

D5 Data confidence

As shown in Table D-4, the number of profiles in each catchment varies quite significantly. There are three (3) catchments in particular that have less than five (5) profiles in each area:

- Kings Creek;
- Redbank; and
- Sarahs Creek/Sancrox.

While there are less profiles available in these three (3) subcatchments, it is important to note that these catchments are by far the smallest catchments in the Hastings floodplain and have amongst the highest number of profiles per square kilometre in the floodplain (1.4, 2.1 and 1.6 profile per km^2, respectively). It is therefore considered that the number of profiles in these three (3) catchments is sufficient to characterise the pH factor for the purpose of this project, as long as they are spatially well distributed. Profiles are well distributed in Redbank and Kings Creek. The profiles in the Sarahs Creek/Sancrox area are clustered around Sarahs Creek, with limited information around Sancrox. To facilitate being able to include Sancrox in the prioritisation, it has been assumed that it has similar ASS presence to Sarahs Creek. This should be confirmed in the area if it is identified for large scale land management changes.

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 subcatchments in the Hastings River floodplain. The water level analysis undertaken is described in detail in Section 4.

E2 Water level gauges

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

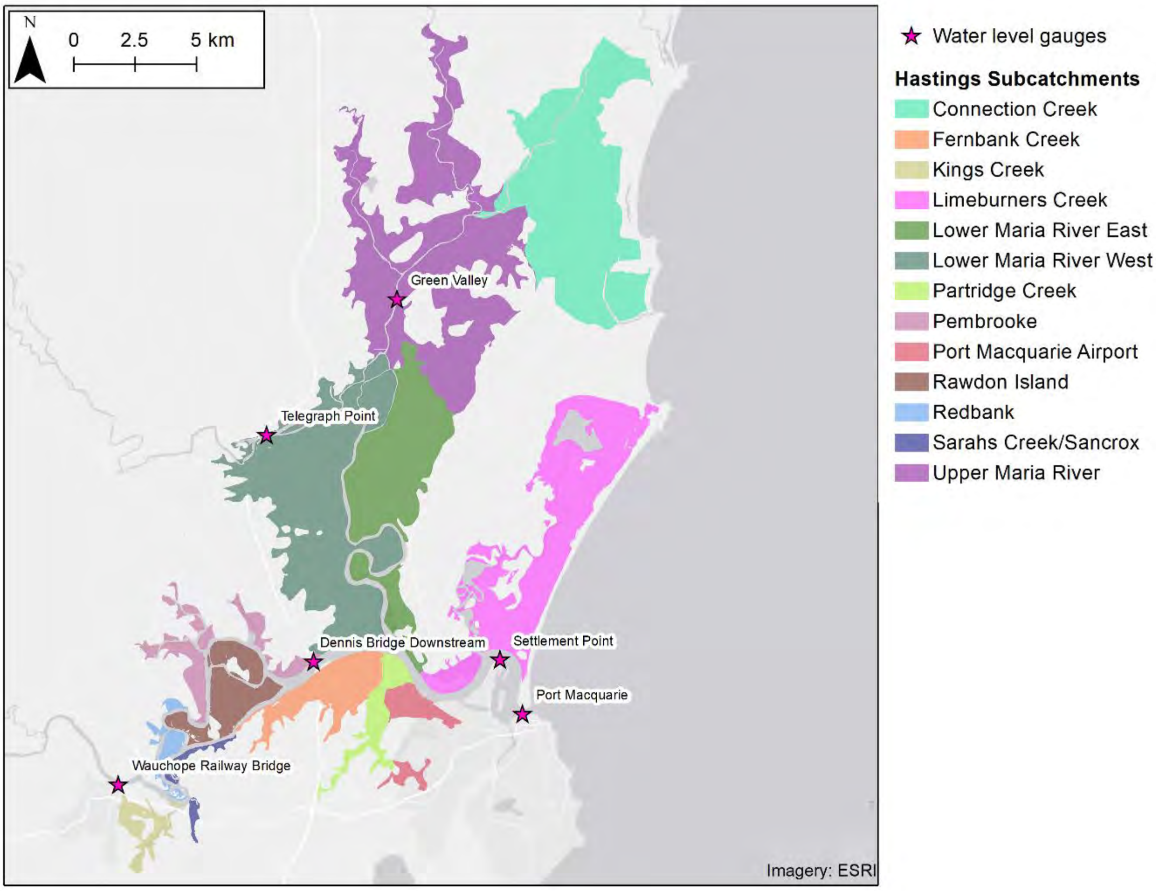

Figure E-1: Locations of water level gauges used for blackwater elevation thresholds

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)
Settlement Point	3.4 (Hastings River)	33.6	0.4
Dennis Bridge Downstream	12.7 (Hastings River)	24.8	0.5
Wauchope Railway Bridge	25.5 (Hastings River)	32.9	0.5
Telegraph Point	18.4 (Maria River)	30.3	0.4
Green Valley	24.2 (Maria River	26.2	0.4

* Excluding data gaps of greater than 6 hours.

Water level time series data at each gauge was analysed to establish a range of levels which can be applied to each floodplain subcatchment whereby the potential for prolonged inundation can be assessed. This was then related to floodplain topography and land use to prioritise blackwater generation across the floodplain. The analysis of the water level time series data was 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)
Settlement Point	0.4	0.4	0.4	0.8
Dennis Bridge Downstream	0.5	0.5	0.6	1.5
Wauchope Railway Bridge	0.5	0.8	1.2	4.2
Telegraph Point	0.4	0.7	0.9	2.1
Green Valley	0.4	1	1.1	1.9

E3 Subcatchment elevation thresholds

The subcatchments of the Hastings 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 such that the downstream boundary condition is well represented by the gauge. 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 are shown in Table E-4. Figure E-2 shows spatially the area covered by the median elevation thresholds in each subcatchment.

Table E-3: Water level stations and subcatchments

Subcatchment	Interpolation of levels (as required)
Limeburners Creek	Settlement Point
Port Macquarie Airport	0.61 x Settlement Point + 0.39 x Dennis Bridge Downstream
Partridge Creek	0.49 x Settlement Point + 0.51 x Dennis Bridge Downstream
Fernbank Creek	Dennis Bridge Downstream
Pembrooke	0.75 x Dennis Bridge Downstream + 0.25 x Wauchope Railway Bridge
Rawdon Island	0.75 x Dennis Bridge Downstream + 0.25 x Wauchope Railway Bridge
Redbank	0.49 x Dennis Bridge Downstream + 0.51 x Wauchope Railway Bridge
Sarahs Creek-Sancrox	0.25 x Dennis Bridge Downstream + 0.75 x Wauchope Railway Bridge
Kings Creek	0.23 x Dennis Bridge Downstream + 0.77 x Wauchope Railway Bridge
Lower Maria River West	0.19 x Dennis Bridge Downstream + 0.81 x Telegraph Point
Lower Maria River East	0.07 x Dennis Bridge Downstream + 0.93 x Telegraph Point
Upper Maria River	Green Valley
Connection Creek	Green Valley

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

Subcatchment	Minimum level (m AHD)	Median level (m AHD)	Mean level (m AHD)	Maximum level (m AHD)
Limeburners Creek	0.4	0.4	0.4	0.8
Port Macquarie Airport	0.4	0.4	0.5	1.1
Partridge Creek	0.5	0.5	0.6	1.2
Fernbank Creek	0.5	0.5	0.6	1.5
Pembrooke	0.5	0.6	0.8	2.2
Rawdon Island	0.5	0.6	0.8	2.2
Redbank	0.5	0.7	1.0	2.9
Sarahs Creek-Sancrox	0.5	0.7	1.1	3.5
Kings Creek	0.5	0.7	1.1	3.6
Lower Maria River West	0.4	0.7	0.9	2
Lower Maria River East	0.4	0.7	0.9	2.1
Upper Maria River	0.4	1	1.1	1.9
Connection Creek	0.4	1	1.1	1.9

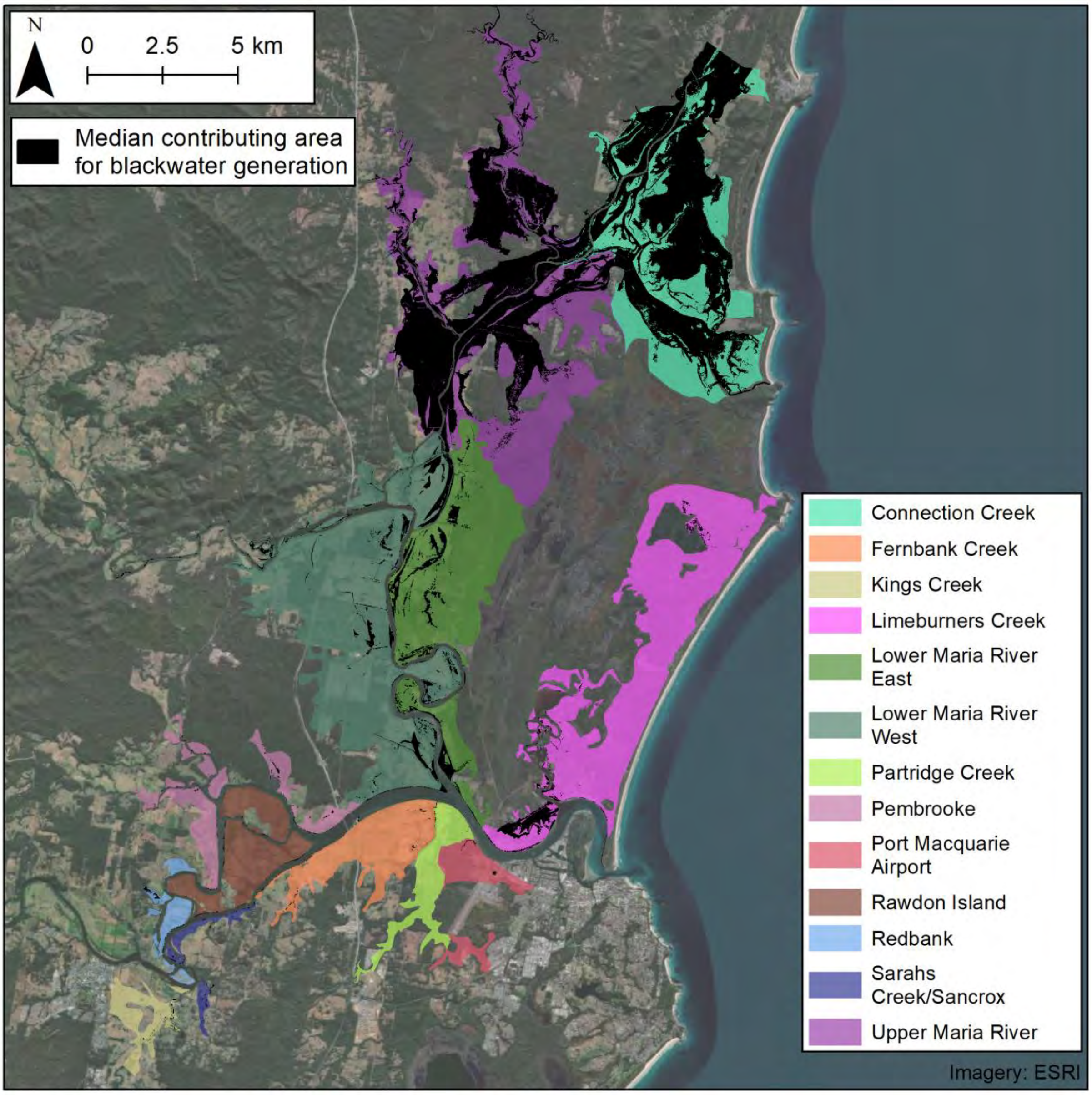

Figure E-2: Areas in the Hastings River floodplain below the median elevation threshold

Appendix F Floodplain infrastructure

F1 Preamble

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

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

The following sections provide information on floodplain infrastructure for the Hastings 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. Note, floodplain infrastructure can often include levee structures used for flood mitigation purposes, however, there are none of these structures across the Hastings River floodplain.

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 data provided by Kempsey Shire Council (KSC);
- Floodgate data provided by Port Macquarie Hasting Council (PMHC);
- An investigation into floodgate structures on the Hastings River floodplain (Smith, 1999); and
- A remediation management plan created for the Partridge Creek subcatchment (Aaso, 2003).

Table F-1: Description of existing data sources

Source	Description
KSC – GIS	GIS shapefiles containing location and ownership information for floodgates 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 not work as executed. 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 not work as executed.

Source	Description
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.
PMHC – GIS	GIS shapefile containing location, maintenance, tenure and access information for flood mitigation structures managed by PMHC. GIS shapefile containing location and ownership information of structures which have been modified to remediate acid sulfate soils. Shapefile provide water levels and tidal flushing levels in metres Australian Height Datum. It is unclear if levels are for the original structure or the modified part of the structure. Field investigations indicate it is likely to only be the modified part of the structure.
PMHC - PDFs	Design drawings for structures located in the Limeburners Creek subcatchment. Note field investigations indicated as constructed dimensions and invert levels differed from the designs.
Smith (1999)	An extensive review completed for floodgate infrastructure on the Hastings River floodplain. Includes an audit of floodgate and drain infrastructure which provides dimension and invert elevations for a number of structures. Invert levels are provided in Australian Height Datum (AHD), however, in some circumstances this appears to be derived from KSC floodplain infrastructure design drawings and are not work as executed measurements. The offset between Standard Datum and AHD used in the report also differs from other literature values.
Aaso (2003)	A remediation management plan developed for the Partridge Creek subcatchment acid sulfate soils. The plan includes invert and dimension measurements for structures in the subcatchment.

Across the Hastings River floodplain existing data for floodplain infrastructure is generally limited to location information. The majority of data available for invert, obvert and crest elevation measurements was found to be in Standard Datum, from design drawings (not as constructed elevations), or from unreliable data sources. Where no other data was available, or data was unreliable, 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). There are no flood mitigation levee structures on the Hastings River floodplain.

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 Hastings 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 discharge directly to the Hastings River estuary.

F2.2 Data collection

Field investigations were completed to obtain invert and dimension data for floodplain infrastructure within the Hastings 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 floodplain structures. A summary table of all structure data measured during the field investigations is provided in Section F6. In 2022, additional floodgate survey was collected by Abbott & Macro to fill remaining data gaps, which is also summarised in Section F6.

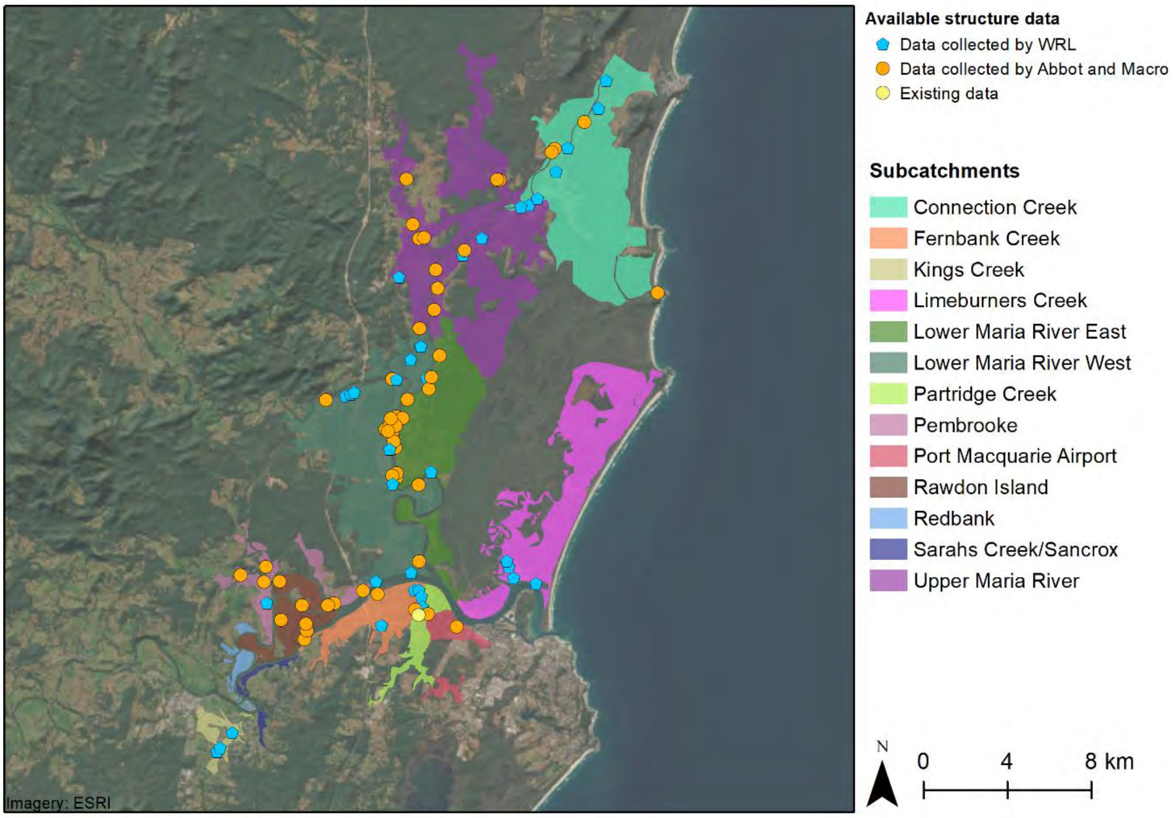

Figure F-1: Summary of end of system infrastructure with data available for the Hastings River floodplain

F3 Assessment of critical floodplain 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 primary EOS structures is the flood mitigation structures on Kings Creek that drain Wauchope.
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 106 EOS structures which have been identified within the Hastings River floodplain.

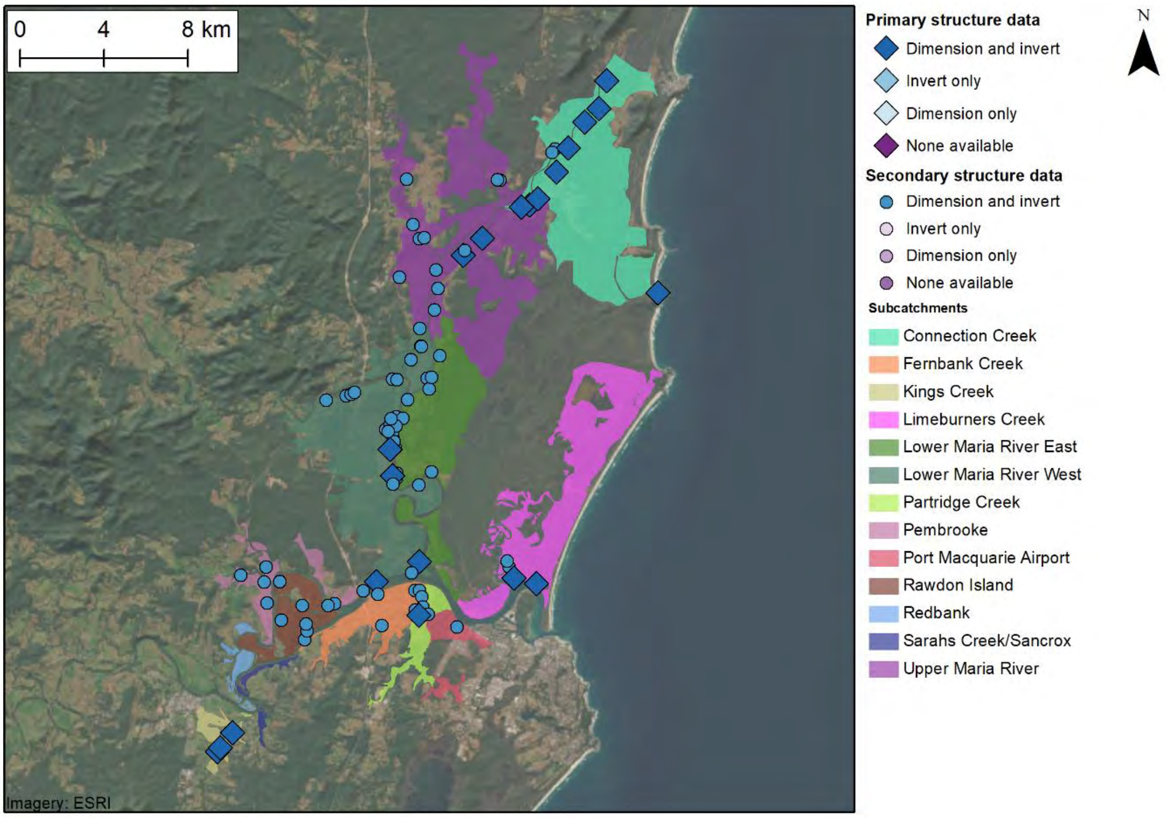

Figure F-2: Summary of data available for end of system structures of the Hastings River floodplain

F4 Infrastructure tenure and maintenance

F4.1 Infrastructure tenure

Information on the tenure of EOS structures across the Hastings River floodplain is presented in Figure F-3.

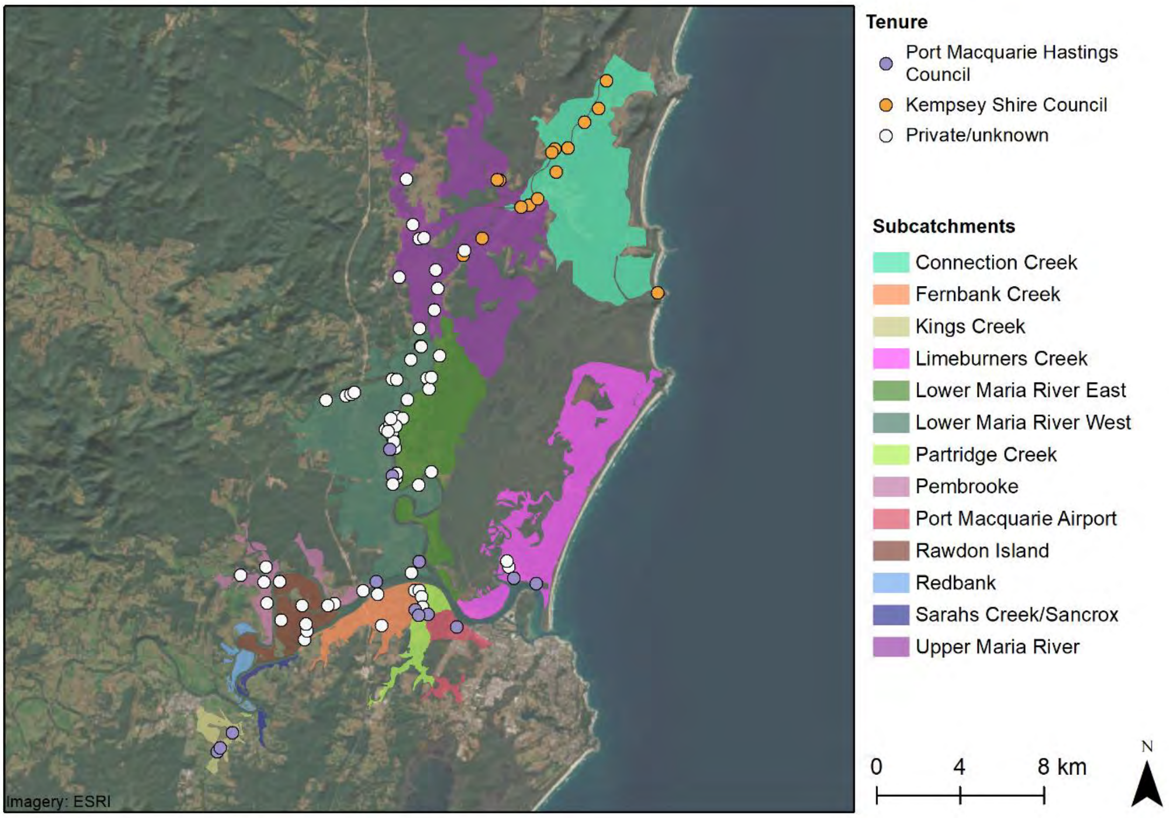

Figure F-3: Tenure of end of system structures on the Hastings River floodplain

F4.2 Maintenance schedule

Maintenance of structures across the Hastings River floodplain is split between Kempsey Shire Council (KSC), Port Macquarie Hastings Council (PMHC) and private ownership. 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 Hastings 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:

- Maria Drain 1 headworks (067G1) (Kempsey Shire Council, 2003); and
- Maria Drain 1 headworks (063G1) (Kempsey Shire Council, 2004).

PMHC has developed a guideline for continued management of their flood mitigation structures (Port Macquarie Hastings Council, 2010). This guideline outlines the maintenance that is required on an annual basis for flood mitigation structures owned by PMHC.

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. Where not otherwise stated, 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 management options.

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.

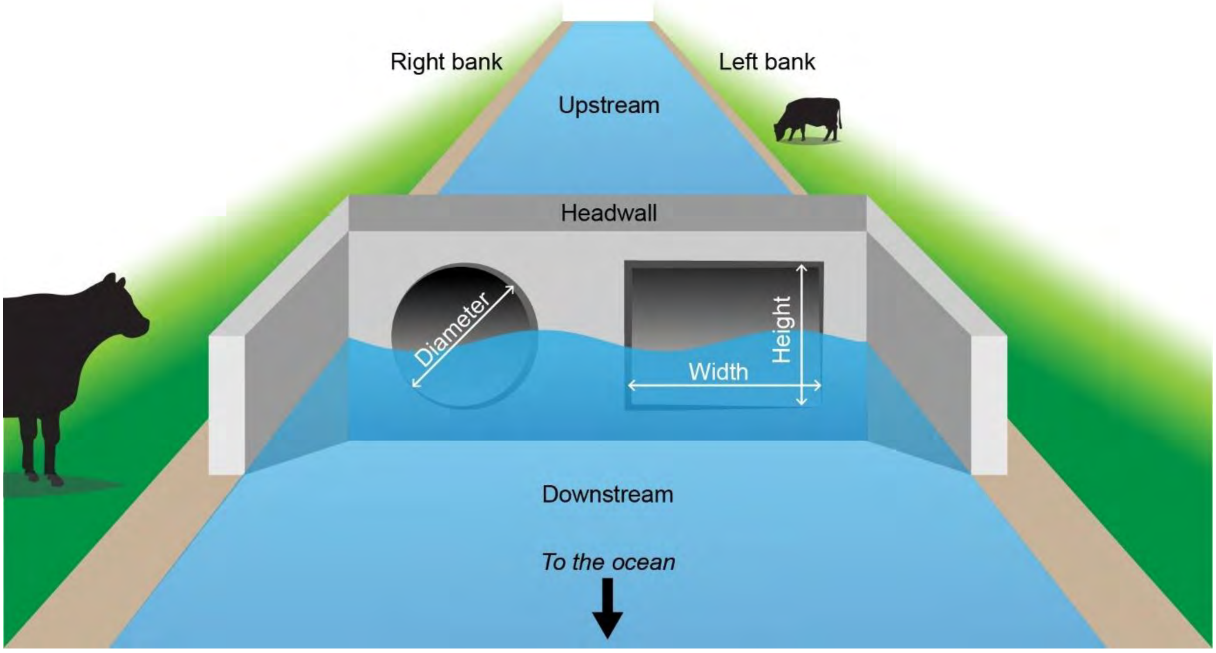

Figure F-4: Example of culverts controlling water in an agricultural drain

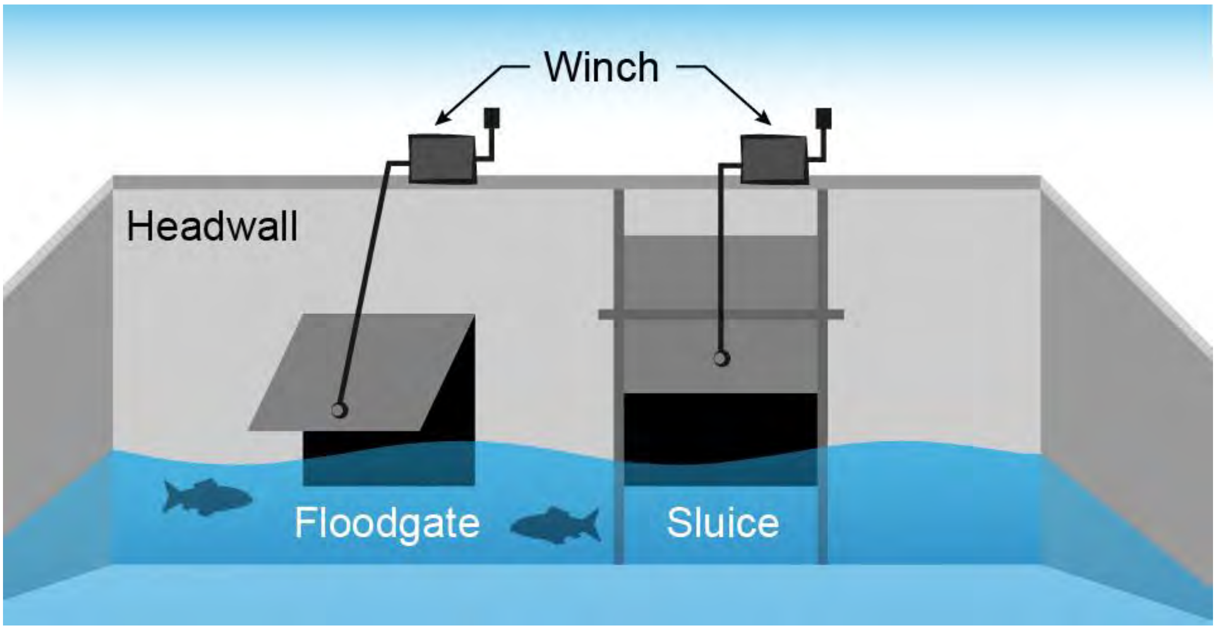

Figure F-5: Example of floodgate and sluice structures which can be fitted to culverts to control flow using a winch

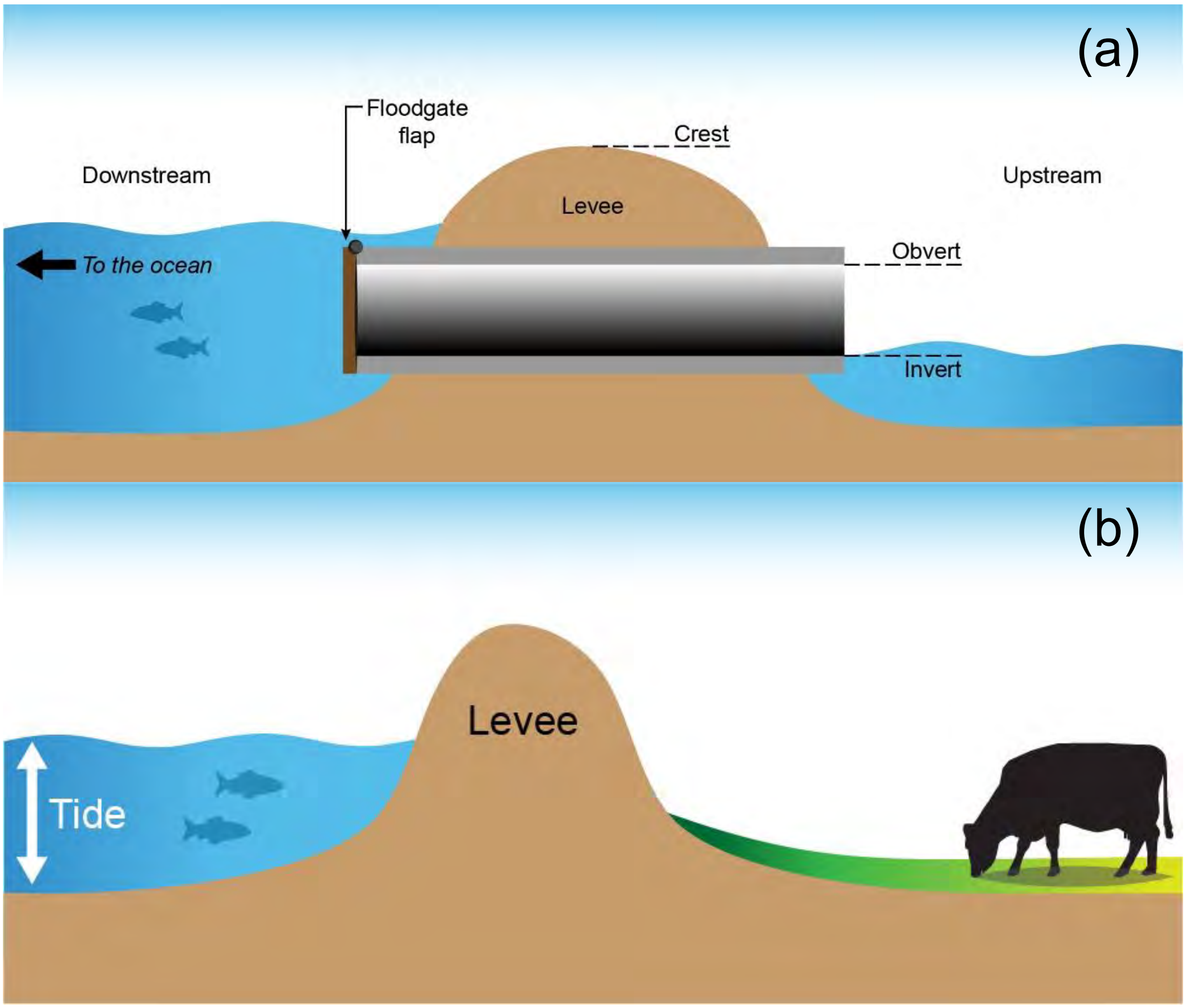

Figure F-6: Example of (a) a floodgate structure ensuring water levels upstream of a levee remain at the low tide level and (b) a levee preventing tidal inundation of the floodplain

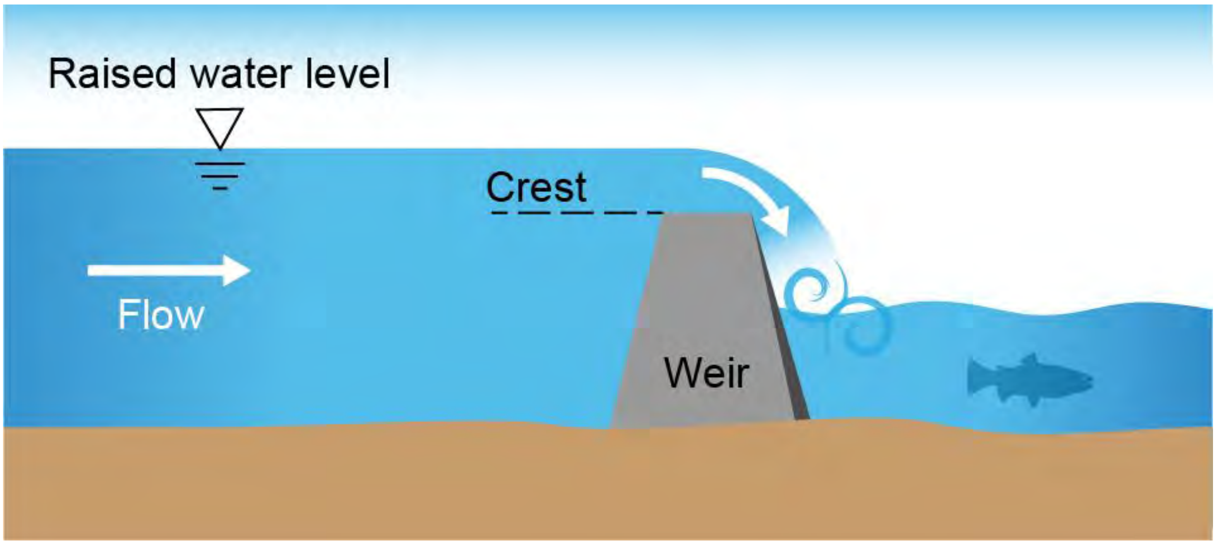

Figure F-7: Example of a weir ensuring a raised water level on the upstream side

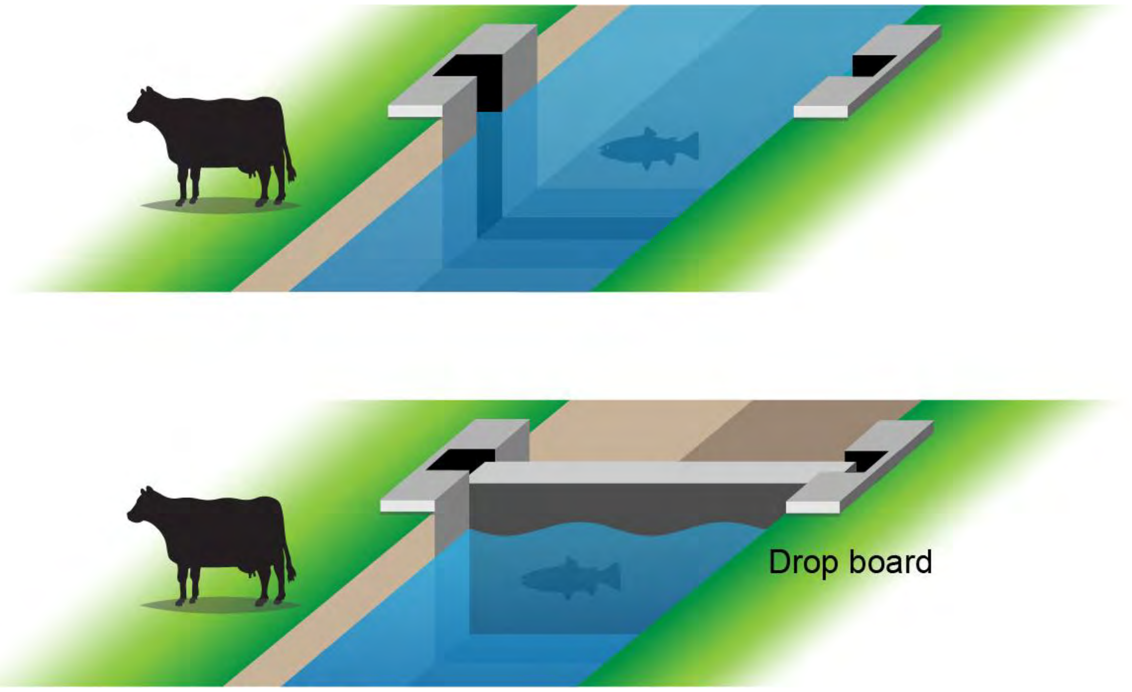

Figure F-8: Example of a drop board structure which can be used to control water levels and prevent inundation

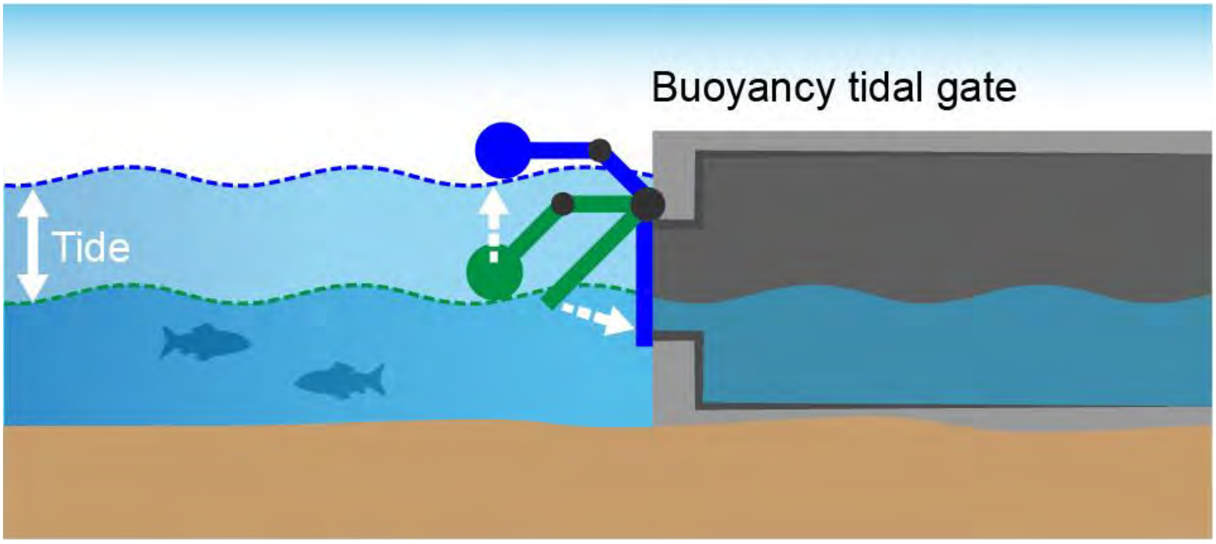

Figure F-9: Example of a buoyancy tidal gate that lets a controlled level of tidal water upstream of the structure (green) before closing due to a buoyancy mechanism and preventing further water ingress (blue)

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 2022 (Table F-4); and
3. A summary table for unsurveyed structures (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
060G1	5/03/2020 14:50	Floodgate	1		2	1.4	490410	6543507	-0.70		Good	Primary	Kempsey Shire Council	
060G1 buoyancy	5/03/2020 14:50	Buoyancy gate	1		0.5	0.8	490410	6543507	-0.60		Fair		Kempsey Shire Council	Invert approximately 0.1 m higher than main culvert.
061G1	5/03/2020 14:31	Floodgate	1	1.5			490827	6543605		-1.23	Fair	Primary	Kempsey Shire Council	Invert approximate only (RTK accuracy was poor). Blockage up and downstream.
062G1	5/03/2020	Floodgate	4		1.8	1.6	491276	6543801		-1.20	Good	Primary	Kempsey Shire Council	Invert very approximate. No GPS reception so invert based on water levels from 500m downstream. Lots of flow through culvert.
063G1	5/03/2020 13:35	Floodgate	1	1.2			492080	6545190		0.01	Fair	Secondary	Kempsey Shire Council	0.5 m wide sluice gate, open during survey.
064G1	5/03/2020 13:23	Floodgate	2		1.8	1.5	492658	6546332	-0.75		Fair	Primary	Kempsey Shire Council	Invert approximate only (RTK accuracy was poor).
065G1	5/03/2020	Floodgate	1	1.5			493738	6547444			Fair	Primary	Kempsey Shire Council	No GPS reception, so invert not measured.
066G1	5/03/2020 12:55	Floodgate	1	1.5			494094	6548191	-1.04		Fair	Primary	Kempsey Shire Council	Invert approximate only (RTK accuracy was poor). Has a buoyancy tidal gate, not measured as fully underwater.
067G1	5/03/2020 12:28	Floodgate	2		1.8	1.6	494497	6549528	-0.44		Good	Primary	Kempsey Shire Council	Invert approximate only (RTK accuracy was poor). Buoyancy tidal gate located on right flap - approximately 0.9 m wide by 0.5 m high.
076G1	4/03/2020 16:30	Floodgate	2		1.8	1.55	487687	6541204	-0.94		Good	Primary	Kempsey Shire Council	RTK accuracy poor.
076G1 buoyancy	4/03/2020 16:35	Buoyancy gate	1		0.5	0.9	487680	6541203		-0.43	Good		Kempsey Shire Council	Size and invert approximate only. Located on the left gate. Wedged open slightly.
078G1	5/03/2020 15:04	Floodgate	1	1.2			488570	6542033		-0.86	Fair	Primary	Kempsey Shire Council	
ASSS_17 left 1	18/09/2019	Culvert	1	0.45			485361	6525277	0.22		Fair	Secondary	Private	One of four culverts. Dry on upstream side, drop boards on upstream side open 0.2 m.
ASSS_17 left 2	18/09/2019	Culvert	1	0.45			485361	6525277	0.24		Fair	Secondary	Private	One of four culverts. Dry on upstream side, drop boards on upstream side open 0.2 m.
ASSS_17 right 1	18/09/2019	Culvert	1	0.45			485361	6525277	0.29		Fair	Secondary	Private	One of four culverts. Dry on upstream side, drop boards on upstream side open 0.2 m.
ASSS_17 right 2	18/09/2019	Culvert	1	0.45			485361	6525277	0.23		Fair	Secondary	Private	One of four culverts. Dry on upstream side, drop boards on upstream side open 0.2 m.
ASSS_18	18/09/2019	Culvert	3	1.2			485683	6524977	-0.52		Other	Secondary	Private	No flaps. Owner said they have been moved further upstream.
ASSS_19	18/09/2019	Floodgate	1	1.2			485724	6524471	0.04		Good	Secondary	Private	
ASSS_27	26/09/2019	Floodgate	3	0.6			489750	6526670	0.12		Fair	Secondary	Private	Buoyancy tidal gate on middle flap, 0.2 m wide by 0.25 m high, with 0.6 m from flap invert to the main

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
														culvert obvert. Drop boards on upstream side of the structure (not inserted).
ASSS_28	26/09/2019	Floodgate	3	0.75			489845	6526392	0.06		Fair	Secondary	Private	Buoyancy tidal gate on middle flap, 0.2 m wide by 0.25 m high, with 0.6 m from flap invert to the main culvert obvert. Drop boards on downstream side of the structure (not inserted). Left flap was stuck open.
ASSS_38	26/09/2019	Floodgate	1		2.1	0.4	485171	6536249	0.51		Fair	Secondary	Private	Old structure downstream removed. Two small flaps located on the side of the main flap - 0.3 high by 0.15 wide with an invert is 0.7 m from top of the weir.
ASSS_39	26/09/2019	Floodgate	1	0.9			485642	6536892	-0.57		Poor	Secondary	Private	New gate and weir upstream. Poor condition - lets flow in.
ASSS_40	26/09/2019	Floodgate	1	0.6			485945	6535363	-0.69		Good	Secondary	Private	New floodgates upstream.
ASSS_45	26/09/2019	Floodgate	1		3	0.3	486152	6530921	0.65		Good	Secondary	Private	Weir with flap - drop boards located immediately downstream (not inserted at time of inspection). Weir is control.
ASSS_61	20/09/2019	Floodgate	3		1	0.6	478331	6524668	0.64		Good	Secondary	Private	Weir with buoyancy tidal gates. Obvert of the gates is the same as the crest of the weir. Dimensions approximate.
ASSS_61 weir	20/09/2019	Weir					478331	6524668			Good	Secondary	Private	Crest of the weir measured at 1.24 m AHD.
FMS_01	4/03/2020 10:40	Floodgate	2	1			490066	6525861		0.14	Good	Primary	Port Macquarie Hastings Council	Left gate has buoyancy tidal gate. Left gate has been winched open.
FMS_02	4/03/2020 9:33	Floodgate	3		1.5	1.5	491136	6525604	-0.42		Fair	Primary	Port Macquarie Hastings Council	Lots of oysters on the floodgates. Buoyancy tidal gate on the right gate.
FMS_12	4/03/2020 15:37	Floodgate	2		2.1	2.1	476090	6517770		-0.16	Good	Primary	Port Macquarie Hastings Council	Winches for each gate.
FMS_15	17/09/2019	Floodgate	2	1.4			475962	6517586	0.30		Good	Primary	Port Macquarie Hastings Council	Invert based on water level. Invert is 0.04 m below water level.
FMS_26	25/09/2019	Floodgate	1	1.8			483518	6525690	-0.33		Good	Primary	Port Macquarie Hastings Council	Buoyancy tidal gate 0.85 m high by 0.50 wide.
FMS_26 buoyancy	25/09/2019	Buoyancy gate	1		0.85	0.5	483527	6525685		-0.28	Good		Port Macquarie Hastings Council	Buoyancy tidal gate 0.85 m high by 0.50 wide.
FMS_32	4/03/2020 12:35	Floodgate	3		2.1	2.3	484161	6531965	-0.11		Good	Primary	Port Macquarie Hastings Council	Buoyancy tidal gate on right two gates. Weir on upstream side of the culvert is 0.4 m above the invert elevation.
FMS_5 left	17/09/2019	Floodgate	1		2.2	2.2	476676	6518476	0.00		Fair	Primary	Port Macquarie Hastings Council	One of three culverts.
FMS_5 centre	17/09/2019	Floodgate	1		2.2	2.2	476676	6518476	-0.03		Fair	Primary	Port Macquarie Hastings Council	One of three culverts.
FMS_5 right	17/09/2019	Floodgate	1		2.2	2.2	476676	6518476	-0.02		Fair	Primary	Port Macquarie Hastings Council	One of three culverts.
WRL_HA_01	18/09/2019	Floodgate	1		0.8	0.6	485568	6525270	-0.13		Poor	Secondary	Private/unknown	Leaking significantly, salty upstream.
WRL_HA_02	18/09/2019	Weir					483767	6523588			Good	Secondary	Private/unknown	Crest of the weir measured at 0.99 m AHD. No vegetation, no water. Across Fernbank Creek.
WRL_HA_03	26/09/2019	Floodgate	1		1.2	0.7	485653	6536887	0.17		Fair	Secondary	Private/unknown	Trees clogging the weir, measured top of the weir plus extension into invert. Two small flaps look to be buried in silt.
WRL_HA_04	5/03/2020 11:07	Culvert	1	1.5			484314	6530335	0.02		Fair	Secondary	Private/unknown	
WRL_HA_05	26/09/2019	Floodgate	1		1.2	0.7	485940	6535365	0.25		Poor	Secondary	Private/unknown	Small gates on the sides in poor condition - 0.3 m high by 0.15 m wide with an invert 1.05 m from crest of the weir.

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_HA_06	4/03/2020 13:01	Culvert	2	0.9			484528	6535316		-0.57	Good	Secondary	Private/unknown	No gates present. Approximately 0.3 m of sediment in bottom of the culverts.
WRL_HA_07	4/03/2020 17:09	Floodgate	2	0.545			485193	6526125	0.99		Good	Secondary	Private/unknown	Sluice on downstream side of the culvert was open approximately 0.2 m above the invert allowing flow into the culvert.
WRL_HA_08	25/09/2019 16:00	Weir					484614	6540177			Fair	Secondary	Private/unknown	Rubble weir with crest elevation of 0.70 m AHD.
WRL_HA_09	4/03/2020 13:37	Culvert	1	0.9			482073	6534538		-0.27	Good	Secondary	Private/unknown	Good condition. No gates present.
WRL_HA_10	4/03/2020 13:27	Culvert	1	1.2			482324	6534618		0.13	Good	Secondary	Private/unknown	Good condition. No gates present.
WRL_HA_11	4/03/2020 13:18	Culvert	1	0.6			482484	6534694	0.27		Good	Secondary	Private/unknown	No gates present. Beginning to fill with sediment.

* Structure ID's have been provided by Kempsey Shire Council and Port Macquarie Hastings Council. Structure ID's for Port Macquarie Hastings Council have been set based upon Councils shapefile ID for either the flood mitigation structure shapefile (FMS_XX) or the acid sulfate soil structure shapefile (ASSS_XX). If a structure was identified that did not have a council ID it has been given a WRL ID (WRL_HA_##).

Table F-4: Summary of existing data identified during the gaps analysis

Structure ID	Type	# Culverts	Diameter (m)	Width (m)	Height (m)	Easting (m)	Northing (m)	Invert (m AHD)	Category	Tenure	Condition	Comment	Data source
FMS_27	Floodgate	5		2.1	2.4	485561	6526647	-0.28	Primary	Port Macquarie Hastings Council	Good	All gates working with good seal. Winch present	Abbott and Macro 2022
FMS_27	Floodgate	5		2.1	2.4	485563	6526648	-0.28	Primary	Port Macquarie Hastings Council	Good	All gates working with good seal. Winch present	Abbott and Macro 2022
FMS_27	Floodgate	5		2.1	2.4	485559	6526644	-0.28	Primary	Port Macquarie Hastings Council	Good	All gates working with good seal. Winch present. Structure modified with auto tidal sluice	Abbott and Macro 2022
FMS_27	Floodgate	5		2.1	2.4	485558	6526642	-0.28	Primary	Port Macquarie Hastings Council	Good	All gates working with good seal. Winch present	Abbott and Macro 2022
FMS_27	Floodgate	5		2.1	2.4	485557	6526641	-0.28	Primary	Port Macquarie Hastings Council	Good	All gates working with good seal. Winch present	Abbott and Macro 2022
ASSS_20	Floodgate	1		1.2	1.2	483601	6525093	-0.46	Secondary	Private	Fair	No floodgate, just box headwall	Abbott and Macro 2022
UNK03	Floodgate	1	0.9			482888	6525241	-0.10	Secondary	Private/unknown	Good		Abbott and Macro 2022
UNK16	Floodgate	1		1.2	1.5	481525	6524635	-0.33	Secondary	Private/unknown	Fair	Some debris keeping gate open	Abbott and Macro 2022
UNK17	Floodgate	1					481224	6524557	1.07	Secondary	Private/unknown	No pipe invert on bund wall given	Abbott and Macro 2022
UNK18		1	0.15			479990	6524545	0.43	Secondary	Private/ unknown	Poor	Small pipe partially blocked	Abbott and Macro 2022
UNK02		1					478932	6525686	0.73	Secondary	Private/unknown	No pipe invert on bund wall given	Abbott and Macro 2022
ASSS_54	Floodgate	1	0.3			478170	6525660	0.43	Secondary	Private	Good		Abbott and Macro 2022
ASSS_55	Floodgate	1	0.45			477058	6525984	0.54	Secondary	Private	Good		Abbott and Macro 2022
ASSS_53	Floodgate	1		0.9	0.35	478282	6526393	-0.45	Secondary	Private	Good	Structure modified with auto tidal sluice, bad erosion around headwall, tide is bypassing the floodgate	Abbott and Macro 2022
UNK19	Floodgate	2	0.75			485543	6530274	0.09	Secondary	Private/ unknown	Good		Abbott and Macro 2022
UNK19	Floodgate	2	0.75			485544	6530274	0.09	Secondary	Private/ unknown	Good		Abbott and Macro 2022
ASSS_46	Floodgate	1	0.9			484480	6530601	0.11	Secondary	Private	Fair	Silt in bottom of pipe, flap broken off not functioning	Abbott and Macro 2022
FMS_29	Floodgate	3		2.1	2.1	484280	6530731	-0.13	Primary	Port Macquarie Hastings Council	Good		Abbott and Macro 2022
FMS_29	Floodgate	3		2.1	2.1	484281	6530729	-0.13	Primary	Port Macquarie Hastings Council	Good	Structure modified with auto tidal sluice	Abbott and Macro 2022
FMS_29	Floodgate	3		2.1	2.1	484281	6530727	-0.13	Primary	Port Macquarie Hastings Council	Good		Abbott and Macro 2022
ASSS_47	Culvert	1	0.9			484506	6530844	-0.12	Secondary	Private	Fair	No floodgate just pipe	Abbott and Macro 2022
ASSS_48	Floodgate	1		3	0.6	484437	6532053	0.06	Secondary	Private	Good		Abbott and Macro 2022
ASSS_58	Floodgate	1		1.5	0.6	484350	6532340	0.28	Secondary	Private	Good		Abbott and Macro 2022
ASSS_49	Floodgate	1		1.5	0.6	484321	6532514	0.17	Secondary	Private	Good		Abbott and Macro 2022
ASSS_59	Floodgate	1		1.8	1.1	484084	6532845	-0.20	Secondary	Private	Good		Abbott and Macro 2022
ASSS_31	Floodgate	1		1.5	0.7	483956	6532925	0.07	Secondary	Private	Good	Cattle farm, structure has winch	Abbott and Macro 2022
ASSS_50	Floodgate	1		2.8	0.6	484298	6532800	0.20	Secondary	Private	Good	Cattle farm	Abbott and Macro 2022
ASSS_32	Floodgate	1		0.9	0.75	484177	6533139	0.05	Secondary	Private	Good	Cattle farm, structure has winch	Abbott and Macro 2022
ASSS_33	Floodgate	1		1.1	0.6	484216	6533440	-0.16	Secondary	Private	Good	Structure has winch	Abbott and Macro 2022
ASSS_34	Floodgate	2	0.45			484483	6533523	-0.26	Secondary	Private	Fair	Small pipes for large drain	Abbott and Macro 2022
ASSS_34	Floodgate	2	0.45			484484	6533524	-0.26	Secondary	Private	Fair	Small pipes for large drain	Abbott and Macro 2022

Structure ID	Type	# Culverts	Diameter (m)	Width (m)	Height (m)	Easting (m)	Northing (m)	Invert (m AHD)	Category	Tenure	Condition	Comment	Data source
UNK12	Culvert	1	0.9			484277	6535316	0.04	Secondary	Private /unknown	Fair	Pipe half blocked with mangrove roots	Abbott and Macro 2022
ASSS_35	Floodgate	2		1.9	0.6	484783	6533457	0.29	Secondary	Private	Good		Abbott and Macro 2022
ASSS_35	Floodgate	2		1.9	0.6	484782	6533460	0.29	Secondary	Private	Good		Abbott and Macro 2022
ASSS_52	Floodgate	1	0.45			484461	6533103	-0.40	Secondary	Private	Good	Wooden headwall	Abbott and Macro 2022
ASSS_57	Culvert	1	1.2			486134	6535415	-0.25	Secondary	Private	Fair	No floodgate just pipe	Abbott and Macro 2022
ASSS_43	Floodgate	1		2.7	0.5	486532	6536432	0.26	Secondary	Private	Good		Abbott and Macro 2022
ASSS_51	Floodgate	1		1.2	0.6	484996	6534354	0.32	Secondary	Private	Good		Abbott and Macro 2022
ASSS_41	Floodgate	1	0.6			485580	6537739	-0.48	Secondary	Private	Fair	Cattle farm	Abbott and Macro 2022
UNK24	Floodgate	1	0.75			486289	6538620	0.21	Secondary	Private/ unknown	Good		Abbott and Macro 2022
UNK23	Floodgate	2	1.5			484966	6544843	-1.01	Secondary	Private/ unknown	Fair	Flap fallen off	Abbott and Macro 2022
UNK09	Floodgate	1	1.5			485255	6542674	-0.36	Secondary	Private/ unknown	Fair	Corrosion on flap small hole	Abbott and Macro 2022
UNK08	Floodgate	1		1.8	1.8	485568	6542013	-0.87	Secondary	Private/ unknown	Good		Abbott and Macro 2022
UNK22	Floodgate	1	1.5			485802	6542062	-0.62	Secondary	Private/unknown	Good	Debris around flap	Abbott and Macro 2022
ASSS_42	Floodgate	1	1.2			486354	6540527	0.03	Secondary	Private	Good		Abbott and Macro 2022
UNK07	Culvert	1	0.45			486445	6539639	0.53	Secondary	Private/ unknown	Fair	No floodgate just pipe	Abbott and Macro 2022
ASSS_21	Floodgate	1	0.6			480107	6522934	0.00	Secondary	Private	Good		Abbott and Macro 2022
089G1	Floodgate	1	1.2			489395	6544786	-0.48	Secondary	Kempsey Shire Council	Fair	Flap fallen off	Abbott and Macro 2022
090G1	Culvert	1	0.6			489284	6544810	0.17	Secondary	Kempsey Shire Council	Fair	No floodgate just pipe	Abbott and Macro 2022
093G1	Floodgate	1	1.2			491888	6546107	-0.57	Secondary	Kempsey Shire Council	Good		Abbott and Macro 2022
094G1	Floodgate	1	1.2			492018	6546288	-0.66	Secondary	Kempsey Shire Council	Fair	Flap almost fallen off	Abbott and Macro 2022
UNK20	Floodgate	1	0.9			487722	6541442	-0.60	Secondary	Private /unknown	Good		Abbott and Macro 2022
ASSS_37	Floodgate	1		4.4	0.5	486030	6534869	-0.12	Secondary	Private	Good		Abbott and Macro 2022
065G1	Floodgate	1	1.2			493445	6547552	-0.52	Primary	Kempsey Shire Council	Good	Structure modified with auto tidal sluice	Abbott and Macro 2022
079G1	Floodgate	12		1.8	2.6	496920	6539458	-0.73	Primary	Kempsey Shire Council	Good	Downstream badly silted up due to beach sand	Abbott and Macro 2022
079G1	Floodgate	12		1.8	2.6	496921	6539455	-0.77	Primary	Kempsey Shire Council	Good	Downstream badly silted up due to beach sand	Abbott and Macro 2022
079G1	Floodgate	12		1.8	2.6	496922	6539453	-0.79	Primary	Kempsey Shire Council	Good	Downstream badly silted up due to beach sand	Abbott and Macro 2022
079G1	Floodgate	12		1.8	2.6	496923	6539452	-0.77	Primary	Kempsey Shire Council	Good	Downstream badly silted up due to beach sand	Abbott and Macro 2022
079G1	Floodgate	12		1.8	2.6	496923	6539449	-0.77	Primary	Kempsey Shire Council	Good	Downstream badly silted up due to beach sand	Abbott and Macro 2022
079G1	Floodgate	12		1.8	2.6	496924	6539447	-0.75	Primary	Kempsey Shire Council	Good	Downstream badly silted up due to beach sand	Abbott and Macro 2022

Structure ID	Type	# Culverts	Diameter (m)	Width (m)	Height (m)	Easting (m)	Northing (m)	Invert (m AHD)	Category	Tenure	Condition	Comment	Data source
079G1	Floodgate	12		1.8	2.6	496924	6539446	-0.76	Primary	Kempsey Shire Council	Good	Downstream badly silted up due to beach sand	Abbott and Macro 2022
079G1	Floodgate	12		1.8	2.6	496925	6539444	-0.77	Primary	Kempsey Shire Council	Good	Downstream badly silted up due to beach sand	Abbott and Macro 2022
079G1	Floodgate	12		1.8	2.6	496925	6539442	-0.79	Primary	Kempsey Shire Council	Good	Downstream badly silted up due to beach sand	Abbott and Macro 2022
079G1	Floodgate	12		1.8	2.6	496925	6539440	-0.77	Primary	Kempsey Shire Council	Good	Downstream badly silted up due to beach sand	Abbott and Macro 2022
079G1	Floodgate	12		1.8	2.6	496926	6539437	-0.74	Primary	Kempsey Shire Council	Good	Downstream badly silted up due to beach sand	Abbott and Macro 2022
079G1	Floodgate	12		1.8	2.6	496926	6539436	-0.75	Primary	Kempsey Shire Council	Good	Structure modified with screw winch, downstream badly silted up due to beach sand	Abbott and Macro 2022
ASSS_25		1	0.6			479005	6523858	0.45	Secondary	Private	Fair	No floodgate just pipe	Abbott and Macro 2022
ASSS_23	Floodgate	1	0.6			480231	6523347	0.48	Secondary	Private	Good		Abbott and Macro 2022
ASSS_24	Culvert	1	0.45			480188	6523656	0.76	Secondary	Private	Poor	Small section of pipe not functioning	Abbott and Macro 2022
UNK11	Culvert	1	0.9			481134	6534335	0.16	Secondary	Private/unknown	Good	No floodgate pipe with headwalls	Abbott and Macro 2022
UNK04	Culvert	2		1.2	0.6	487365	6523536	-0.05	Secondary	Port Macquarie Hastings Council	Good		Abbott and Macro 2022
UNK04	Culvert	2		1.2	0.6	487363	6523533	-0.05	Secondary	Port Macquarie Hastings Council	Good		Abbott and Macro 2022
UNK05	Culvert	3	0.9			485984	6524136	0.29	Secondary	Port Macquarie Hastings Council	Good	No floodgate just pipe	Abbott and Macro 2022
UNK05	Culvert	3	0.9			485986	6524136	0.28	Secondary	Port Macquarie Hastings Council	Good	No floodgate just pipe	Abbott and Macro 2022
UNK05	Culvert	3	0.9			485987	6524135	0.30	Secondary	Port Macquarie Hastings Council	Good	No floodgate just pipe	Abbott and Macro 2022
ASSS_03	Culvert	3		0.9	0.6	485387	6524346	0.11	Secondary	Port Macquarie Hastings Council	Good	No floodgate	Abbott and Macro 2022
ASSS_03	Culvert	3		0.9	0.6	485385	6524347	0.10	Secondary	Port Macquarie Hastings Council	Good	No floodgate	Abbott and Macro 2022
ASSS_03	Culvert	3		0.9	0.6	485384	6524347	0.11	Secondary	Port Macquarie Hastings Council	Good	No floodgate	Abbott and Macro 2022
UNK10	Culvert		1.8			485539	6524075	-0.635	Primary	Port Macquarie Hastings Council			Partridge Creek Hot Spot Remediation Management Plan (Aaso, 2003)

Table F-5 Summary of unsurveyed structures

Structure ID	Easting	Northing	Sub-catchment	Comment
092G1	488621.7	6545674	Upper Maria River	Inspected, not found
ASSS_01	485636.3	6523576	Partridge Creek	Inspected, not found
ASSS_02	486166.4	6523071	Port Macquarie Airport	Inspected, not found
ASSS_22	479492	6523066	Rawdon Island	Inspected, not found
ASSS_30	484071.4	6532367	Lower Maria River West	Inspected, not found
ASSS_36	485651.4	6534548	Lower Maria River East	Inspected, not found
ASSS_44	486297	6535769	Lower Maria River East	Inspected, structure removed
ASSS_56	477343.9	6525978	Pembrooke	Inspected, not found
ASSS_64	485699.5	6522492	Partridge Creek	Inspected, not found
ASSS_65	485400	6521952	Partridge Creek	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., 2023). Locations of cross-sectional measurements surveyed across the Hastings 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-10.

Figure G-1: General location of cross-sections surveyed on the Hastings 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)
143	489492.8	6545297.8	489501.1	6545330.4
145	484619.4	6540193.9	484640.3	6540171.6
146	483762.3	6526309.2	483798.2	6526289.6
147	479170.4	6523104.2	479172.0	6523117.9
148	482524.9	6523932.0	482523.7	6523921.1
149	484932.1	6523882.2	484943.4	6523877.2
193	487043.7	6534676.3	487045.2	6534690.4
194	487040.8	6534695.8	487042.0	6534706.3
195	487679.3	6541200.5	487680.8	6541210.6

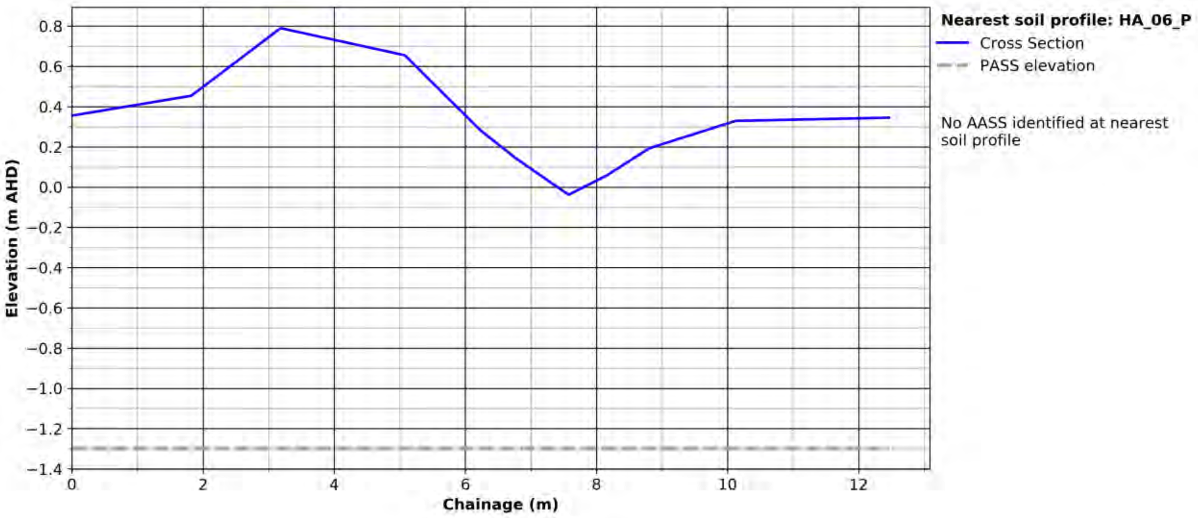

Figure G-2: Hastings cross-section 143

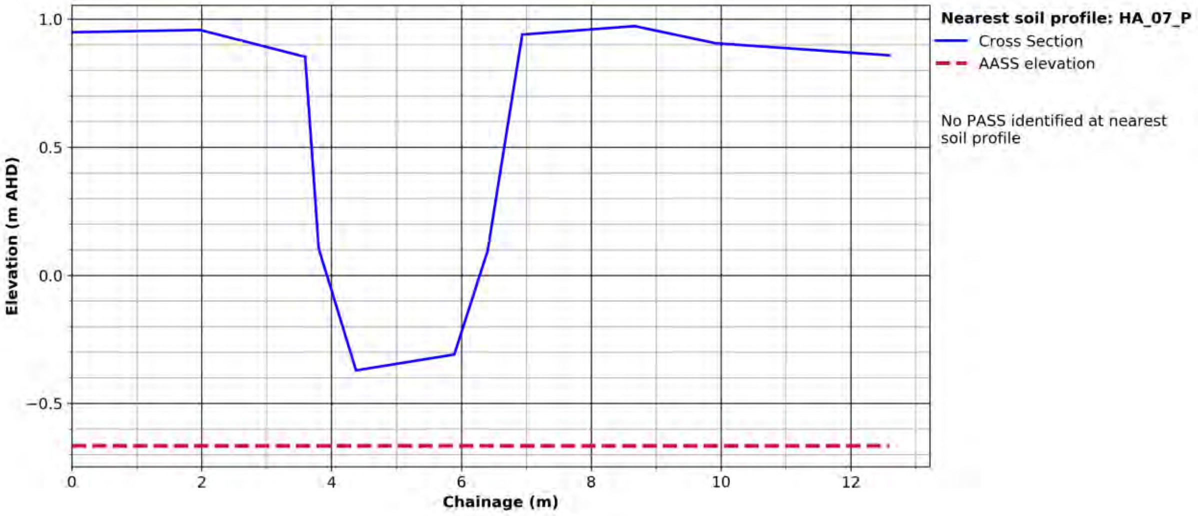

Figure G-3: Hastings cross-section 145

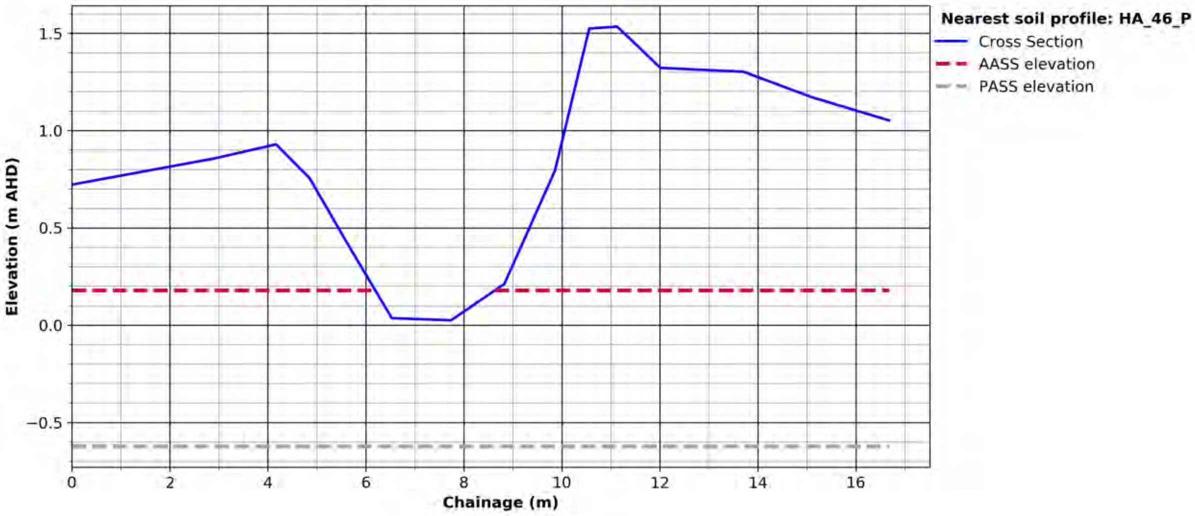

Figure G-4: Hastings cross-section 146

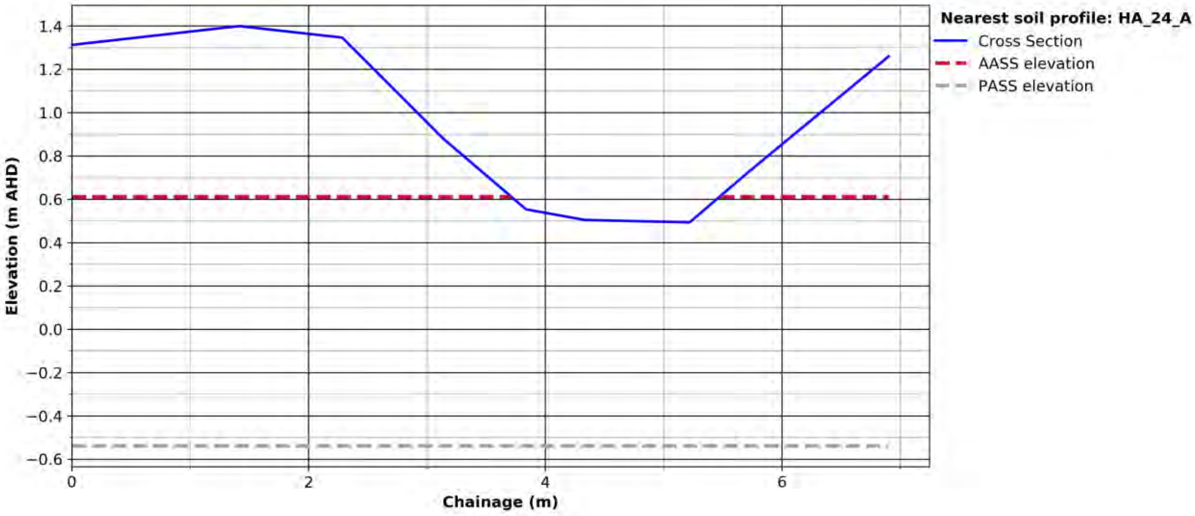

Figure G-5: Hastings cross-section 147

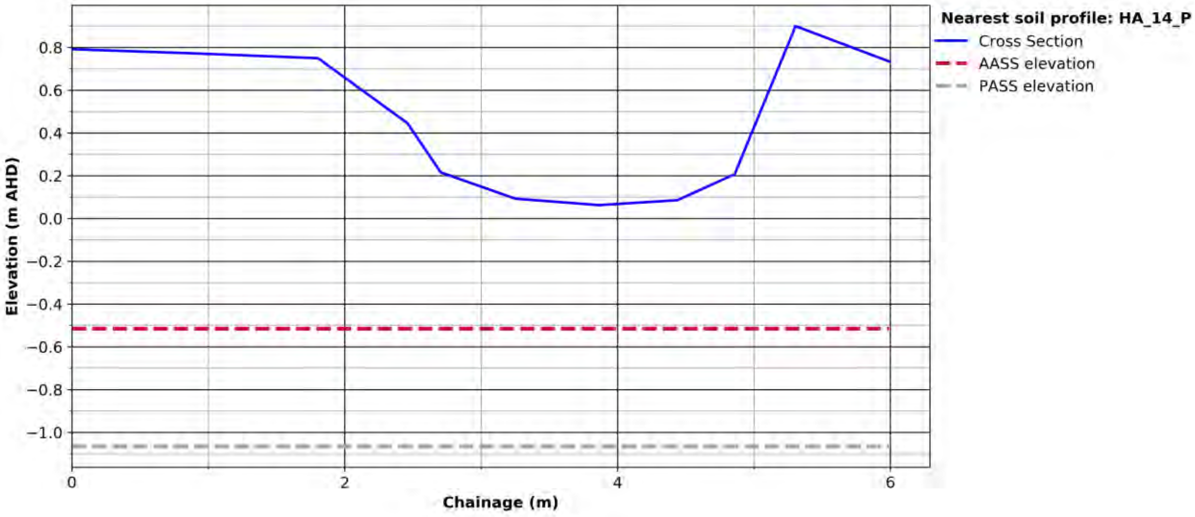

Figure G-6: Hastings cross-section 148

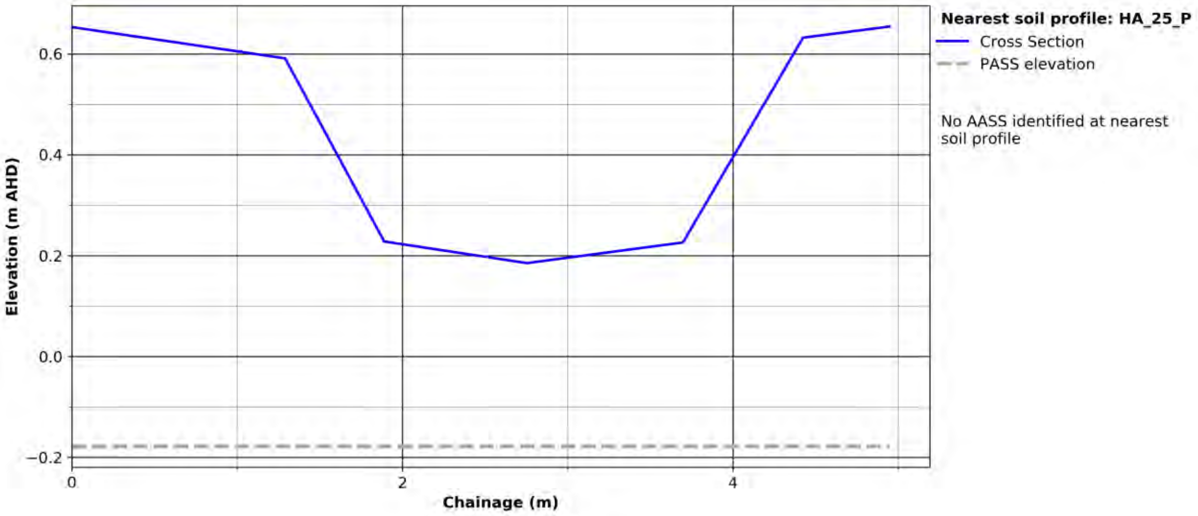

Figure G-7: Hastings cross-section 149

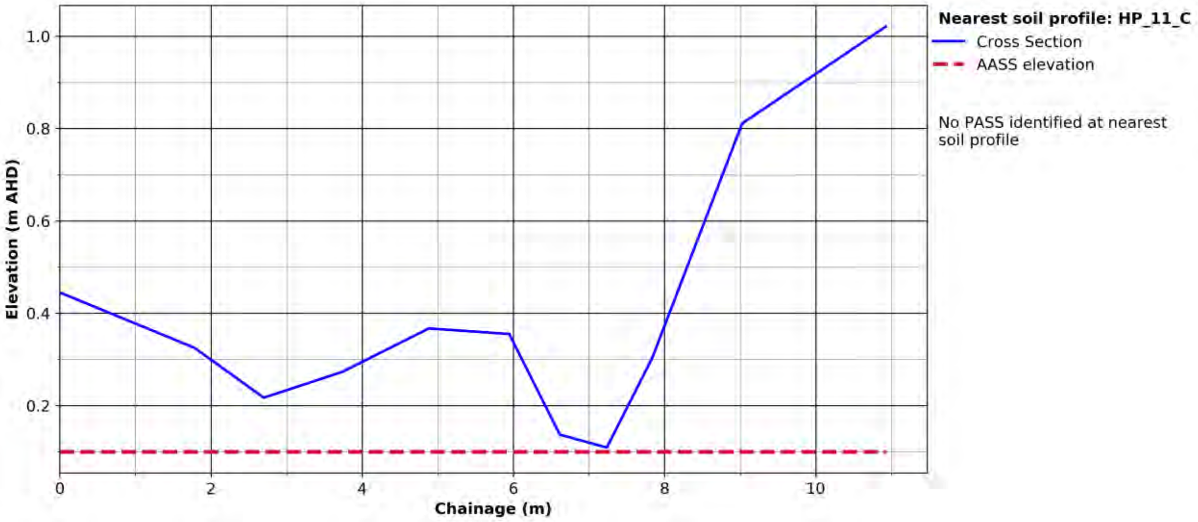

Figure G-8: Hastings cross-section 193

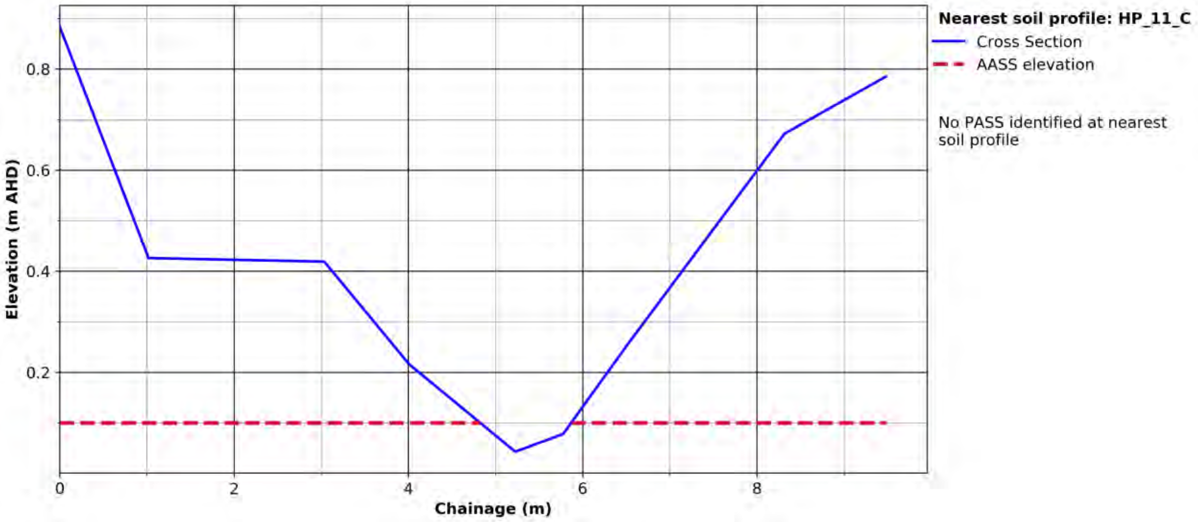

Figure G-9: Hastings cross-section 194

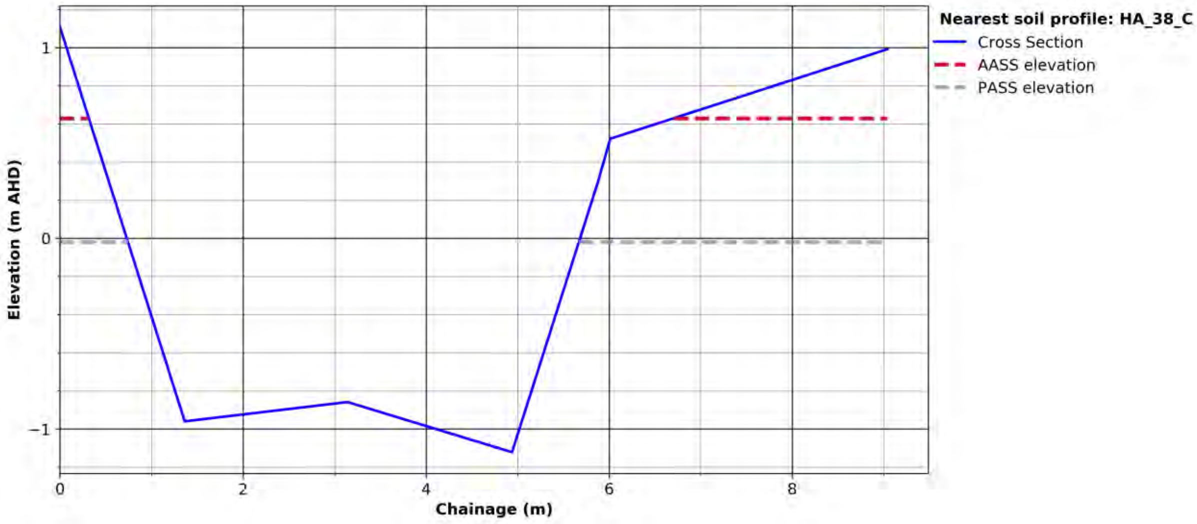

Figure G-10: Hastings cross-section 195

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 Hastings 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 Hastings River estuary has 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 Hastings River water quality objectives

In 2006, water quality objectives (WQOs) were developed for the Hastings River catchment (along with Camden Haven) 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 Hastings River estuary and include objectives for the protection of:

- Aquatic ecosystems;
- Visual amenity;
- Primary and secondary contact recreation;
- Aquatic foods (cooked);
- Livestock, irrigation, homestead and industrial 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 Hastings 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	Electrical conductivity (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 Hastings 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, reviews of existing water quality data have been completed by Tulau (1999), Umwelt (2000), Aaso (2003)(for Partridge Creek) and Dove (2003).

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 mono-sulfidic 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 it 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.

Numerous studies have measured dissolved oxygen levels and/or nutrient levels throughout the Hastings River estuary. The State Pollution Control Commission (1987) investigated sources of pollution to the estuary that may have impacts on the aquatic environment and found low nutrient levels and normal dissolved oxygen levels. The Department of Environment and Conservation NSW (2006) assessed sections of the Maria River near the Kumbatine and Maria River National Parks finding low dissolved oxygen levels which are common for a low-gradient coastal river system. Low dissolved oxygen levels in the Maria River were also observed by Bush et al. (2006). Investigations completed by Port Macquarie-Hastings Council (2007) observed that nitrogen levels in the estuary appeared to be linked to runoff events. Subsequent investigations by Ryder et al. (2012) and Ryder et al. (2017) confirmed this finding. They also noted that phosphorus levels appeared to be elevated during low flow periods, at the same time low dissolved oxygen measurements occurred. Despite this no excess algal biomass was observed across the estuary which could stimulate an eutrophication event. Monitoring of dissolved oxygen and other indicators of blackwater has continued across the Hastings River estuary to ensure continued environmental objectives are achieved (NSW DPIE, 2019).

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 Hastings River estuary, a number of studies have measured water acidity (pH). Early investigations completed by the State Pollution Control Commission (1987) and Manly Hydraulics Laboratory (1994) did not find any significantly low pH levels. In subsequent years, some ASS hotspots began to emerge with ERM Mitchell McCotter Pty Ltd (1997) highlighting the Partridge Creek area as severely affected by ASS with low pH measurements exporting water to downstream ecosystems. Tulau (1999) listed Partridge Creek along with the Maria River and Rawdon Island as hot spots for ASS noting factors such as flushing and buffer capacity as key to the Hastings River ability to cope with acid runoff events. A number of investigations that followed highlighted the impact from drainage of ASS confirming the findings of Tulau (1999), and also finding that acid runoff was linked to rainfall events (Aaso, 2003; Bush et al., 2006; Dove and Sammut, 2013; Smith, 1999; Umwelt, 2000). To alleviate the impact of ASS at Partridge Creek a remediation program was completed in 2004 (Hastings Council, 2004). Subsequent investigations found that remediation efforts had effectively reduced the acid export from the system (Hastings Council, 2004; Johnston et al., 2014; Rothnie, N.D.). Some literature did indicate that the effects of remediation were not immediately evident (Bush et al., 2006). Numerous studies have suggested that the impacts of ASS is linked to the assimilation capacity of receiving waters (Dove, 2003; Dove and Sammut, 2013; Ryder et al., 2017; Smith, 1999). Continued monitoring of the pH levels within the estuary is continuing to assess environmental outcomes (NSW DPIE, 2019).

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

Study	Sampling dates	Location	Parameters	Findings
State Pollution Control Commission (1987)	October 1984, December 1984	Hastings River estuary	Nitrogen, phosphorus, non-filterable residue, volatile suspended solids, turbidity, electrical conductivity/salinity, pH, chlorphyll a, temperature, dissolved oxygen, Secchi depth, light penetration	No significantly low pH measurements were observed. High salinity levels were measured within the Hastings River to Sandy Point (>30ppt). Low nutrient levels were observed in the estuary. Dissolved oxygen levels were observed within guideline limits.
Manly Hydraulics Laboratory (1994)	August 1994	Maria River; Pipers Creek; Connection Creek	pH, salinity, temperature, dissolved oxygen, redox potential	No significantly low pH measurements were observed. Salinity levels of 6.0 ppt were measured at the most upstream monitoring location on Connection Creek.
ERM Mitchell McCotter Pty Ltd (1997)	April 1992 to December 1994; August 1996, November 1996	Partridge Creek	pH, chloride, sulfate, aluminium, iron, total dissolved solids, electrical conductivity, turbidity	Long term measurements collected by Port Macquarie – Hastings Council for pH showed fluctuations between 3 and 8. Measurements across the site indicated low pH levels and high aluminium and iron concentrations caused by the oxidisation of acid sulfate soils. It was found export of poor water quality from Partridge Creek was likely to impact downstream ecosystems.
Tulau (1999)	Not applicable	Hastings River estuary	Not applicable	Contains a literature review including multiple datasets that are not publicly available. Connection Creek and the Upper Maria River system were observed to have low pH and high aluminium concentrations resulting from acid sulfate soils in the absence of tidal buffering. The anabranch systems around Torrens and Fentons Islands were found to limit saline transport further upstream reducing buffering capacity for acidic water. The Lower Maria River (below its confluence with the Wilsons River) was found to have a large flushing, dilution and buffering capacity. It was estimated that 145 tonnes of sulfuric acid are exported from Partridge Creek each year. A moderate buffering capacity is expected around Rawdown Island where acid scalding has been observed. The Maria River, Partridge Creek and Rawdon Island were identified as acid sulfate soil hotspots.
Smith (1999)	18 to 19 June 1999	Hastings River estuary	Temperature, electrical conductivity/salinity, pH, oxidation reduction potential, dissolved oxygen, turbidity	There was a decrease in water quality with low pH levels further upstream along the Maria River. Acid discharges were observed across the Hastings River estuary corresponding with drainage infrastructure. Thompson Creek, Maria River, Pipers Creek and Partridge Creek and Fernbank Creek were identified as high acid drainage areas.
Umwelt (2000)	Not applicable	Hastings River estuary	Not applicable	Contains a literature review including multiple datasets that are not publicly available. Poor water quality with low pH across the estuary is linked to rainfall events following oxidisation of acid sulfate soils. The Maria River, Partridge Creek and Fernbank Creek were identified as sources of acidic water.
Dove (2003)	17 November 1997 to 30 March 1999	Hastings River; Limeburners Creek	pH, electrical conductivity, dissolved oxygen, temperature	Contains a literature review including multiple datasets that are not publicly available. No evidence was found for export of acid from acid sulfate soils in Limeburners Creek, however, a lowering in pH was attributed to other locations in the estuary.
Aaso (2003)	June 1999 to February 2000	Partridge Creek	pH, electrical conductivity	Contains a review of existing data available for the Partridge Creek area. Partridge Creek was shown to continuously discharge acidic water in the range of 2.9 to 4.0. The main source of acid discharge during rainfall events was from a scald adjacent to Françoise Drain.
Hastings Council (2004)	Not specified	Partridge Creek	pH	Acid flux was modelled for conditions prior to remediation works indicating a ~70% reduction in acid export compared to measurements of current export rates.
Ashley and Napier (2005)	Not specified	Kooloonbung Creek	pH, electrical conductivity, copper, lead, zinc, cadmium, arsenic, antimony, iron, manganese, chromium, nickel, aluminium, sulphur	There is little evidence of acidification of soils or development of iron oxides as a result in the Kooloonbung area.
Department of Environment and Conservation NSW (2006)	April 2005	Maria River	pH, dissolved oxygen	Acidic and anoxic conditions were observed on the Maria River.
Bush et al. (2006)	1/03/2002 to 22/07/2005;	Maria River; Partridge Creek	pH, electrical conductivity, dissolved oxygen, oxidation reduction potential, temperature	Persisting low dissolved oxygen and low pH levels were measured on the Maria River. Observations did not show an immediate improvement in pH following remediation works at Partridge Creek

Study	Sampling dates	Location	Parameters	Findings
Port Macquarie-Hastings Council (2007)	1998 to 2007	Hastings River estuary	Nitrogen, phosphorus, chlorophyll a, dissolved oxygen, suspended solids, pH, salinity	Nutrient loads can be linked to catchment runoff events. Poor water quality was more frequent resulting from nutrients than physiochemical parameters. There is a reduction in poor water quality resulting from physiochemical parameters.
Roper et al. (2010)	1970 to 2008	Hastings 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 Hastings 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 Hastings River was given a 'moderate' rating (along with 42% of all estuaries, 6% of estuaries were given a 'high' rating and no estuaries were 'very high').
Rothnie (N.D.)	Not specified	Partridge Creek	Temperature, electrical conductivity, pH, oxidation reduction potential, dissolved oxygen, iron, bicarbonate	Measurements indicated that remediation works had differing outcomes at different locations across the site.
Ryder et al. (2012)	January 2011 to December 2011	Hastings River estuary	pH, temperature, electrical conductivity/salinity, dissolved oxygen, turbidity, Secchi depth, chlorophyll a, total suspended solids, nitrogen, phosphorus,	Nitrogen loads were found to be highest further downstream in the estuary, however, it corresponded with high flow events suggesting a catchment source. High phosphorus loads were found throughout the estuary and correlated to low flow events. Chlorophyll a levels indicated excess algal biomass only in the Hastings River. Low dissolved oxygen was found to occur during low flow and warmer temperature events. Acid levels and aluminium loading was observed to occur following high flow events.
Dove and Sammut (2013)	18 to 19 June 1999; 29 to 30 November 1999; 1 to 2 December 2000; 12 to 13 February 2001	Hastings River estuary	pH, electrical conductivity, temperature, iron, aluminium, manganese, silicon, zinc, sulfate, chloride	Acidification events were observed at upstream sections of the Hastings River and in the Maria River following rainfall events. Increases in acidity were attributed to poor buffering capacity, floodgates and high drainage density.
Johnston et al. (2014)	January 2004 to March 2006; July 2012 to April 2013	Partridge Creek	pH, electrical conductivity, redox potential	Restoration efforts have resulted in an increase in pH being discharged from the wetland by 2 to 3 pH units. The average pH has increased from approximately 3 or 4 to >5.5.
Ryder et al. (2017)	May 2014 to June 2015	Hastings River estuary	pH, temperature, electrical conductivity/salinity, dissolved oxygen, turbidity, Secchi depth, nitrogen, phosphorus, chlorophyll a, total suspended solids	The poorest water quality was observed at the tidal limit of the estuary. Observations indicated pH, dissolved oxygen and phosphorus contributed to poor water quality during prolonged periods of low flows. Elevated levels of nitrogen were observed across the estuary.
NSW Food Authority (2019)	2000 to 2019	Limeburners Creek; Big Bay; Hastings River; Rawdon Island	Salinity, temperature	Average salinity was recorded as 29 ppt with a 10th percentile of 20.1 ppt and 90th percentile of 34 ppt.
NSW DPIE (2019)	2007 to 2019	Hastings River	Secchi depth, temperature, electrical conductivity (salinity), turbidity, chlorophyll a, colour, nitrogen, phosphorus, pH, CDOM, fDOM, dissolved oxygen, blue green algae, silicon	Salinity measurements varied from 0 ppt to 30 ppt. pH measurements varied from 7.2 to 9.2. Dissolved oxygen measurements varied from 72.6% to 124.1%.

H4 Field investigations

During field investigations, surface water and groundwater water quality measurements were opportunistically collected at various locations across the Hastings 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., 2023).

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 Hastings River floodplain. Surface water quality measurements for the Hastings River floodplain are presented in Figure H-1 and Figure H-2 for pH and electrical conductivity, respectively. Groundwater quality measurements for the Hastings River floodplain are presented in Figure H-3 and Figure H-4 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)
060G1	5/03/2020	490410	6543507	3.8	4,492	3.7	4,478
061G1	5/03/2020	490827	6543605	5.7	4,320	5.6	4,377
062G1	5/03/2020	491276	6543801	3.2	3,268		
064G1	5/03/2020	492658	6546332	5.3	5,944	5.4	6,402
065G1	5/03/2020	493738	6547444	5.2	3,914		
066G1	5/03/2020	494094	6548191	5.4	3,494	5.2	3,583
067G1	5/03/2020	494497	6549528	5.5	1,838	5.4	1,789
076G1	4/03/2020	487687	6541204			3.1	3,548
078G1	5/03/2020	488570	6542033	4.0	4,905		
ASSS_17	18/09/2019	485361	6525277			7.3	51,500
ASSS_19	18/09/2019	485724	6524471	7.3	50,800		
ASSS_27	26/09/2019	489750	6526670	7.1	53,667	7.6	56,562
ASSS_28	26/09/2019	489845	6526392	7.8	56,602	7.6	56,562
ASSS_38	26/09/2019	485171	6536249	7.0	38,540	7.0	38,540
ASSS_39	26/09/2019	485642	6536892	7.1	38,826	7.1	38,826
ASSS_40	26/09/2019	485945	6535363	7.0	34,656	7.0	34,656
ASSS_45	26/09/2019	486152	6530921	5.0	13,850	6.9	46,592
ASSS_61	20/09/2019	478331	6524668	7.1	41,270		
FMS_15	17/09/2019	475962	6517586	7.6	34,000		
FMS_26	25/09/2019	483518	6525690	7.4	51,439	7.6	51,142

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)
FMS_5	17/09/2019	476676	6518476	7.2	38,900		
WRL_HA_01	18/09/2019	485568	6525270	7.3	51,500		
WRL_HA_03	26/09/2019	485653	6536887	6.9	38,992	6.9	38,992
WRL_HA_04	5/03/2020	484314	6530335	5.8	2,026		
WRL_HA_05	26/09/2019	485940	6535365			7.0	34,656
WRL_HA_08	25/09/2019	484614	6540177			2.7	12,334

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)
HA_17_A	19/09/2019	486145	6524157	7.6	55,700
HA_14_P	19/09/2019	482496	6523954	6.3	42,532
HA_36_P	20/09/2019	478246	6526322	7.6	47,500
HA_45_P	18/09/2019	483854	6523322	5.2	2,200
HA_19_P	17/09/2019	478183	6518800	6.8	39,100
HA_06_P	27/09/2019	489483	6545293	6.6	23,686
HA_24_A	24/09/2019	479170	6523079	4.4	29,564
HA_43_P	26/09/2019	486057	6531276	6.8	7,620
HA_16_A	19/11/2019	483502	6525932	6.7	50,427
HA_04_PA	31/01/2020	494274	6548234		32,473
HA_29_PA	28/01/2020	483540	6532060	7.7	27,541
HP_11_C	4/03/2020	487046	6534686	5.1	1,750
HA_37_X	5/03/2020	481712	6525301	5.6	353

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)
HA_17_A	19/09/2019	486145	6524157	4.5	2,485
HA_25_P	19/09/2019	484935	6523853	5.3	3,160
HA_14_P	19/09/2019	482496	6523954	5.7	21,282
HA_01_P	20/09/2019	478202	6524666	5.7	39,124
HA_40_P	18/09/2019	485363	6525339	5.9	15,000
HA_45_P	18/09/2019	483854	6523322	5.9	7,450
HA_24_P	18/09/2019	485548	6524685	5.0	22,500
HA_19_P	17/09/2019	478183	6518800	4.1	20,600
HA_34_P	17/09/2019	476519	6518424	6.2	729
HA_20_P	17/09/2019	475869	6518358	4.4	3,325
HA_33_P	17/09/2019	475859	6517570	4.6	14,906
HA_21_P	16/09/2019	480494	6524800	3.3	25,500
HA_35_P	16/09/2019	479088	6525550	4.7	25,400
HA_03_A	24/09/2019	487607	6547304	4.7	2,296
HA_06_P	27/09/2019	489483	6545293	6.0	6,350
HA_07_P	25/09/2019	484605	6540165	3.9	7,007
HA_10_P	26/09/2019	486050	6536299	4.7	17,598
HA_13_P	26/09/2019	489990	6526656	5.8	24,145
HA_24_A	24/09/2019	479170	6523079	4.2	3,463
HA_46_P	25/09/2019	483783	6526231	4.4	11,571
HA_35_A	19/11/2019	480540	6525580	6.5	974
HA_04_PA	31/01/2020	494274	6548234		2,577
HA_29_AA	31/01/2020	476496	6522197		23,786
HA_29_PA	28/01/2020	483540	6532060	3.8	11,409
HP_11_C	4/03/2020	487046	6534686	4.2	17,070
HA_38_C	4/03/2020	487710	6541317	3.9	19
HA_37_X	5/03/2020	481712	6525301	5.6	492

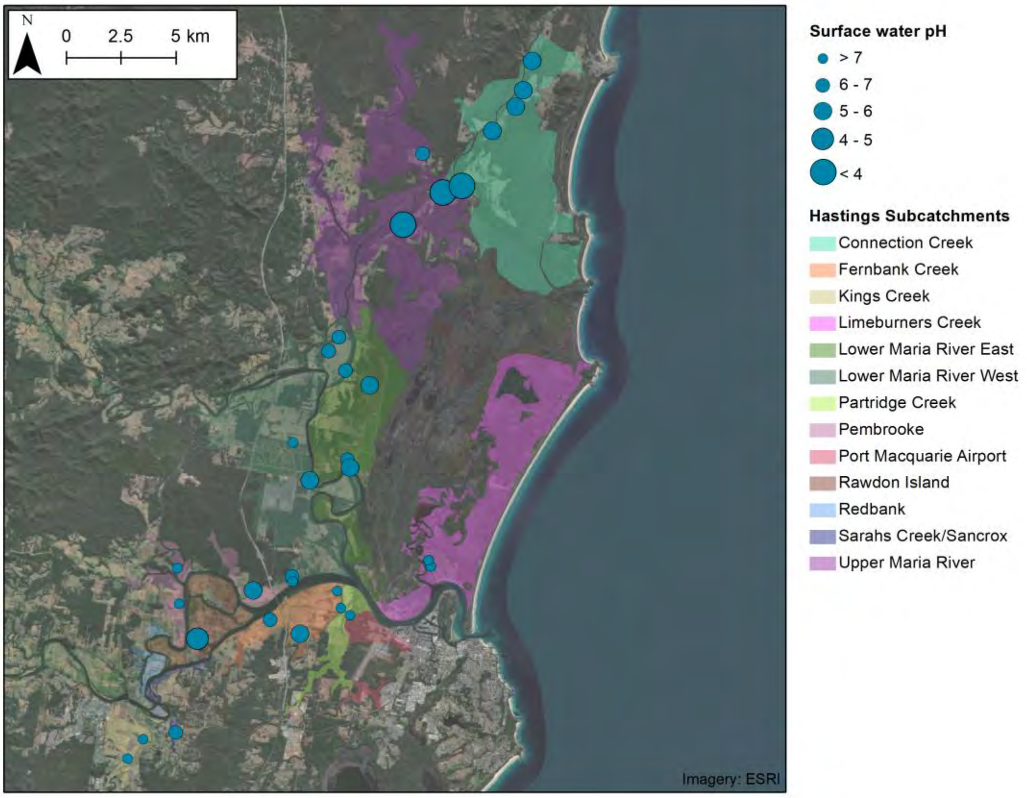

Figure H-1: Surface water pH measurements taken across the Hastings River floodplain

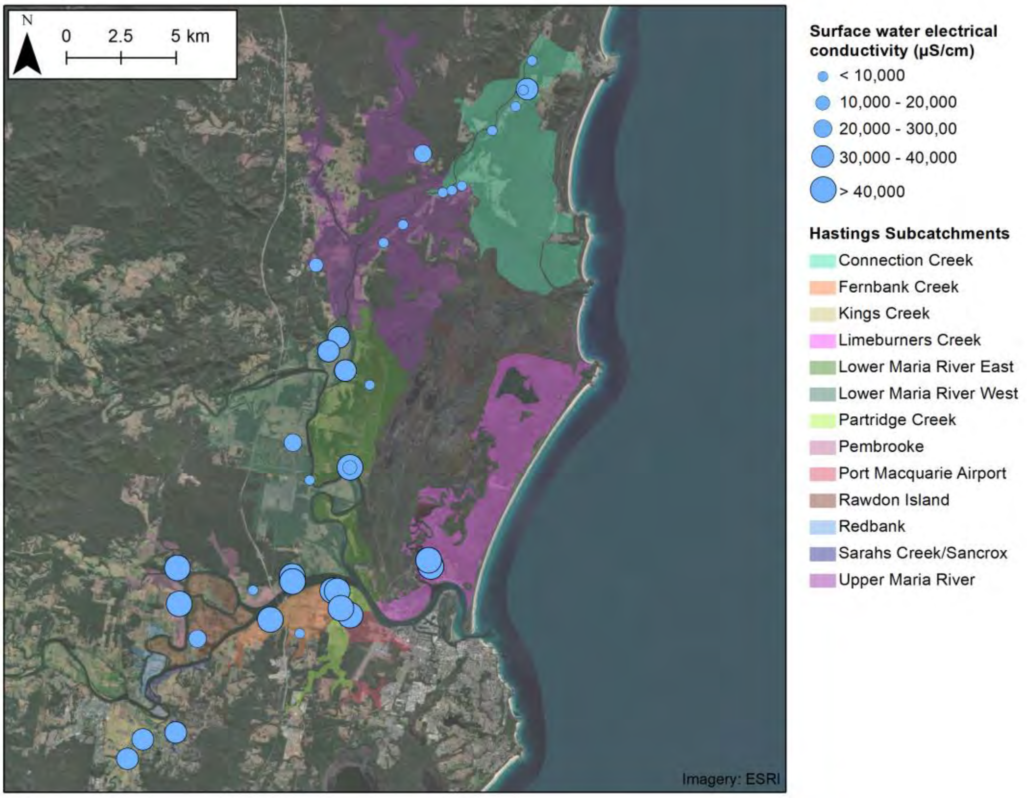

Figure H-2: Surface water electrical conductivity measurements taken across the Hastings River floodplain

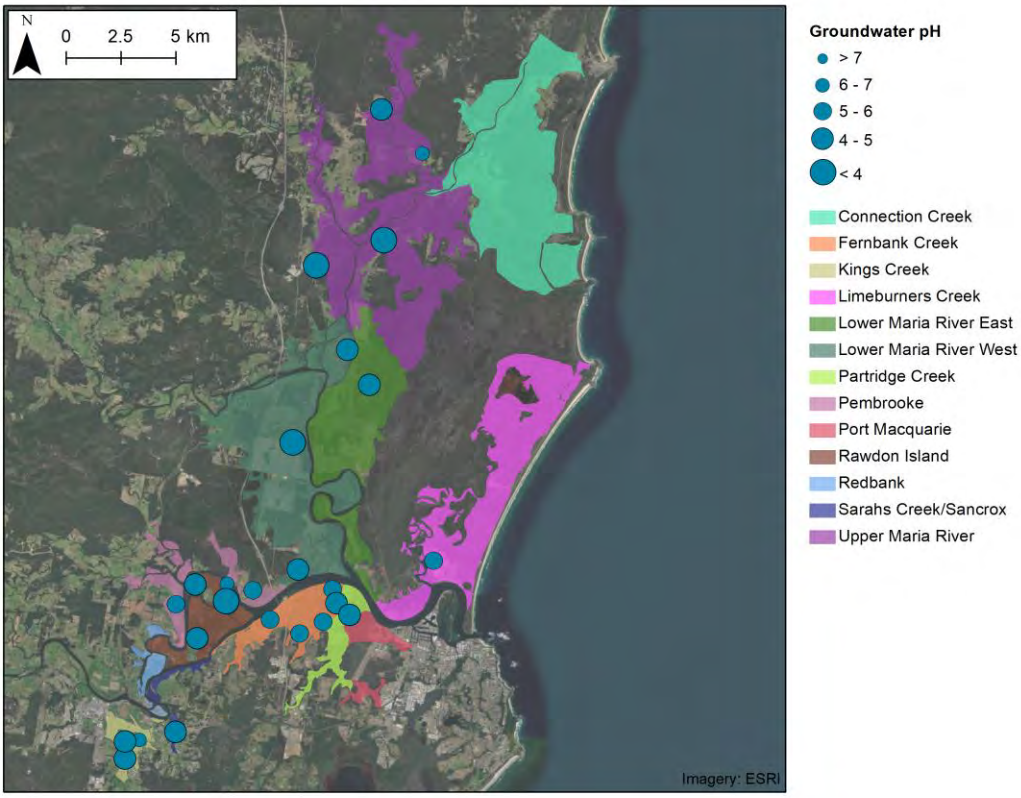

Figure H-3: Groundwater pH measurements taken across the Hastings River floodplain

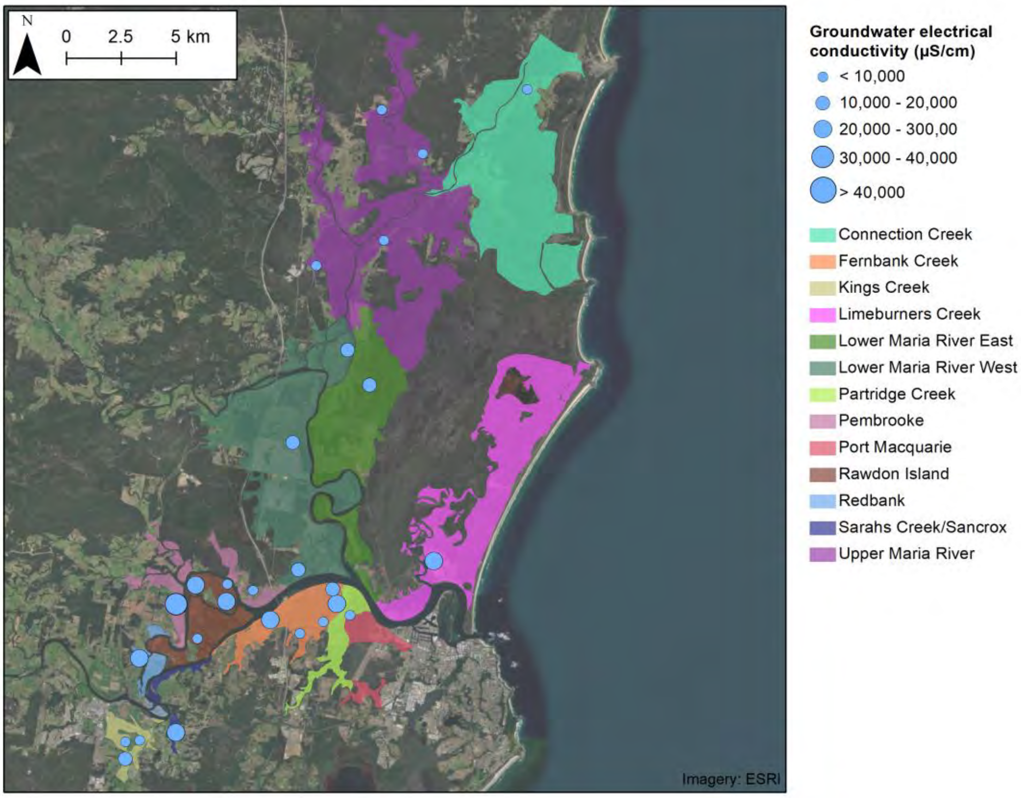

Figure H-4: Groundwater electrical conductivity measurements taken across the Hastings River floodplain

Appendix I Hydrodynamic modelling

I1 Preamble

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

I2 Hydrodynamic model

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

I2.1 Numerical model

Numerical modelling of the Hastings 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-1:

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

Equation I-1

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

I2.2 Model domain

A 2-D RMA-2 hydrodynamic model of the Hastings River floodplain was adopted from the most recent work of (Advisian, 2019). This RMA model was previously calibrated and verified using historic flood mark information and had been adopted for a range of recent studies including the Hibbard Precinct Flood Study (2019), Hastings River floodplain Risk Management Study (2012) as well as various studies associated with the Pacific Highway Upgrade (2007 onwards) (Advisian, 2019). The model covered the entire Hastings River floodplain, extending to the tidal limits of most of the major rivers, tributaries and creeks in the estuary, including the Hasting River, Maria River, Limeburners Creek and Kings Creek.

For this study, the previously developed numerical model of the Hastings River estuary was modified to simulate the typical tidal water level variations within the estuary. The floodplain hydrodynamic model was cropped to only include the main flow channels up to 2 m AHD. This was done primarily to reduce model simulation time since the tidal hydrodynamic model would be simulated for longer periods (i.e. annual time cycles) as opposed to a flood model which is simulated for a much shorter duration (i.e. days or weeks). The model was also extended using 1-D elements to simulate tidal currents through Maria River upstream of Gulgini. This was done to ensure the model extent covered all areas of interest for this study. The updated Hastings River estuary RMA-2 hydrodynamic model used for this study is shown in Figure I-1.

Figure I-1: Hastings River estuary – tidal hydrodynamic model extent

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 Hastings River and its tributaries was based on the hydrodynamic model developed by Advisian (2019). The model resolution and bathymetry from this study was slightly modified based on single beam bathymetry data sourced from NSW Office of Heritage (OEH) for downstream areas near the Hasting River entrance. This was done to improve the representation of the shoals and flow pathways from the ocean entrance into the Hastings River. The bathymetry dataset was also used to define the extended sections of the model at Maria River upstream of Gulgini as discussed above.

Catchment inflows were based on observed river flow data from WaterNSW gauging stations in the upper Hastings 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 done 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 MHL station at Port Macquarie (station number 207420).

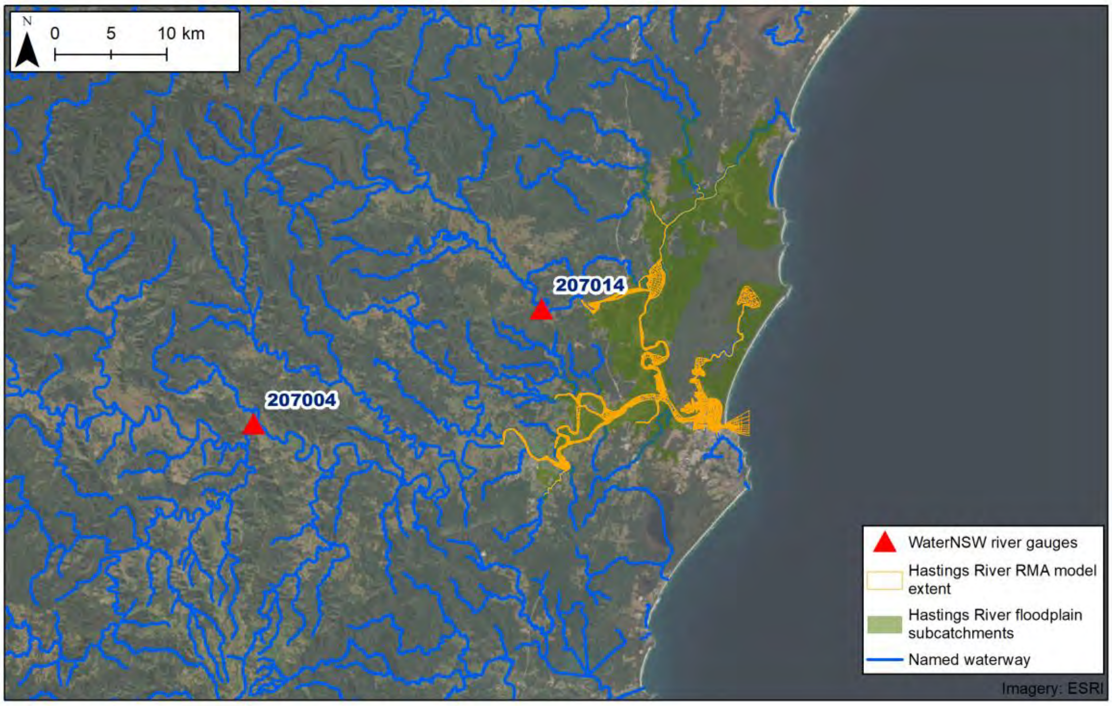

Figure I-2: Location of WaterNSW river flow gauges with relation to the hydrodynamic model extent

Table I-1: Summary of model boundary conditions

Gauging Station Name	Data Source	Station Number	Scale Factor
Hasting River at Ellenborough	WaterNSW	207004	1.478
Wilson at Avenal	WaterNSW	207014	1.020
Port Macquarie	MHL	207420	NA

I2.4 Model calibration

The hydrodynamic model for the Hastings River estuary was calibrated to selected water level and tidal flow gauging stations for 1999. The year 1999 was selected based on short-term tidal flow gauging of the Hastings River estuary which was recorded at various locations within the estuary on 24 October 1999 (MHL, 1999). 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 the value of 0.023 was adopted for the main channel and 0.075 was adopted for floodplain areas with dense vegetation to achieve final calibrations.

The flow calibration results are shown in Figure I-5 to Figure I-14. The water level calibration results for a 10-day window during this period are shown in Figure I-15 to Figure I-19. The model was calibrated (for dry weather periods) to less than 0.1 m for the entire estuary.

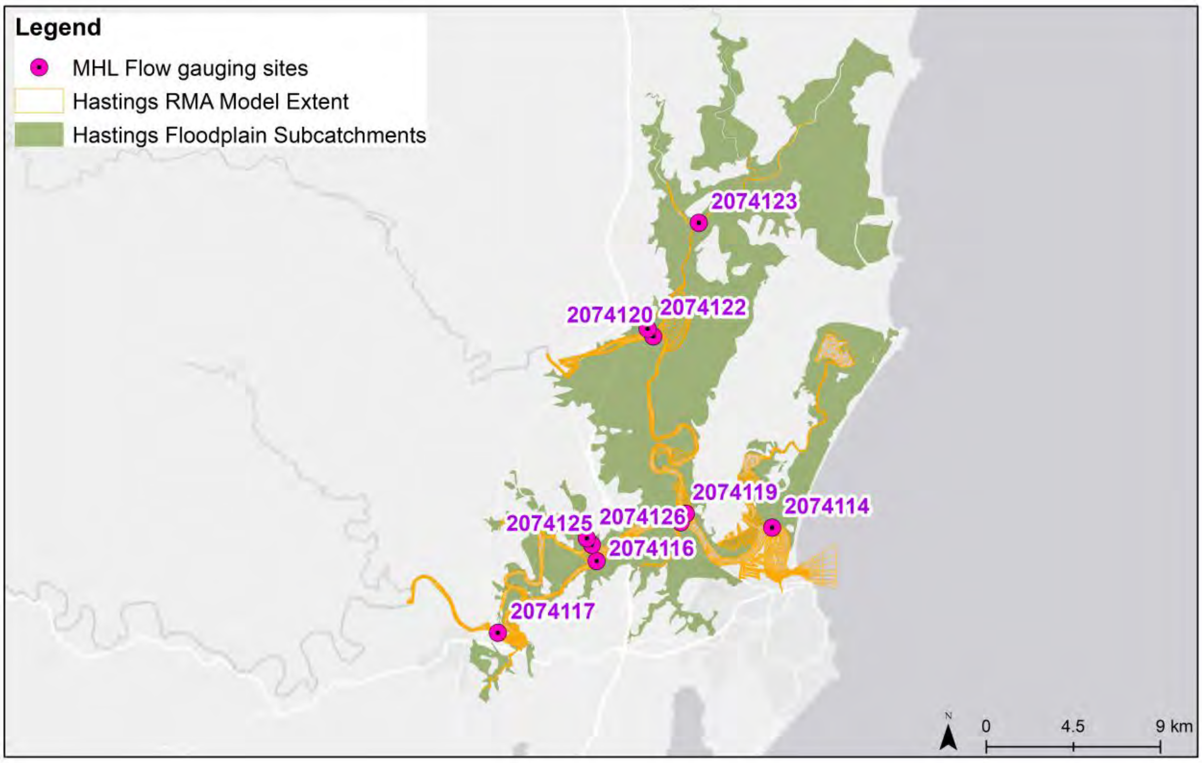

Figure I-3: Location of selected tidal flow gauging stations used for calibration of the Hastings River estuary hydrodynamic model

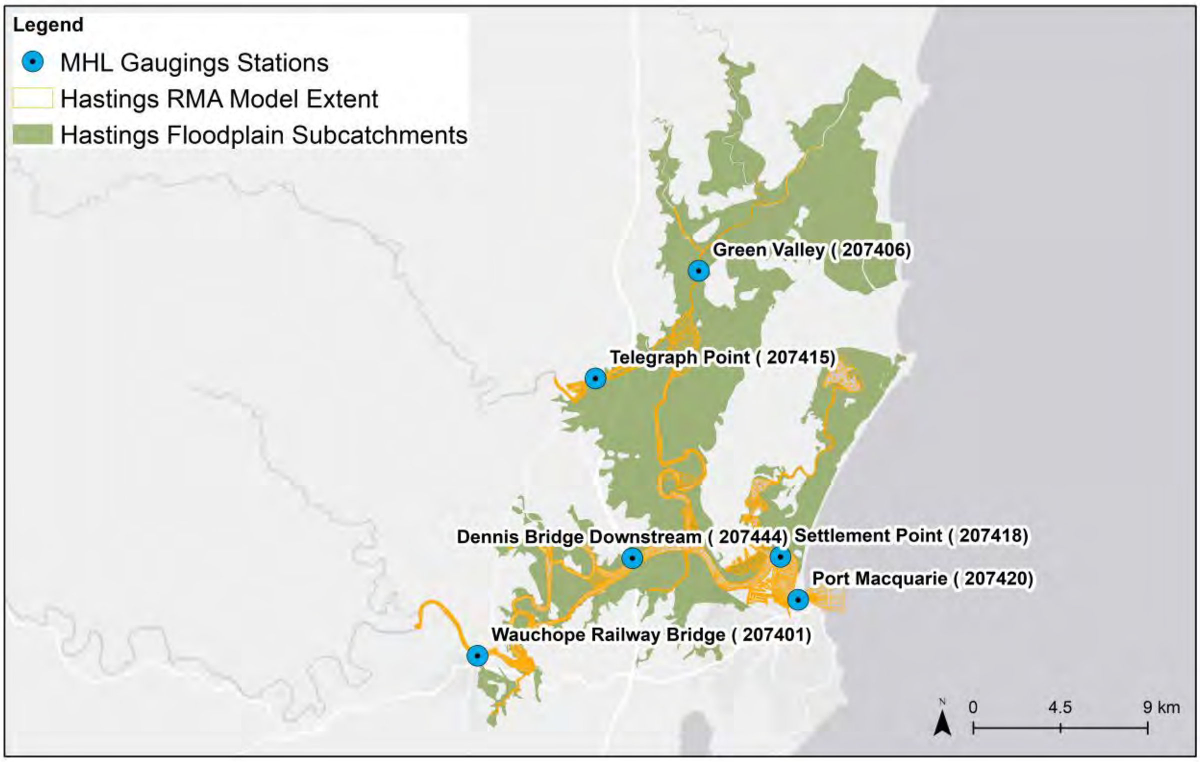

Figure I-4: Location of selected water level stations used for calibration of the Hastings River estuary hydrodynamic model

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. 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 20-day window for the Hastings River estuary for 2013 and 2019 are provided in Figure I-20 to Figure I-29.

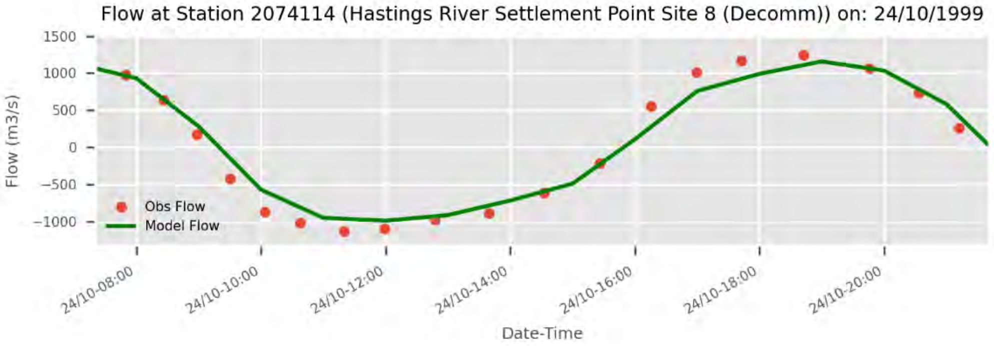

Figure I-5: Hastings hydrodynamic model flow calibrations at Station 2074114

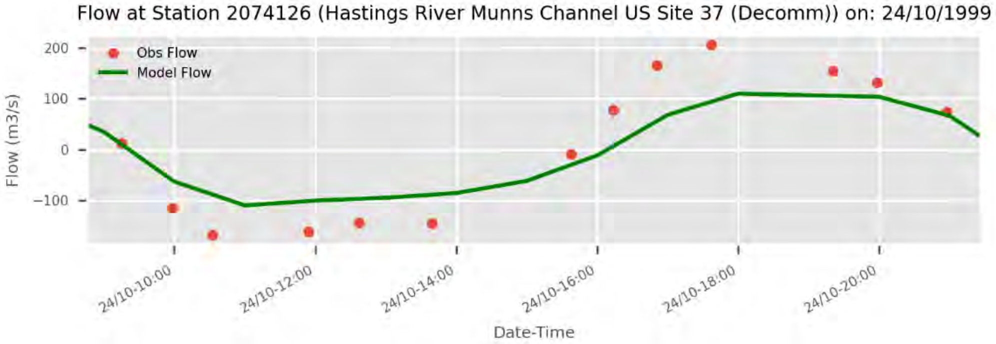

Figure I-6: Hastings hydrodynamic model flow calibrations at Station 2074126

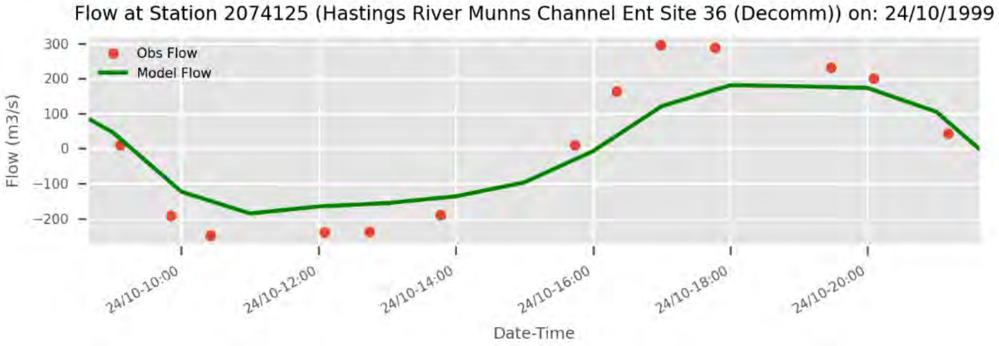

Figure I-7: Hastings hydrodynamic model flow calibrations at Station 2074125

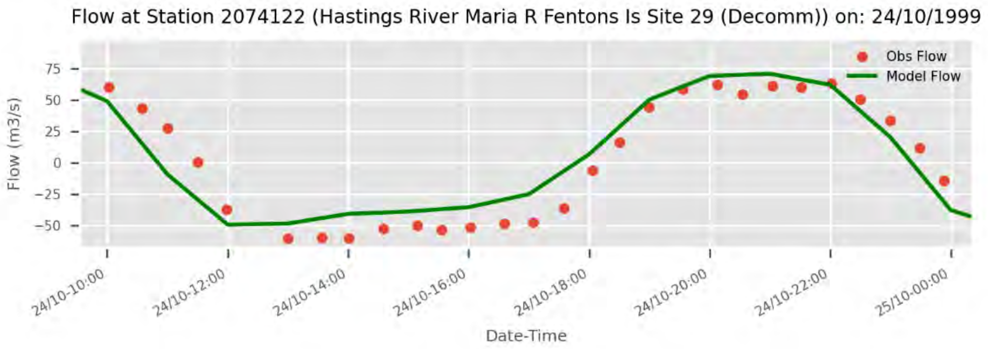

Figure I-8: Hastings hydrodynamic model flow calibrations at Station 2074122

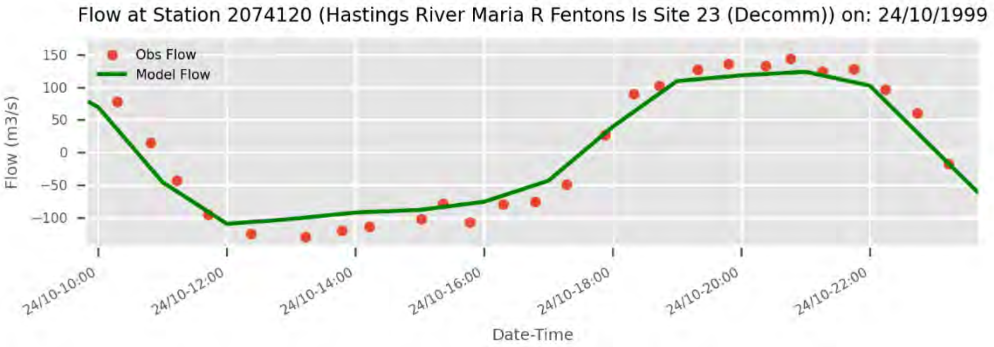

Figure I-9: Hastings hydrodynamic model flow calibrations at Station 2074120

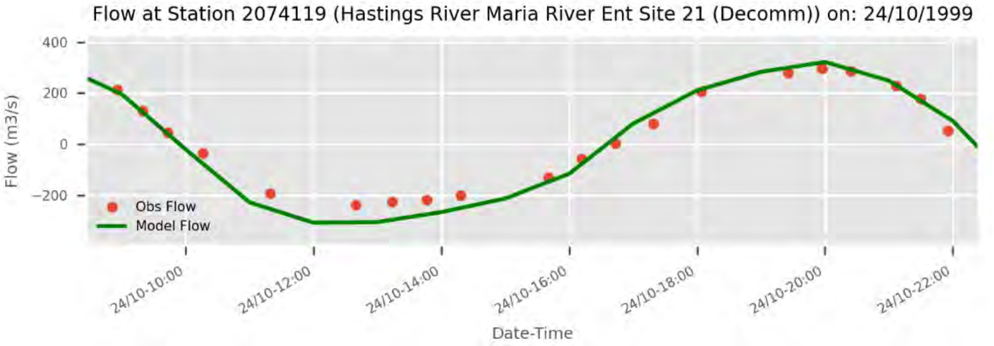

Figure I-10: Hastings hydrodynamic model flow calibrations at Station 2074119

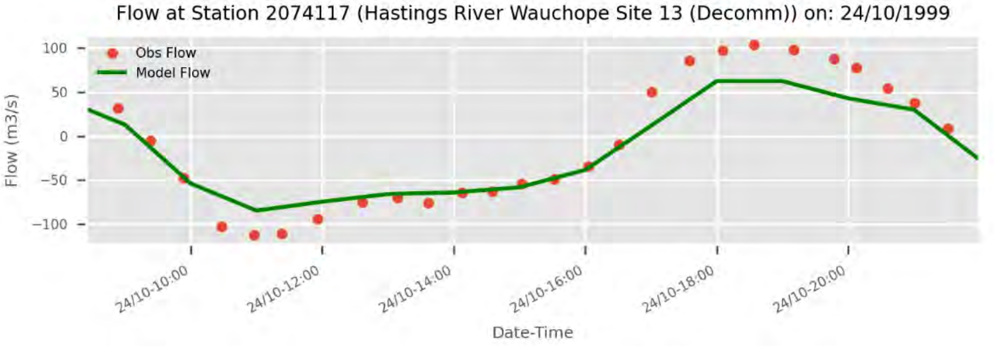

Figure I-11: Hastings hydrodynamic model flow calibrations at Station 2074117

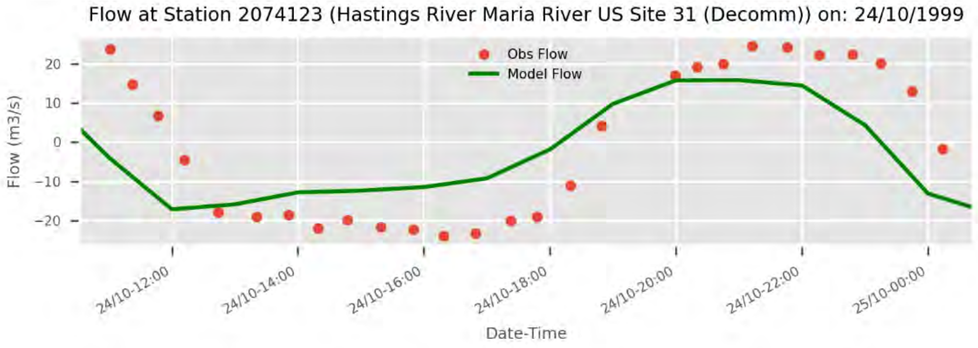

Figure I-12: Hastings hydrodynamic model flow calibrations at Station 2074123

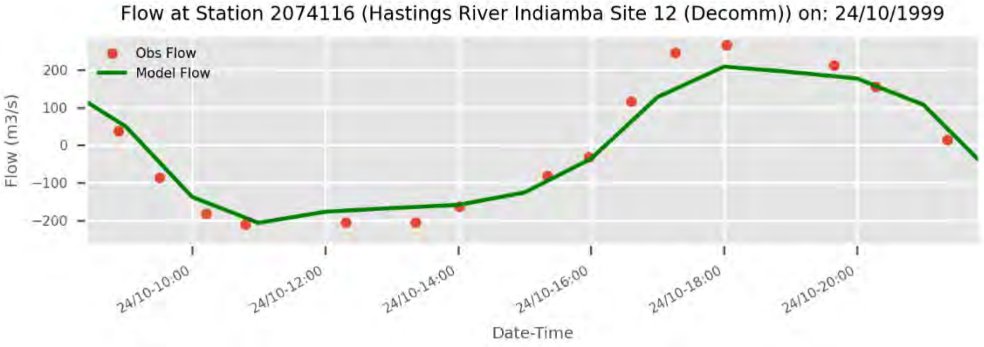

Figure I-13: Hastings hydrodynamic model flow calibrations at Station 2074116

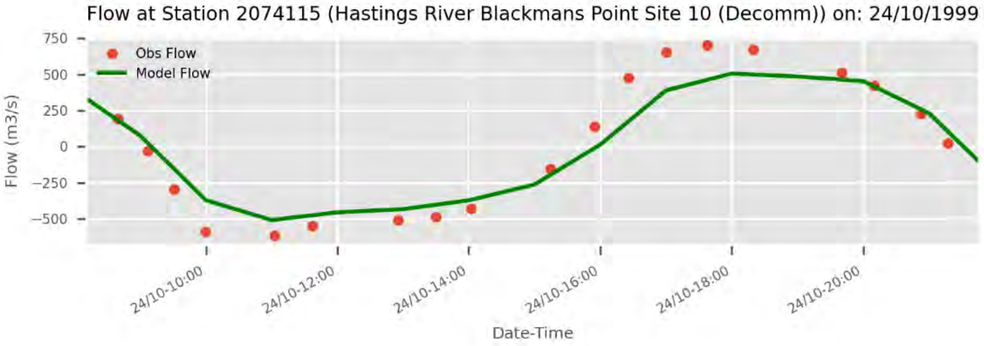

Figure I-14: Hastings hydrodynamic model flow calibrations at Station 2074115

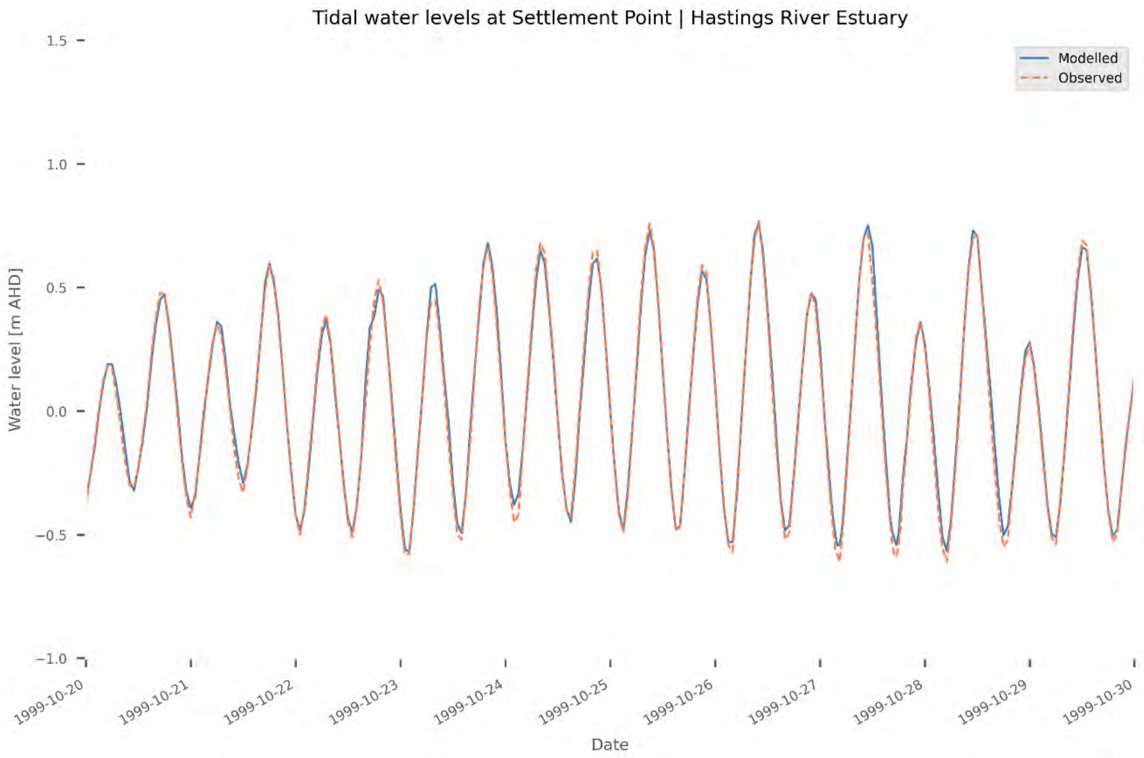

Figure I-15: Hastings hydrodynamic model calibration results at Settlement Point (207418)

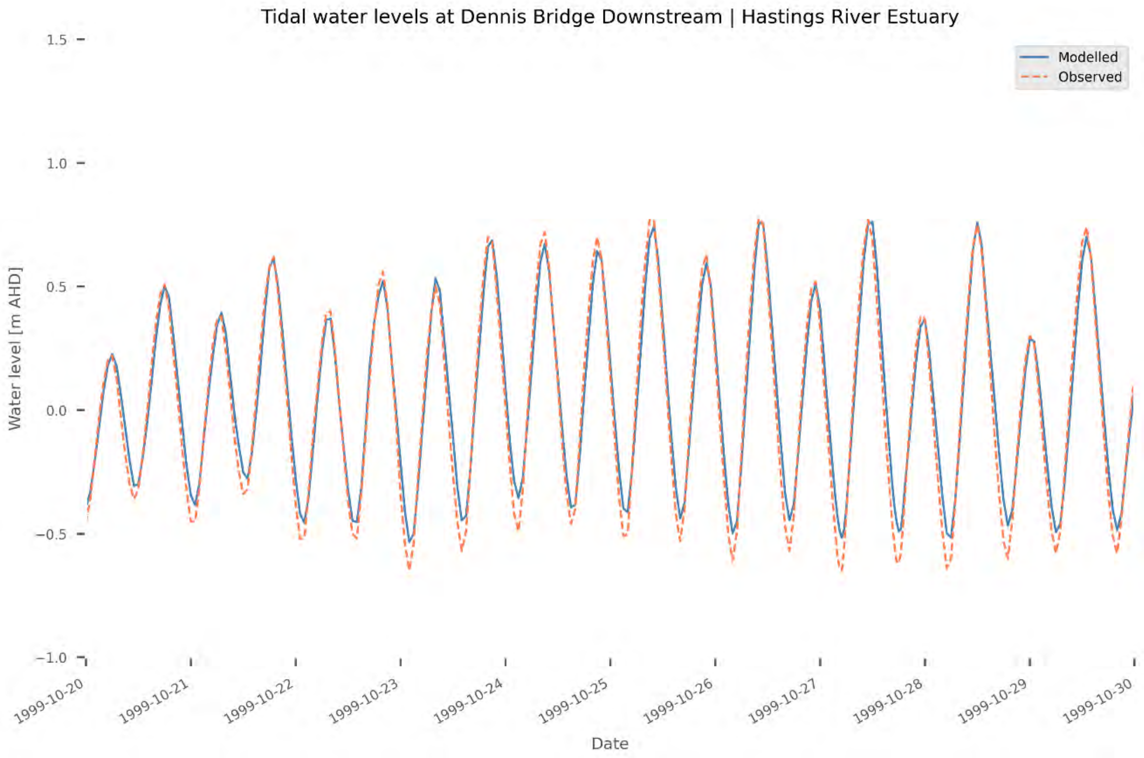

Figure I-16: Hastings hydrodynamic model calibration results at Dennis Bridge Downstream (207444)

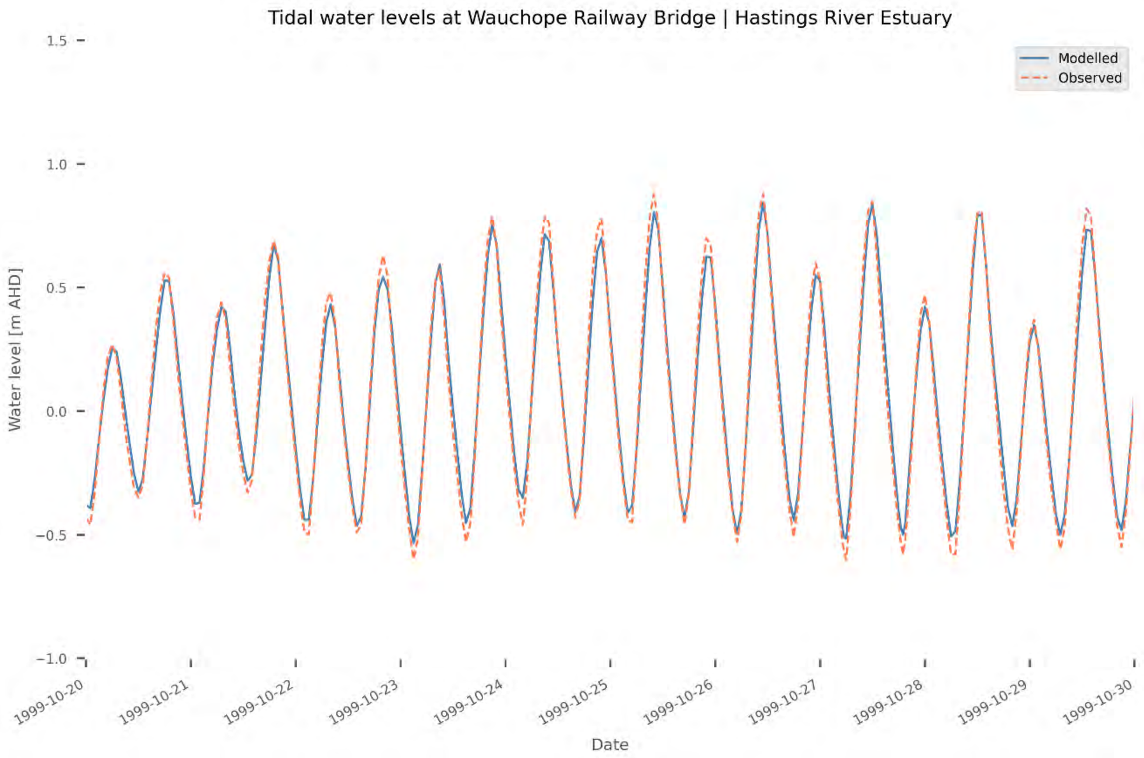

Figure I-17: Hastings hydrodynamic model calibration results at Wauchope Railway Bridge (207401)

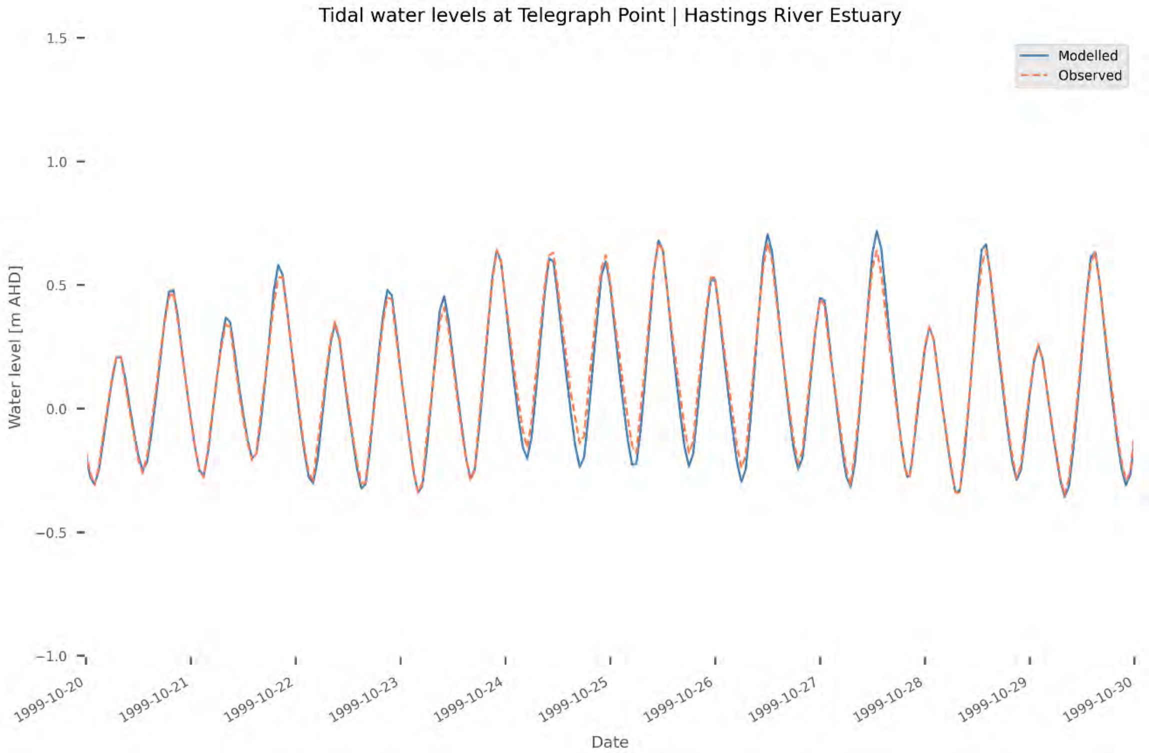

Figure I-18: Hastings hydrodynamic model calibration results at Telegraph Point (207415)

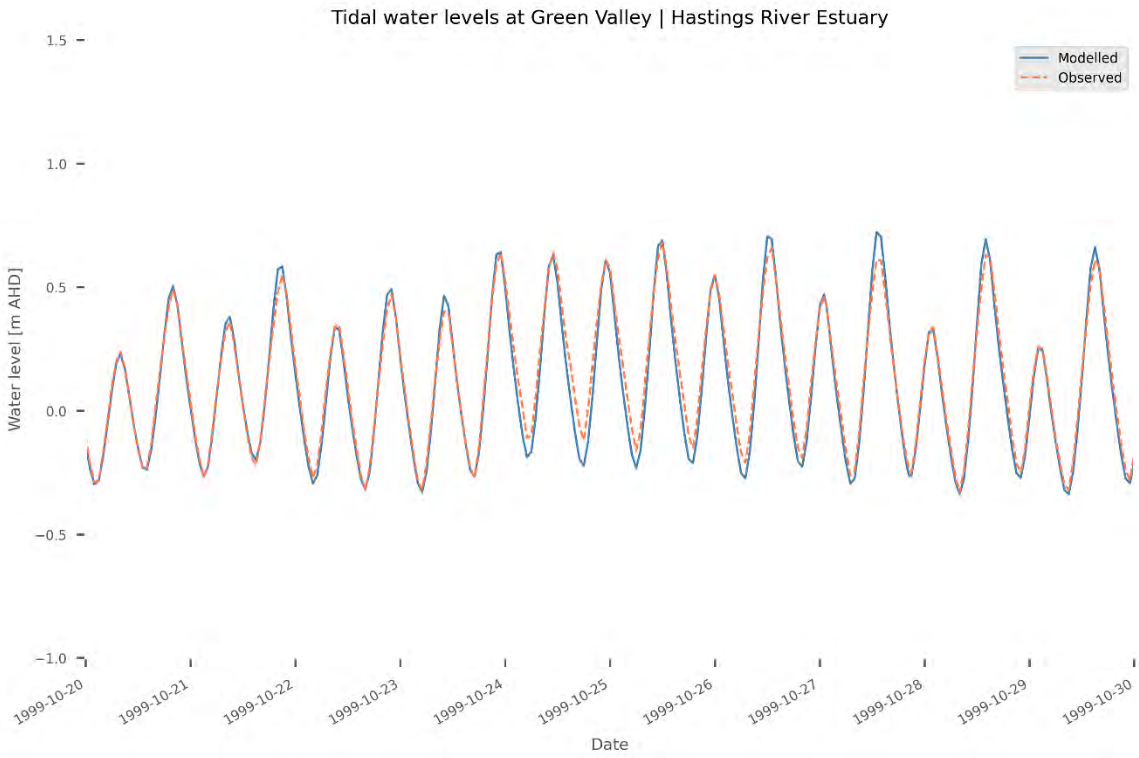

Figure I-19: Hastings hydrodynamic model calibration results at Green Valley (207406)

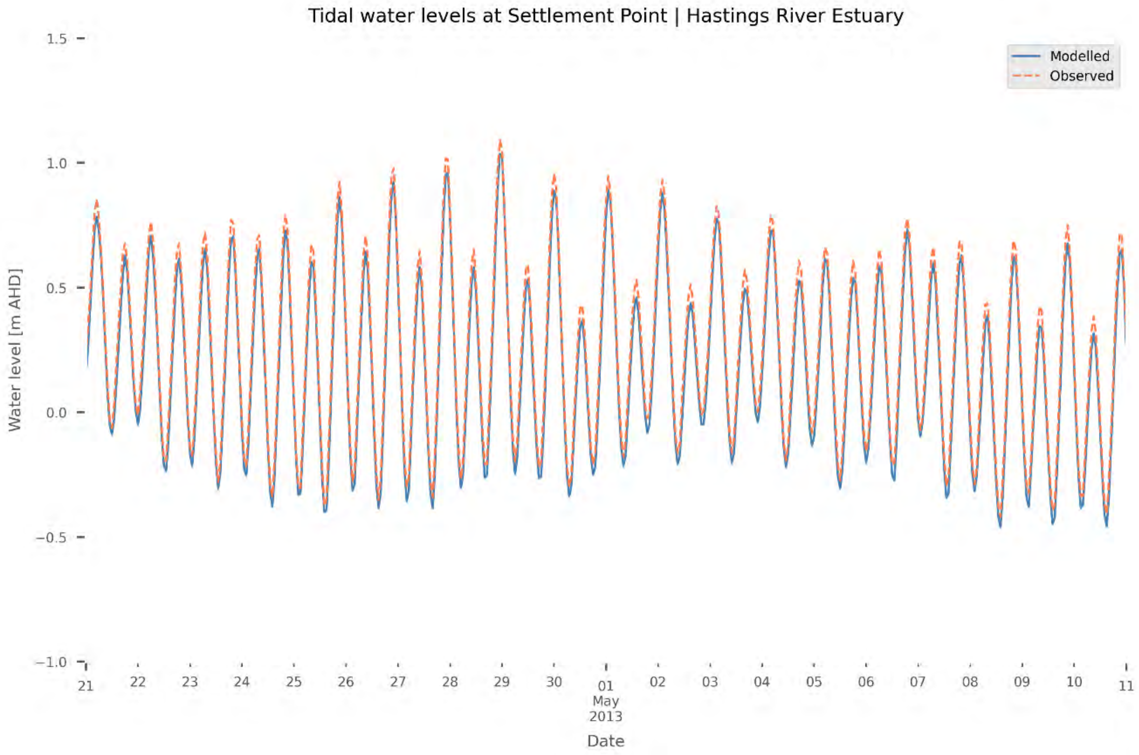

Figure I-20: Hastings hydrodynamic model verification results (2013) at Settlement Point (207418)

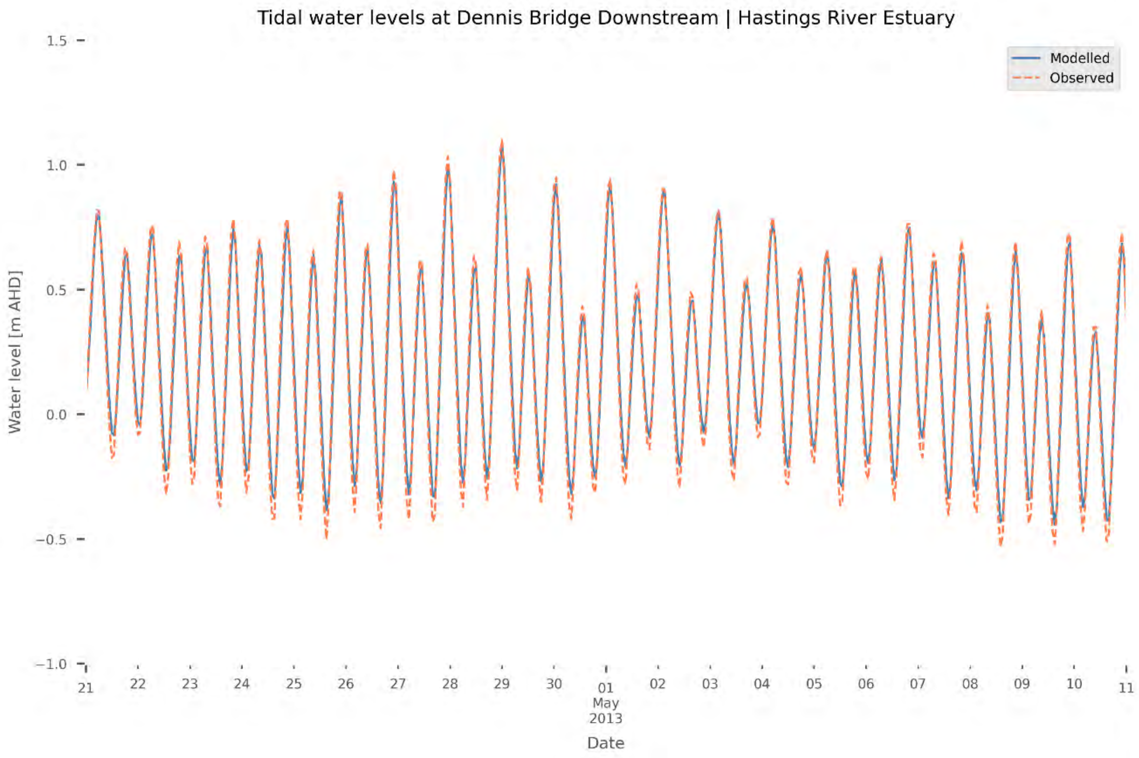

Figure I-21: Hastings hydrodynamic model verification results (2013) at Dennis Bridge Downstream (207444)

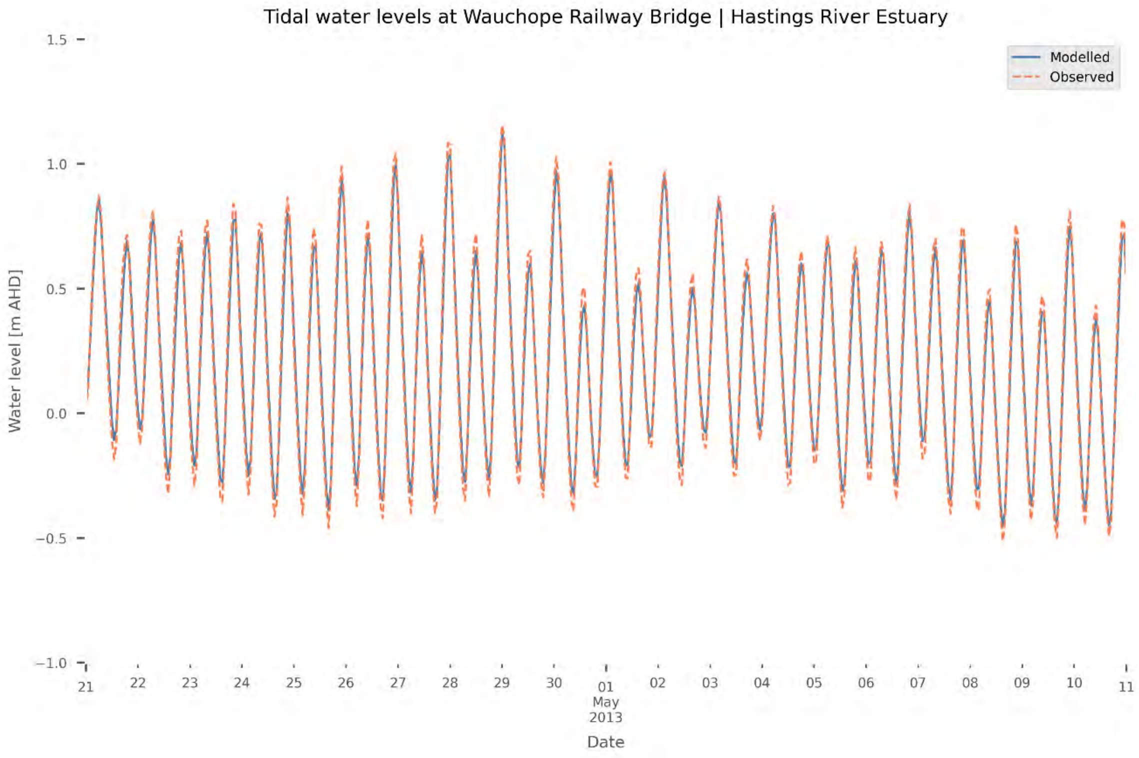

Figure I-22: Hastings hydrodynamic model verification results (2013) at Wauchope Railway Bridge (207401)

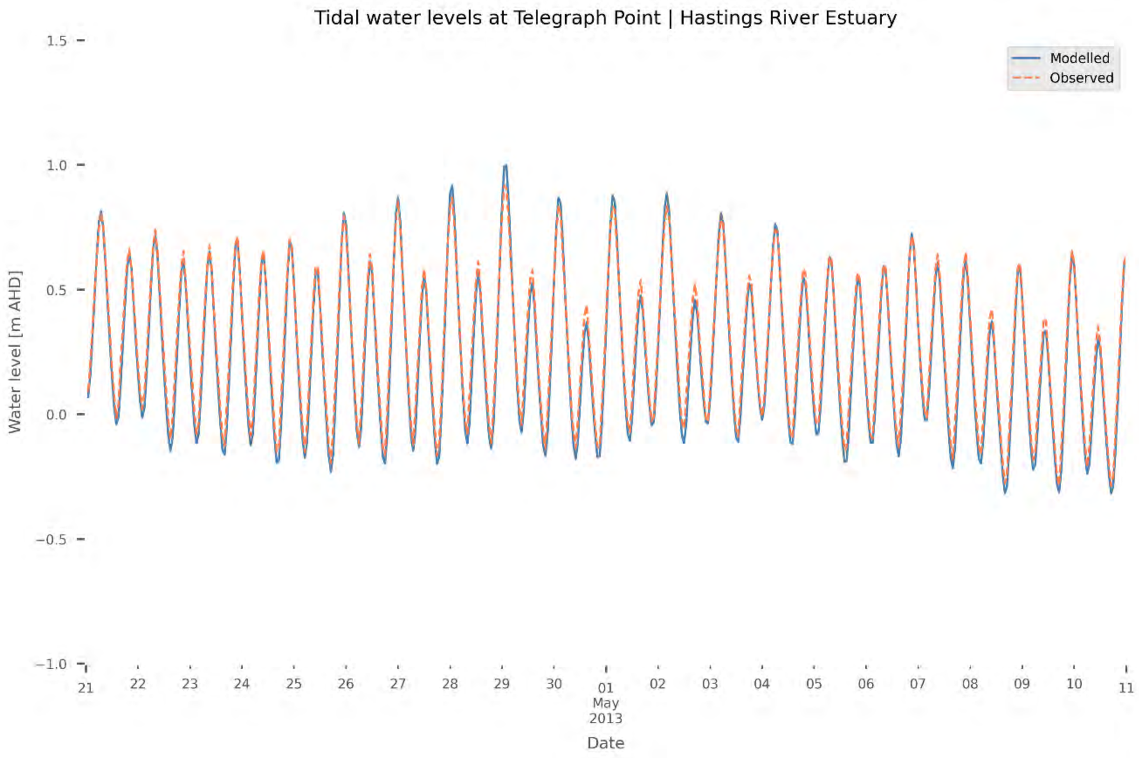

Figure I-23: Hastings hydrodynamic model verification results (2013) at Telegraph Point (207415)

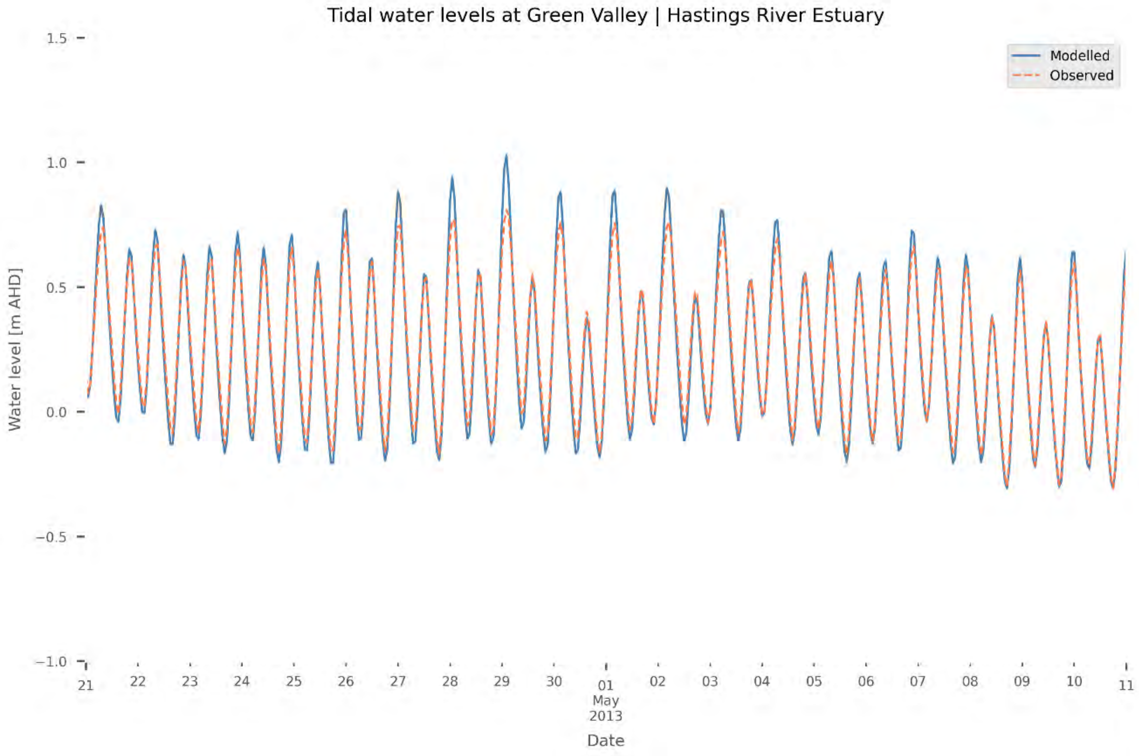

Figure I-24: Hastings hydrodynamic model verification results (2013) at Green Valley (207406)

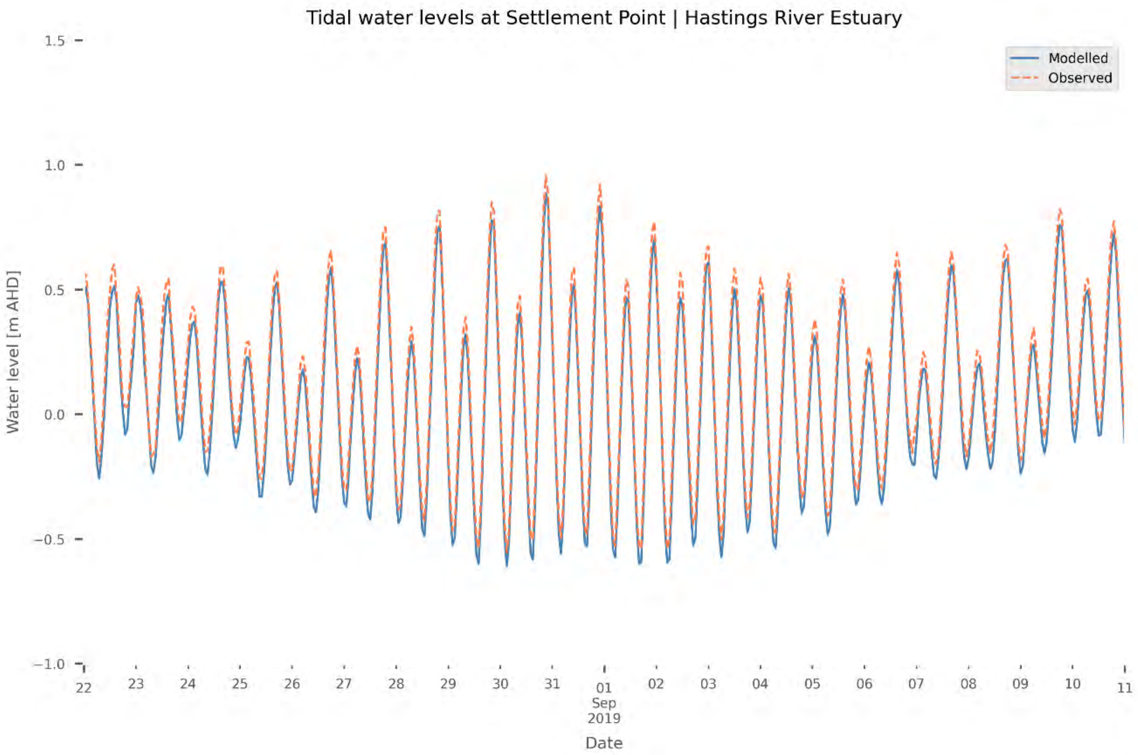

Figure I-25: Hastings hydrodynamic model verification results (2019) at Settlement Point (207418)

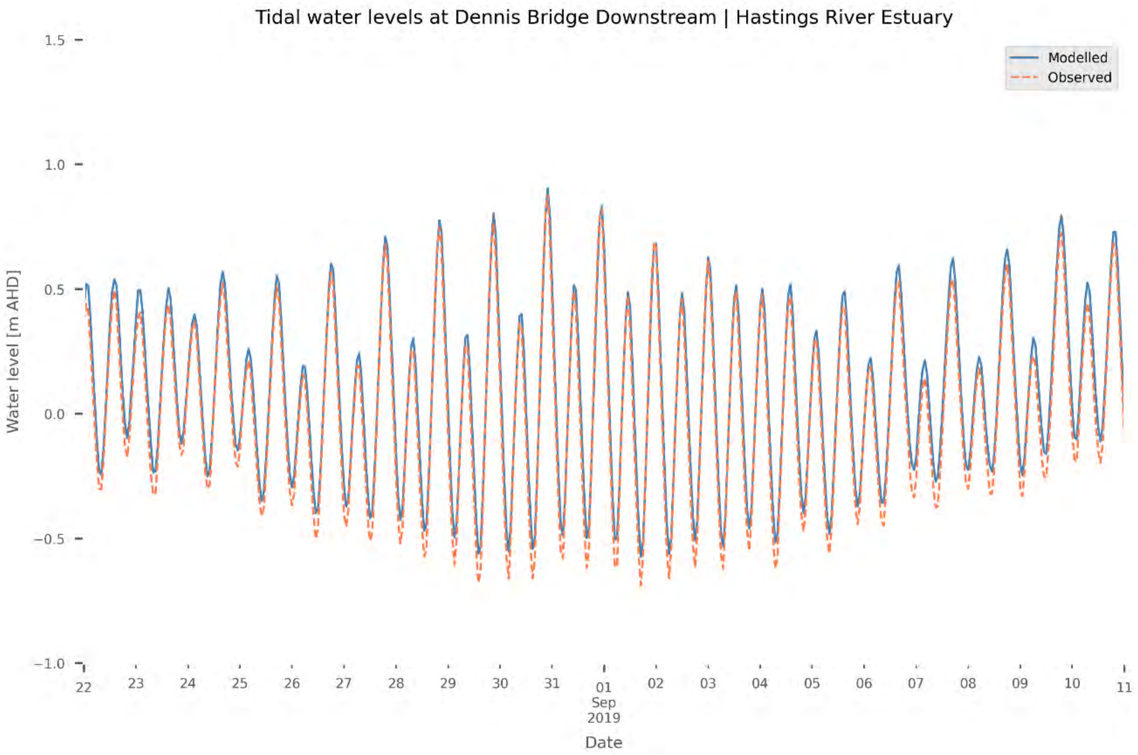

Figure I-26: Hastings hydrodynamic model verification results (2019) at Dennis Bridge Downstream (207444)

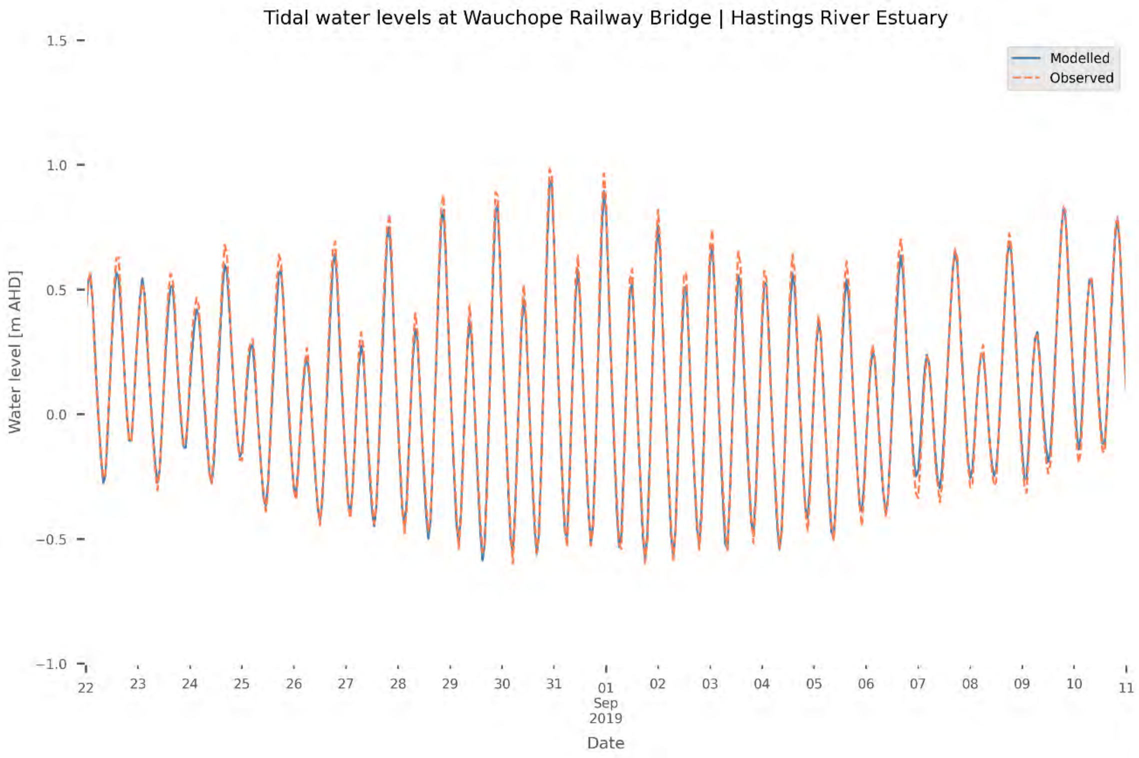

Figure I-27: Hastings hydrodynamic model verification results (2019) at Wauchope Railway Bridge (207401)

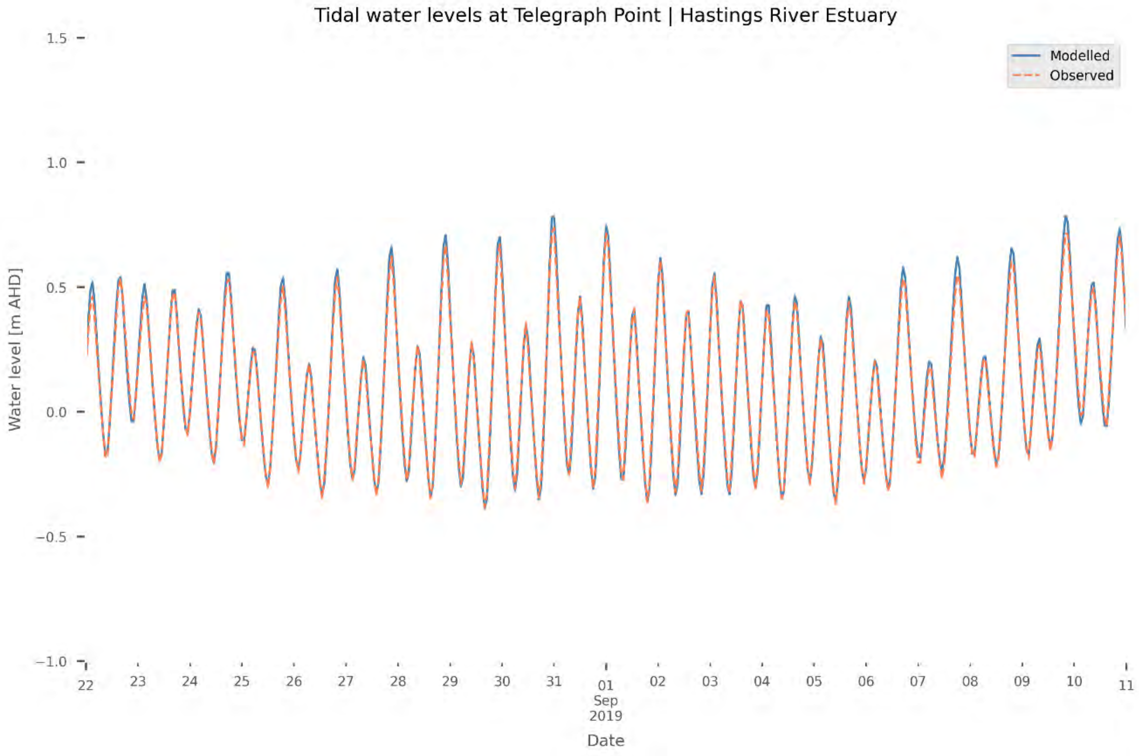

Figure I-28: Hastings hydrodynamic model verification results (2019) at Telegraph Point (207415)

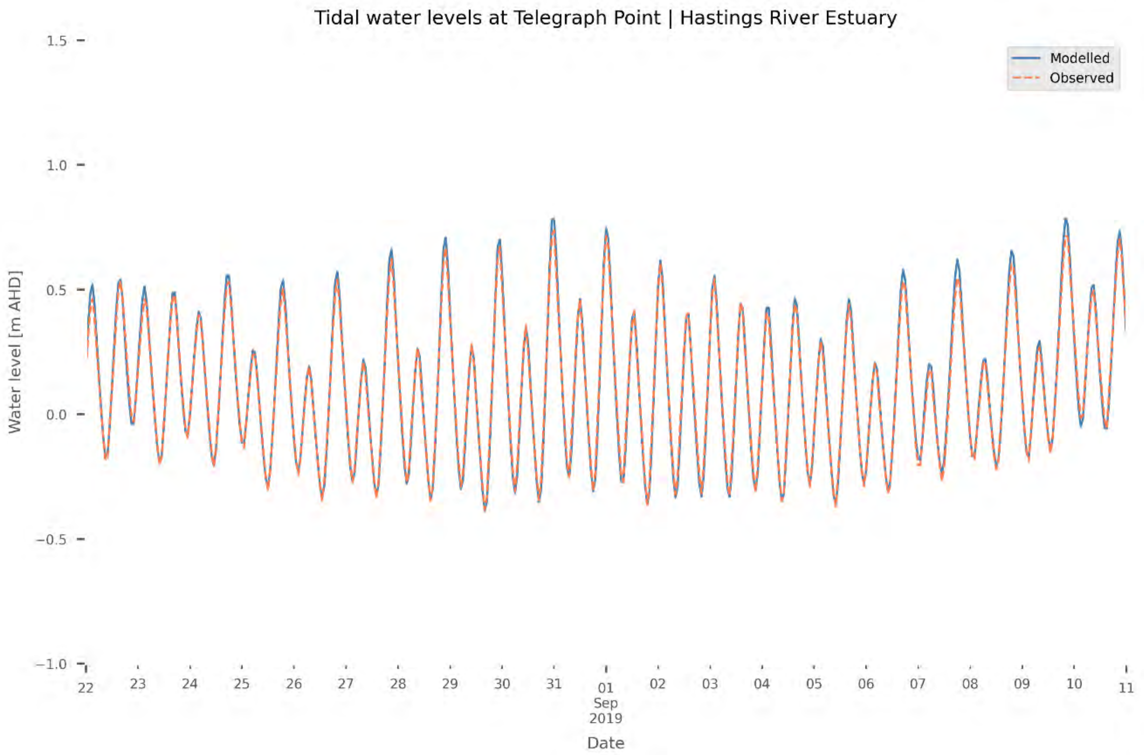

Figure I-29: Hastings hydrodynamic model verification results (2019) at Green Valley (207406)

Appendix J Sensitive environmental receivers

J1 Preamble

Acid discharges from ASS-affected floodplains are well reported to cause stress to sensitive environmental receivers (Glamore, 2003; Rayner, 2010; Sammut et al., 1996; Winberg and Heath, 2010). Furthermore, water control structures associated with ASS-affected drains, such as one-way floodgates, prohibit the passage of aquatic species and limit the overall primary production of estuaries (Winberg and Heath, 2010). Sensitive environmental receivers are widespread throughout the Hastings 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 Hastings 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 Management SEPP coastal wetlands	SER within subcatchment*
		Saltmarsh	Seagrass	Mangroves		
Connection Creek	20,700	12,300	20,900	4,800	0	Coastal wetlands
Fernbank Creek	100	0	0	0	0	Saltmarsh, mangroves, coastal wetlands, fish habitat
Kings Creek	8,100	7,700	6,700	0	0	Mangroves, coastal wetlands, fish habitat
Limeburners Creek	0	0	0	0	0	Saltmarsh, seagrass, mangroves, coastal wetlands, fish habitat
Lower Maria River East	0	0	0	0	0	Saltmarsh, seagrass, mangroves, coastal wetlands, fish habitat
Lower Maria River West	0	0	0	0	0	Saltmarsh, mangroves, coastal wetlands, fish habitat
Partridge Creek	0	0	0	0	0	Saltmarsh, mangroves, coastal wetlands, fish habitat
Pembrooke	0	0	0	0	0	Saltmarsh, mangroves, coastal wetlands, fish habitat
Port Macquarie Airport	0	0	0	0	0	Saltmarsh, mangroves, coastal wetlands, fish habitat
Rawdon Island	0	0	0	0	0	Saltmarsh, mangroves, coastal wetlands, fish habitat
Redbank	4,600	3,800	2,400	0	0	Mangroves, coastal wetlands, fish habitat
Sarahs Creek/ Sancrox	2,400	2,000	1,100	0	0	Coastal wetlands, fish habitat
Upper Maria River	9,500	3,900	9,600	0	0	Coastal wetlands, 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

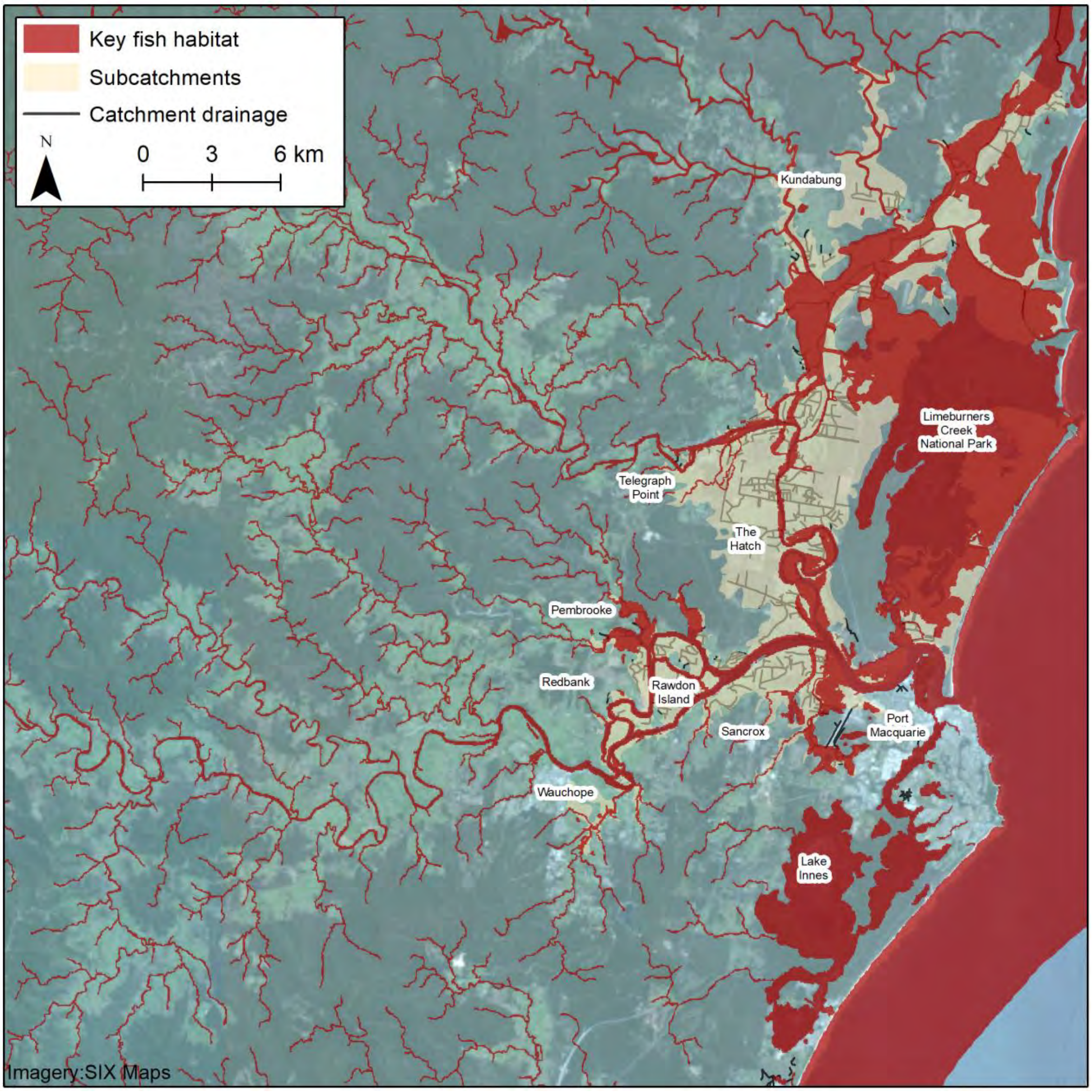

Figure J-1: Key fisheries habitat (Source: NSW DPI Fisheries)

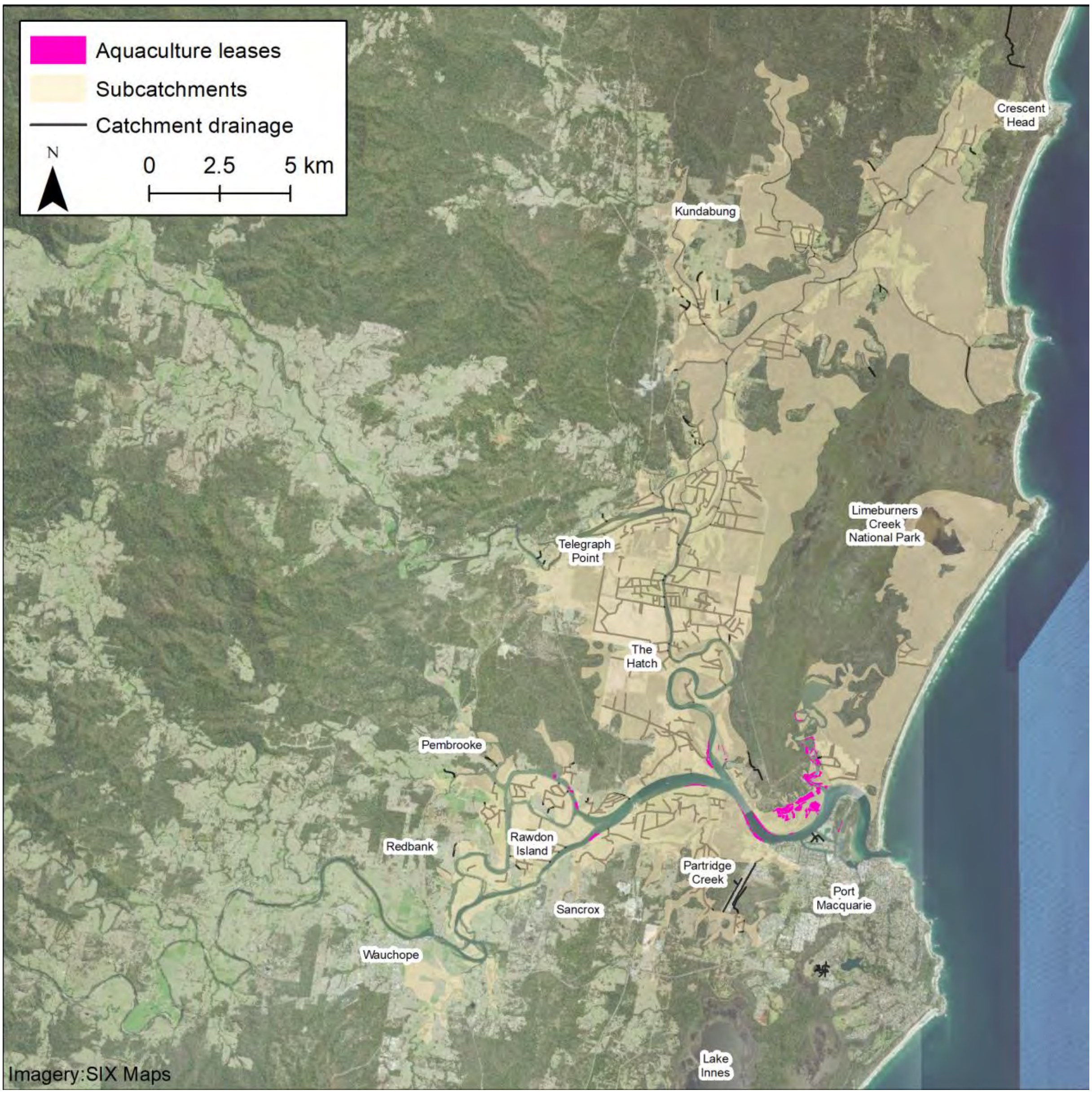

Figure J-2: Priority oyster leases (Source: NSW DPI Fisheries)

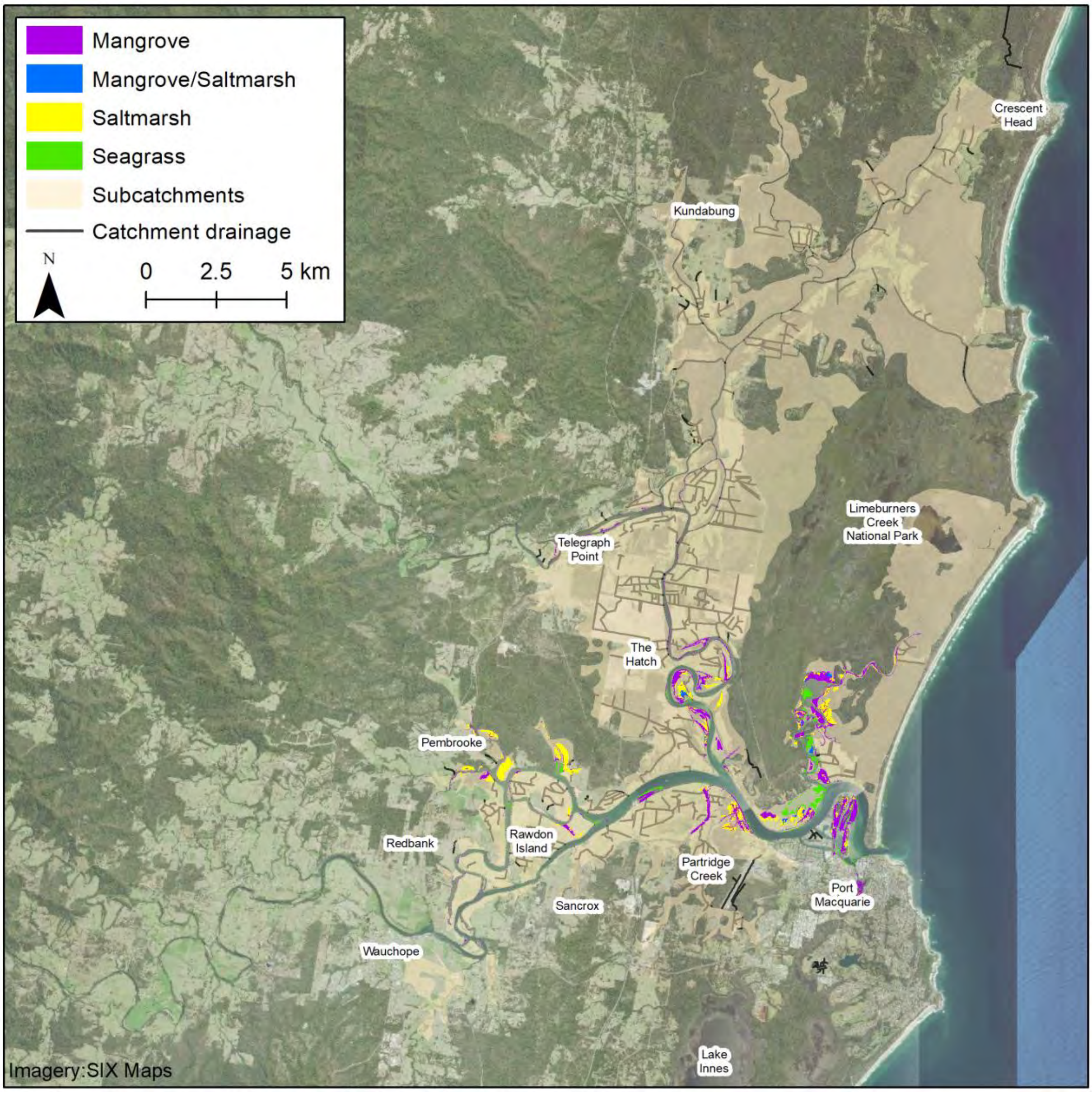

Figure J-3: Estuarine macrophytes (Source: NSW DPI Fisheries)

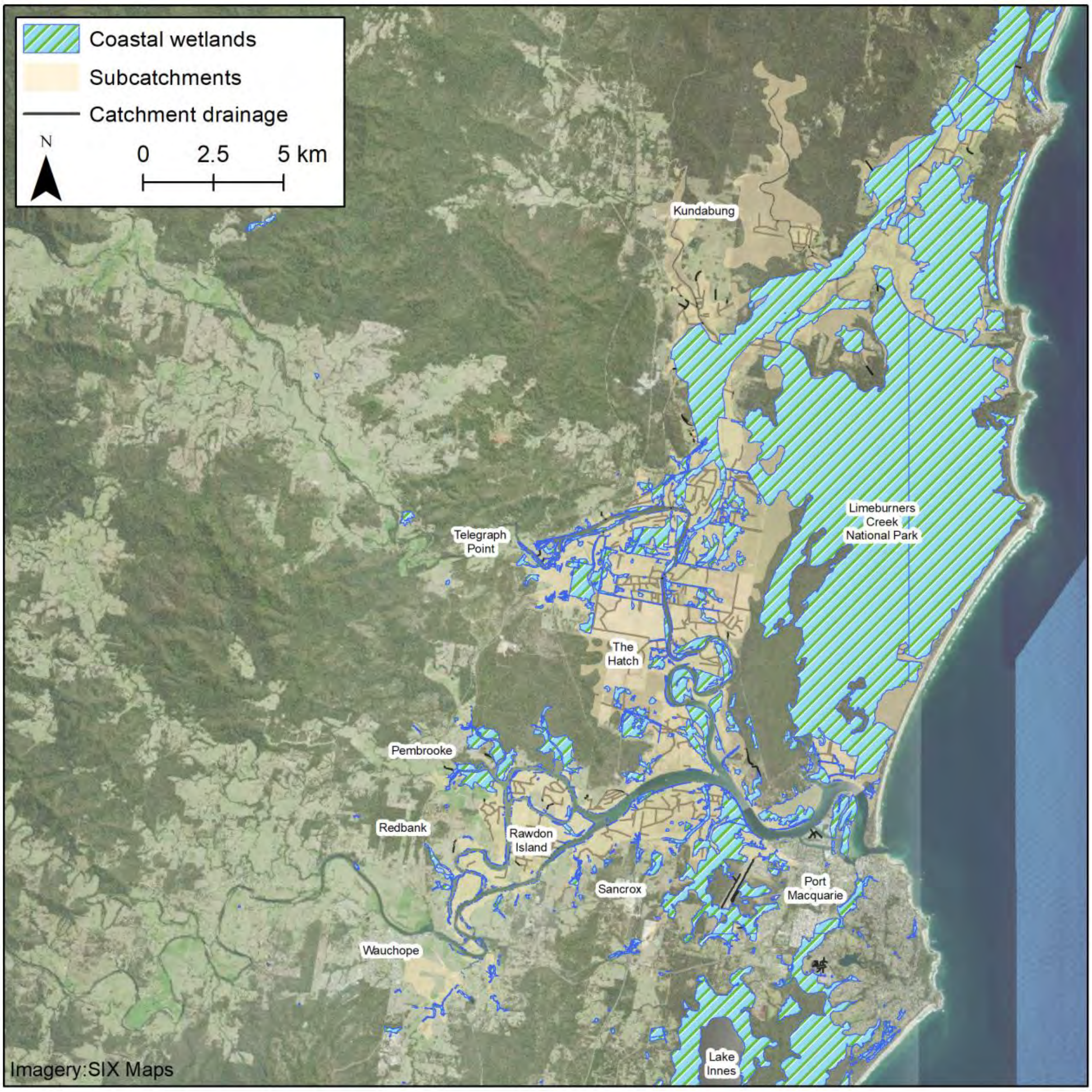

Figure J-4: Coastal Management SEPP coastal wetlands (Source: SEED NSW data portal)1

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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 heritage items are protected under the Environment Protection and Biodiversity Conservation Act 1999. Heritage items protected include:

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

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

K2 Aboriginal heritage

Aboriginal sites across the Hastings 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 Port Macquarie - Hastings 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.

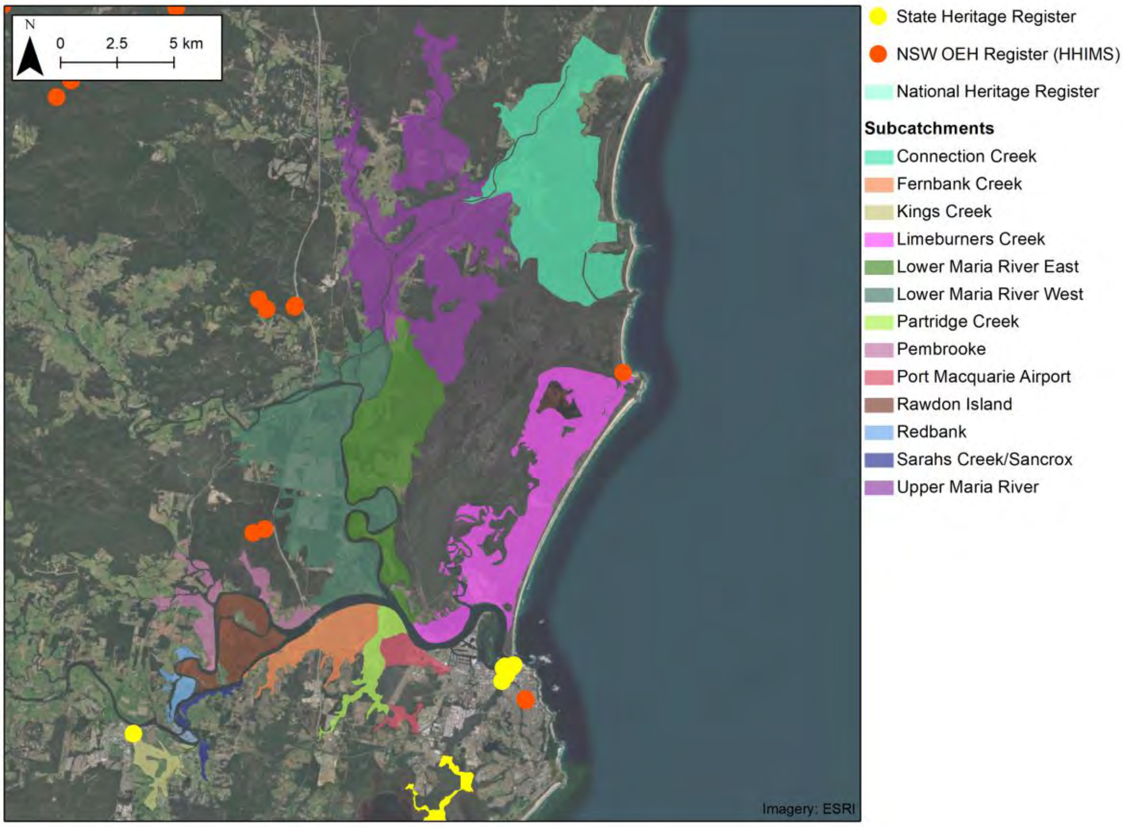


Figure K-1: Heritage items listed on Australian and NSW registers with location information

A total of 149 items were identified as listed on State Agency Registers and the Port Macquarie - Hastings 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.

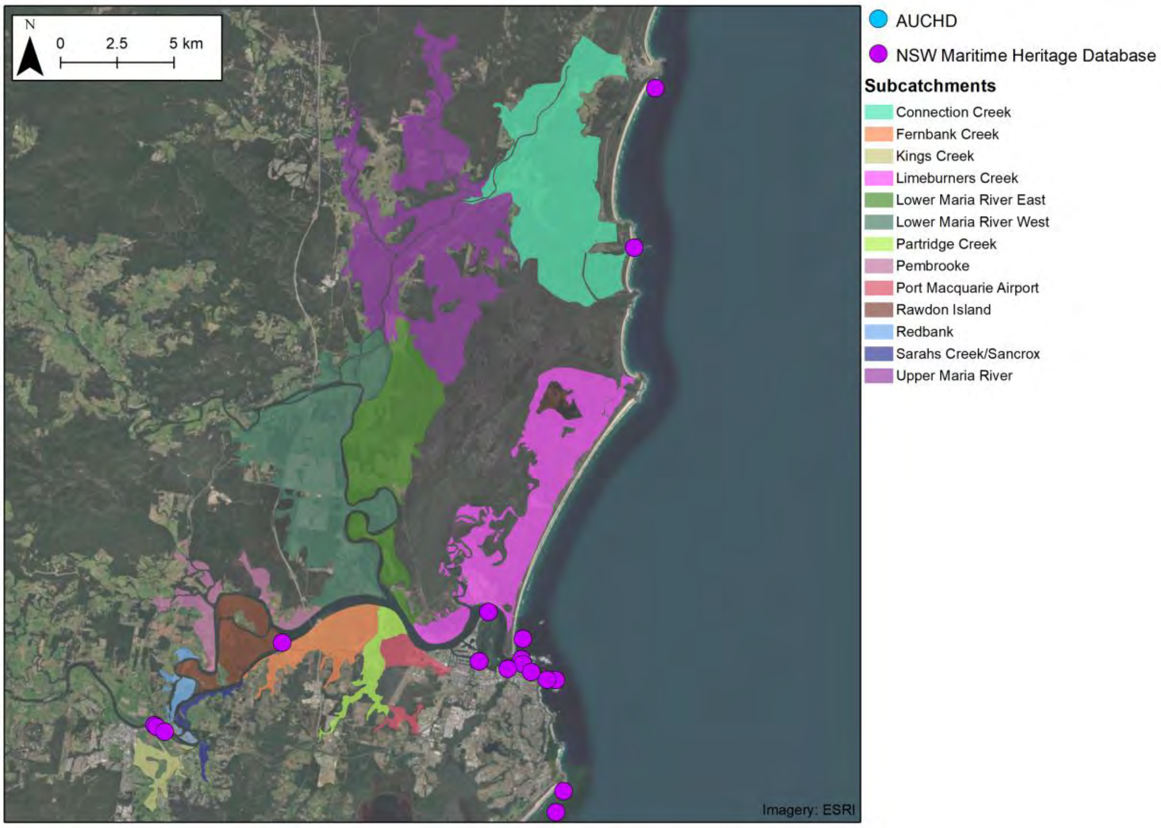


Figure K-2: Maritime heritage items listed on Australian and NSW registers

Appendix L Soil profile data sheets

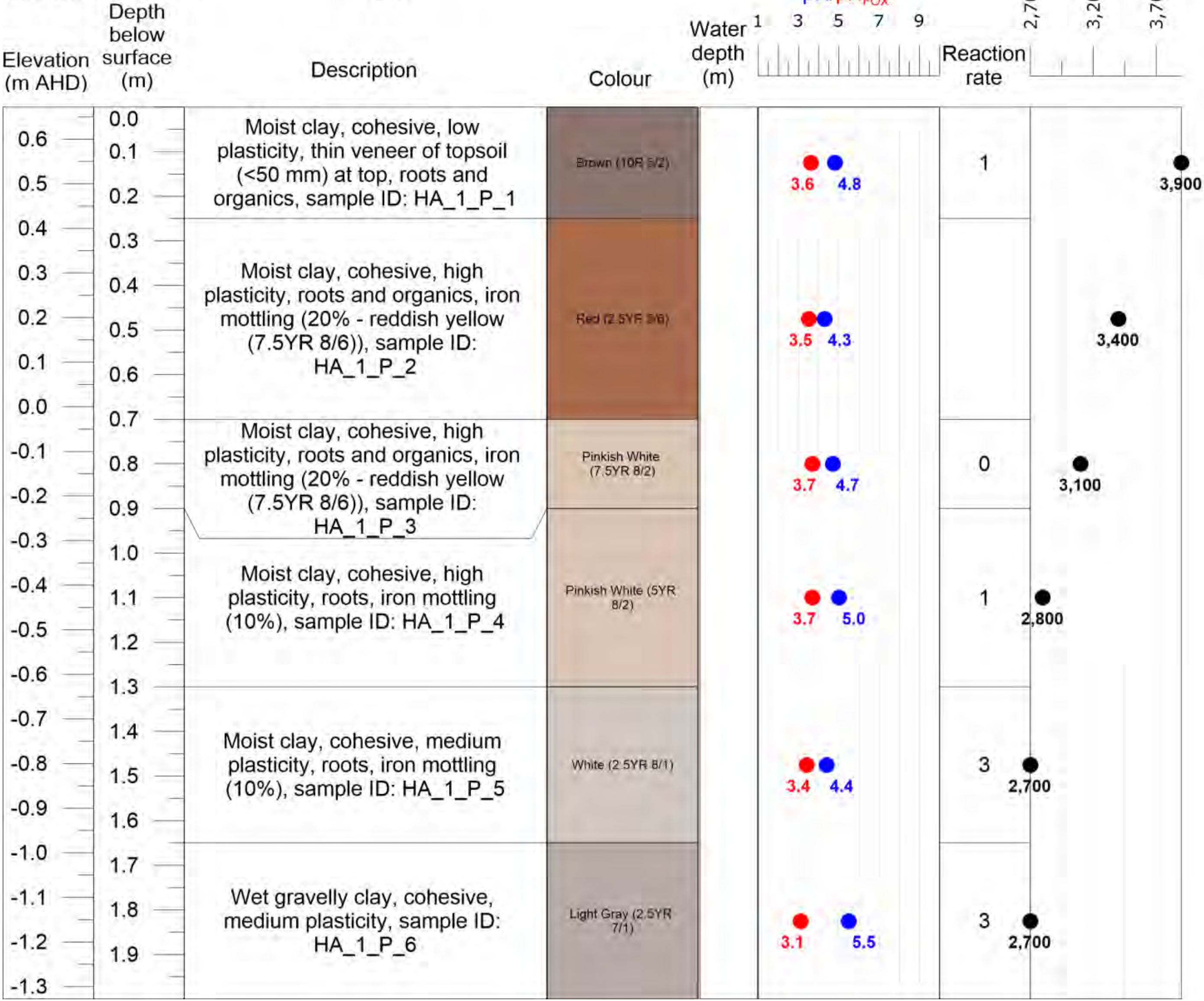
Soil profile details:

Project Number:	2018064	Profile ID:	HA_01_P
River/estuary:	Hastings	Sample date:	20/09/19
Easting:	478201.8	Sampled by:	AJH TAT
Northing:	6524665.8		

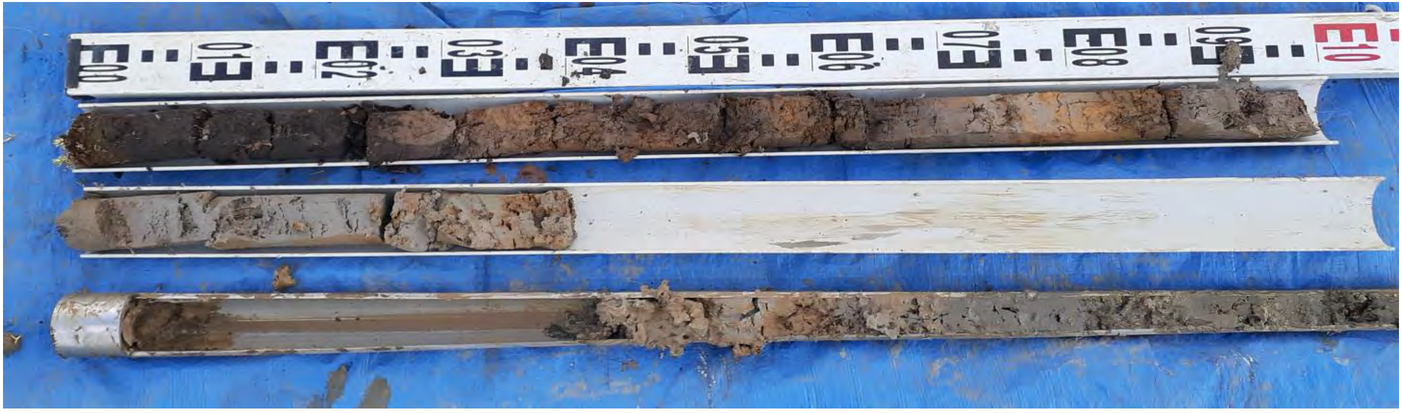
Ground elevation (m AHD):	0.67
Hydraulic conductivity (m/d):	12.49

Water quality:

Surface water EC (µS/cm):	Not measured
Surface water pH:	Not measured
Groundwater EC (µS/cm):	39,124
Groundwater pH:	5.7



Description	Colour	Soil pH/pH_{FOX}	Reaction rate	Soil EC (µS/cm)
Moist clay, cohesive, low plasticity, thin veneer of topsoil (<50 mm) at top, roots and organics, sample ID: HA_1_P_1	Brown (10R 5/2)	3.6 4.8	1	3,900
Moist clay, cohesive, high plasticity, roots and organics, iron mottling (20% - reddish yellow (7.5YR 8/6)), sample ID: HA_1_P_2	Red (2.5YR 5/6)	3.5 4.3		3,400
Moist clay, cohesive, high plasticity, roots and organics, iron mottling (20% - reddish yellow (7.5YR 8/6)), sample ID: HA_1_P_3	Pinkish White (7.5YR 8/2)	3.7 4.7	0	3,100
Moist clay, cohesive, high plasticity, roots, iron mottling (10%), sample ID: HA_1_P_4	Pinkish White (5YR 8/2)	3.7 5.0	1	2,800
Moist clay, cohesive, medium plasticity, roots, iron mottling (10%), sample ID: HA_1_P_5	White (2.5YR 8/1)	3.4 4.4	3	2,700
Wet gravelly clay, cohesive, medium plasticity, sample ID: HA_1_P_6	Light Gray (2.5YR 7/1)	3.1 5.5	3	2,700



Soil profile details:

Project Number:	2018064	Profile ID:	HA_02_A
River/estuary:	Hastings	Sample date:	30/01/20
Easting:	491864.9	Sampled by:	DWJ TAT
Northing:	6544698.9		

Ground elevation (m AHD):	0.49
Hydraulic conductivity (m/d):	10.32

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	Water depth (m)	Soil pH/pH_{FOX}	Reaction rate	Soil EC (µS/cm)
Dry top soil, non-cohesive, organics/roots, sample ID: HA_02A_01	Very Dark Gray (5YR 3/1)		5.4 / 3.5	2	160
Moist clay, high plasticity, cohesive, iron mottle 30%, macropores 1 - 3mm, roots, sample ID: HA_02A_02	Pinkish Gray (5YR 6/2)		5.5 / 3.9	1	120
Moist sandy clay, non-cohesive, very fine angular well graded sand, iron mottle 5 - 10%, macropores 1 - 3mm, roots, sample ID: HA_02A_03	Light Reddish Brown (5YR 6/3)		5.7 / 3.9	1	70
Moist clay, high plasticity, cohesive, extensive iron mottling (0.6 - 0.65m and 0.75 - 0.85m) - 100% of these sections otherwise 10% - iron mottle colour is brownish yellow (10YR 6/8), macropores 1 - 3mm, roots, sample ID: HA_02A_04	Pinkish Gray (5YR 6/2)		5.4 / 3.6	1	130
Wet clay, high plasticity, sticky cohesive, large macropores - 4mm, roots, iron mottle 5%, sample ID: HA_02A_05	Gray (5YR 5/1)		5.5 / 3.6	2	200
Wet sand, non-cohesive, visible water, medium - fine angular well graded white sand, water table at 1.46m, macropores - 3mm,roots, sample ID: HA_02A_06		1.46	5.4 / 2.9	5	83

Soil profile details:

Project Number:	2018064	Profile ID:	HA_03_A
River/estuary:	Hastings	Sample date:	24/09/19
Easting:	487606.6	Sampled by:	DWJ TAT
Northing:	6547304.4		

Ground elevation (m AHD):	0.42
Hydraulic conductivity (m/d):	0.41

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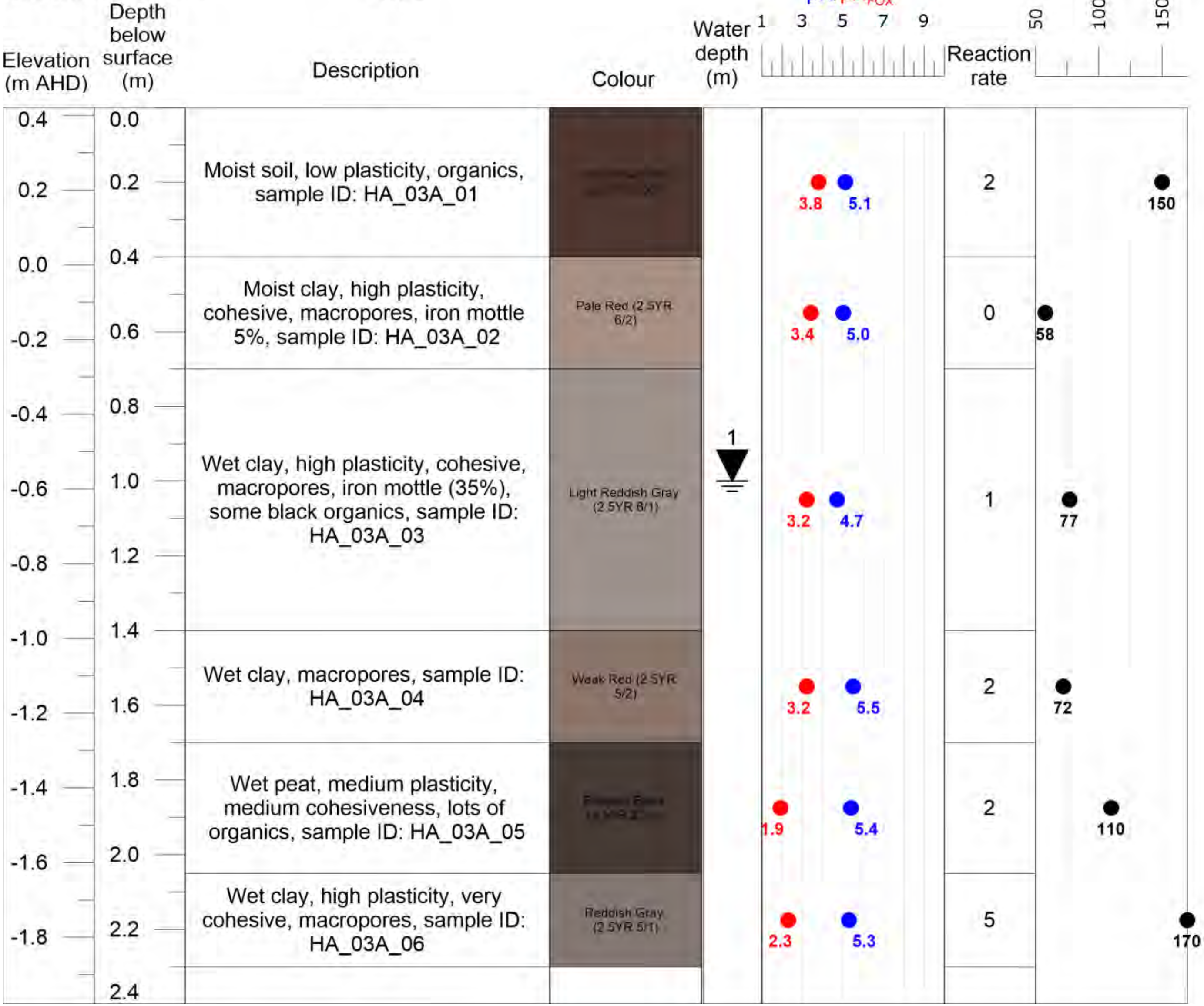
Water quality:

Surface water EC (μS/cm):	Not measured
Surface water pH:	Not measured
Groundwater EC (μS/cm):	2,296
Groundwater pH:	4.71



Depth below surface (m)	Description	Colour	pH	pH$_{FOX}$	Reaction rate	Soil EC (μS/cm)
0.0–0.4	Moist soil, low plasticity, organics, sample ID: HA_03A_01	[illegible]	5.1	3.8	2	150
0.4–0.7	Moist clay, high plasticity, cohesive, macropores, iron mottle 5%, sample ID: HA_03A_02	Pale Red (2.5YR 6/2)	5.0	3.4	0	58
0.7–1.4	Wet clay, high plasticity, cohesive, macropores, iron mottle (35%), some black organics, sample ID: HA_03A_03	Light Reddish Gray (2.5YR 6/1)	4.7	3.2	1	77
1.4–1.7	Wet clay, macropores, sample ID: HA_03A_04	Weak Red (2.5YR 5/2)	5.5	3.2	2	72
1.7–2.05	Wet peat, medium plasticity, medium cohesiveness, lots of organics, sample ID: HA_03A_05	[illegible]	5.4	1.9	2	110
2.05–2.35	Wet clay, high plasticity, very cohesive, macropores, sample ID: HA_03A_06	Reddish Gray (2.5YR 5/1)	5.3	2.3	5	170

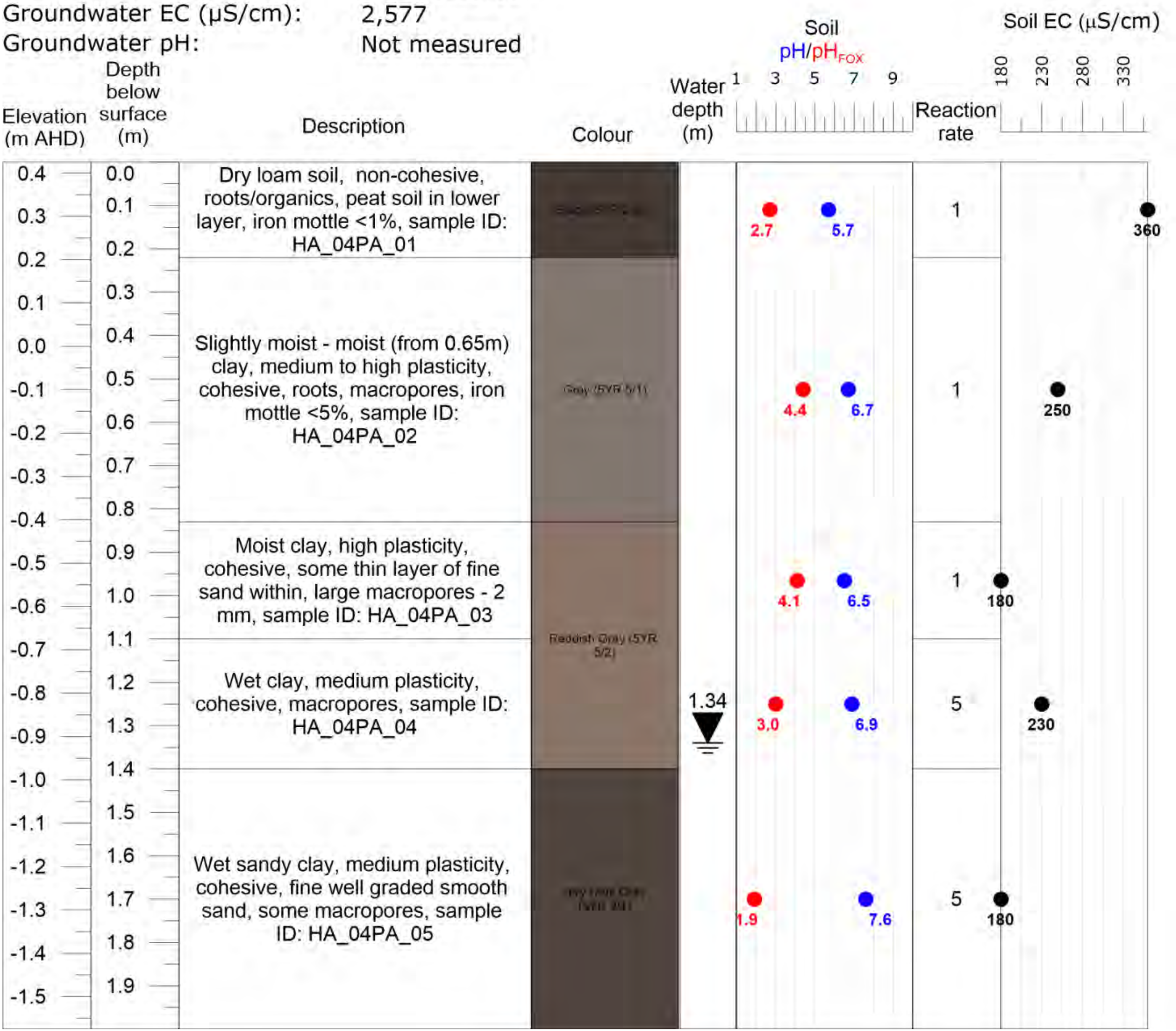
Soil profile details:

Project Number:	2018064	Profile ID:	HA_04_PA
River/estuary:	Hastings	Sample date:	31/01/20
Easting:	494274.4	Sampled by:	DWJ TAT
Northing:	6548234.4		

Ground elevation (m AHD): 0.42
Hydraulic conductivity (m/d): Not measured

Water quality:

Surface water EC (µS/cm):	32,473
Surface water pH:	Not measured
Groundwater EC (µS/cm):	2,577
Groundwater pH:	Not measured



Description	Colour	Water depth (m)	Soil pH/pH$_{FOX}$	Reaction rate	Soil EC (µS/cm)
Dry loam soil, non-cohesive, roots/organics, peat soil in lower layer, iron mottle <1%, sample ID: HA_04PA_01	[illegible]		5.7 / 2.7	1	360
Slightly moist - moist (from 0.65m) clay, medium to high plasticity, cohesive, roots, macropores, iron mottle <5%, sample ID: HA_04PA_02	Gray (5YR 5/1)		6.7 / 4.4	1	250
Moist clay, high plasticity, cohesive, some thin layer of fine sand within, large macropores - 2 mm, sample ID: HA_04PA_03	Reddish Gray (5YR 5/2)		6.5 / 4.1	1	180
Wet clay, medium plasticity, cohesive, macropores, sample ID: HA_04PA_04		1.34	6.9 / 3.0	5	230
Wet sandy clay, medium plasticity, cohesive, fine well graded smooth sand, some macropores, sample ID: HA_04PA_05	[illegible]		7.6 / 1.9	5	180

Soil profile details:

Project Number:	2018064	Profile ID:	HA_06_P
River/estuary:	Hastings	Sample date:	27/09/19
Easting:	489483.2	Sampled by:	DWJ TAT
Northing:	6545293.3		

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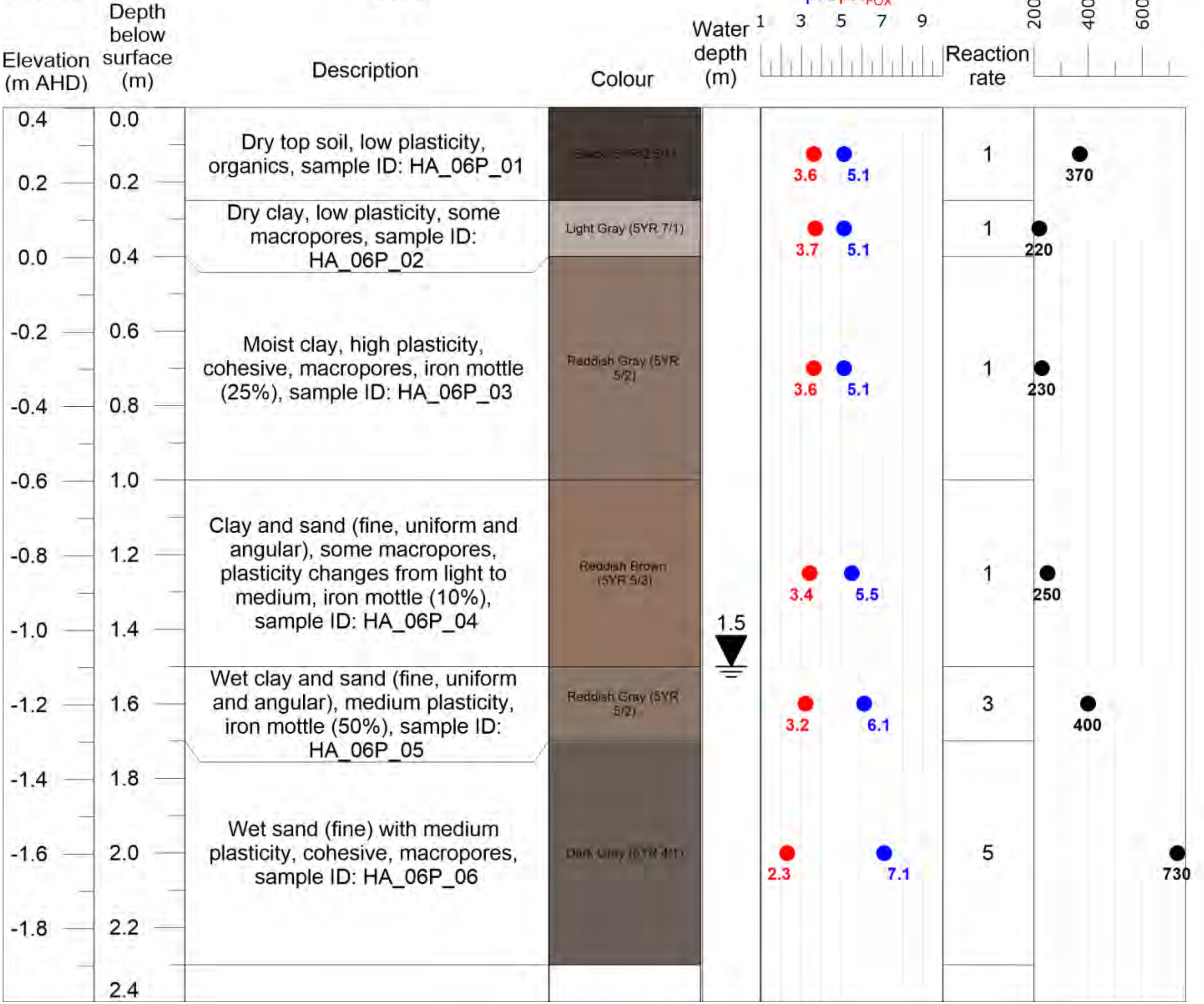
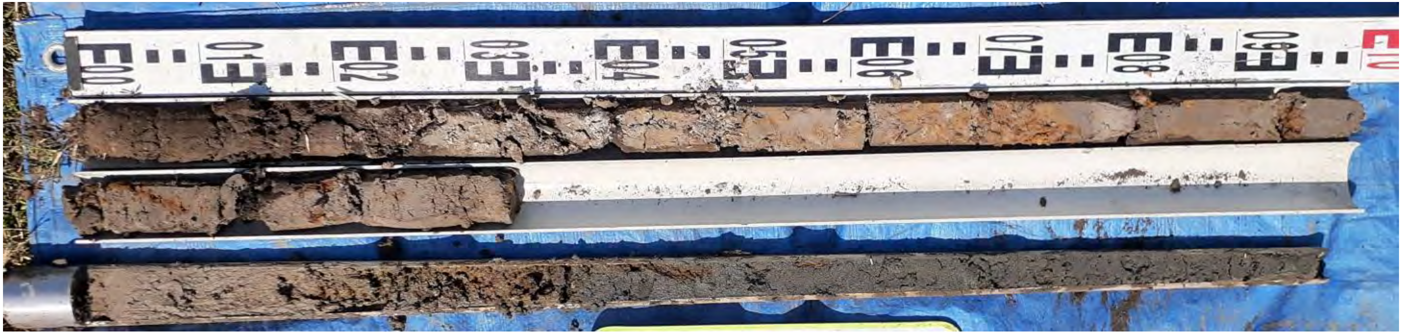
Ground elevation (m AHD):	0.40
Hydraulic conductivity (m/d):	2.70

Water quality:

Surface water EC (µS/cm):	23,686
Surface water pH:	6.57
Groundwater EC (µS/cm):	6,350
Groundwater pH:	6.01



Description	Colour	pH$_{FOX}$	pH	Reaction rate	Soil EC (µS/cm)
Dry top soil, low plasticity, organics, sample ID: HA_06P_01	Black (5YR 2.5/1)	3.6	5.1	1	370
Dry clay, low plasticity, some macropores, sample ID: HA_06P_02	Light Gray (5YR 7/1)	3.7	5.1	1	220
Moist clay, high plasticity, cohesive, macropores, iron mottle (25%), sample ID: HA_06P_03	Reddish Gray (5YR 5/2)	3.6	5.1	1	230
Clay and sand (fine, uniform and angular), some macropores, plasticity changes from light to medium, iron mottle (10%), sample ID: HA_06P_04	Reddish Brown (5YR 5/3)	3.4	5.5	1	250
Wet clay and sand (fine, uniform and angular), medium plasticity, iron mottle (50%), sample ID: HA_06P_05	Reddish Gray (5YR 5/2)	3.2	6.1	3	400
Wet sand (fine) with medium plasticity, cohesive, macropores, sample ID: HA_06P_06	Dark Gray (5YR 4/1)	2.3	7.1	5	730



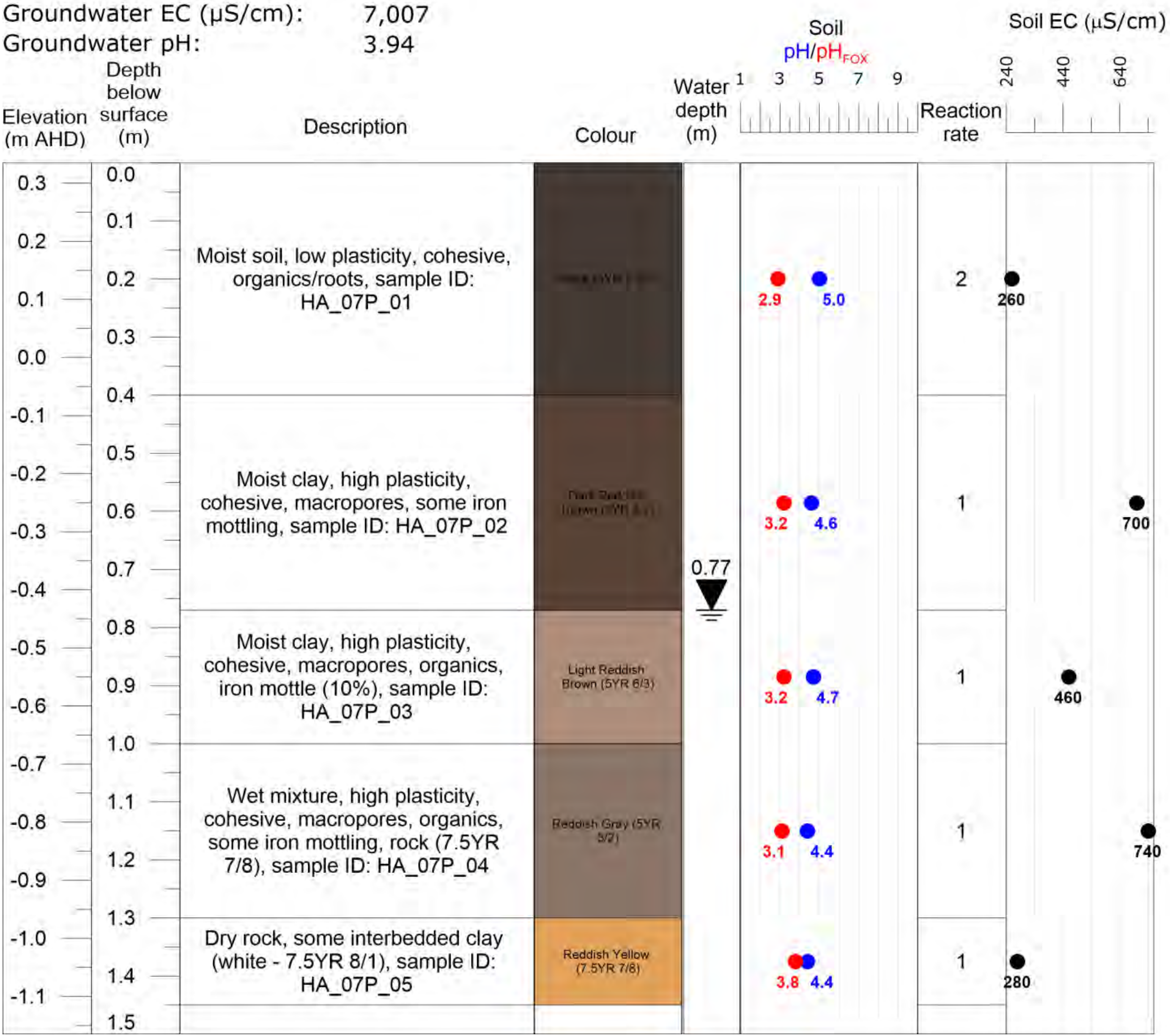
Soil profile details:

Project Number:	2018064	Profile ID:	HA_07_P
River/estuary:	Hastings	Sample date:	25/09/19
Easting:	484605	Sampled by:	DWJ TAT
Northing:	6540164.9		

Ground elevation (m AHD):	0.34
Hydraulic conductivity (m/d):	~200

Water quality:

Surface water EC (µS/cm):	12,334
Surface water pH:	2.74
Groundwater EC (µS/cm):	7,007
Groundwater pH:	3.94



Description	Colour	Soil pH	Soil pH_{FOX}	Reaction rate	Soil EC (µS/cm)
Moist soil, low plasticity, cohesive, organics/roots, sample ID: HA_07P_01	[illegible]	5.0	2.9	2	260
Moist clay, high plasticity, cohesive, macropores, some iron mottling, sample ID: HA_07P_02	Dark Reddish Brown (5YR [illegible])	4.6	3.2	1	700
Moist clay, high plasticity, cohesive, macropores, organics, iron mottle (10%), sample ID: HA_07P_03	Light Reddish Brown (5YR 6/3)	4.7	3.2	1	460
Wet mixture, high plasticity, cohesive, macropores, organics, some iron mottling, rock (7.5YR 7/8), sample ID: HA_07P_04	Reddish Gray (5YR 5/2)	4.4	3.1	1	740
Dry rock, some interbedded clay (white - 7.5YR 8/1), sample ID: HA_07P_05	Reddish Yellow (7.5YR 7/8)	4.4	3.8	1	280

Soil profile details:

Project Number:	2018064	Profile ID:	HA_10_P
River/estuary:	Hastings	Sample date:	26/09/19
Easting:	486049.9	Sampled by:	DWJ TAT
Northing:	6536298.7		

Ground elevation (m AHD):	0.48
Hydraulic conductivity (m/d):	2.98

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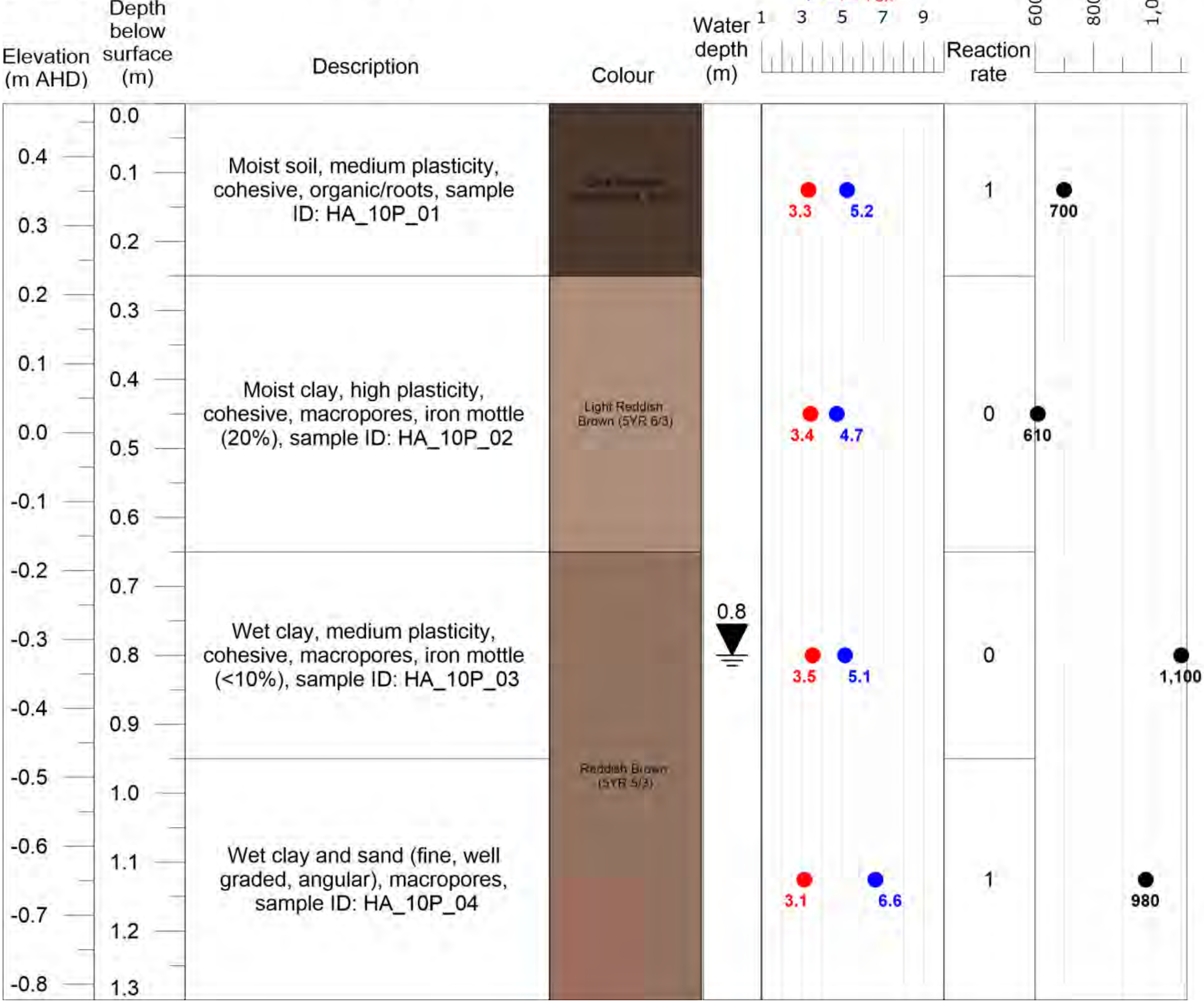
Water quality:

Surface water EC (µS/cm):	Not measured
Surface water pH:	Not measured
Groundwater EC (µS/cm):	17,598
Groundwater pH:	4.7



Description	Colour	Water depth (m)	Soil pH	Soil pH$_{FOX}$	Reaction rate	Soil EC (µS/cm)
Moist soil, medium plasticity, cohesive, organic/roots, sample ID: HA_10P_01	[illegible]		5.2	3.3	1	700
Moist clay, high plasticity, cohesive, macropores, iron mottle (20%), sample ID: HA_10P_02	Light Reddish Brown (5YR 6/3)		4.7	3.4	0	610
Wet clay, medium plasticity, cohesive, macropores, iron mottle (<10%), sample ID: HA_10P_03	Reddish Brown (5YR 5/3)	0.8	5.1	3.5	0	1,100
Wet clay and sand (fine, well graded, angular), macropores, sample ID: HA_10P_04			6.6	3.1	1	980

Soil profile details:

Project Number:	2018064	Profile ID:	HA_13_P
River/estuary:	Hastings	Sample date:	26/09/19
Easting:	489990.4	Sampled by:	DWJ TAT
Northing:	6526655.9		

Ground elevation (m AHD): 0.75
Hydraulic conductivity (m/d): 0.11

Water quality:

Surface water EC (µS/cm): 53,667
Surface water pH: 7.12
Groundwater EC (µS/cm): 24,145
Groundwater pH: 5.77

Water depth (m): 0.9

Description	Colour	Soil pH	Soil pH_{FOX}	Reaction rate	Soil EC (µS/cm)
Dry soil, non-cohesive, organics, iron mottle (5%), sample ID: HA_13P_01	Dark Reddish Brown (5YR [illegible])	4.7	3.0	1	1,600
Moist clay, low plasticity, cohesive, macropores, sample ID: HA_13P_02	Dark Reddish Brown (5YR [illegible])	5.2	3.5	0	2,000
Moist clay, high plasticity, cohesive, macropores, sample ID: HA_13P_03	Pinkish Gray (5YR 6/2)	5.5	3.8	0	1,600
Sticky and wet clay, some sand (fine and angular), low plasticity, macropores, sample ID: HA_13P_04	Pinkish Gray (5YR 6/2)	5.5	3.1	0	1,400
Wet sandy clay (fine, well graded and angular), low plasticity, cohesive, macropores, sample ID: HA_13P_05	Reddish Gray (5YR 5/2)	6.4	1.8	5	1,900
Wet sand (fine, well graded and angular), some clay/silt, macropores, sample ID: HA_13P_06	Gray (5YR 5/1)	6.6	2.0	5	1,300

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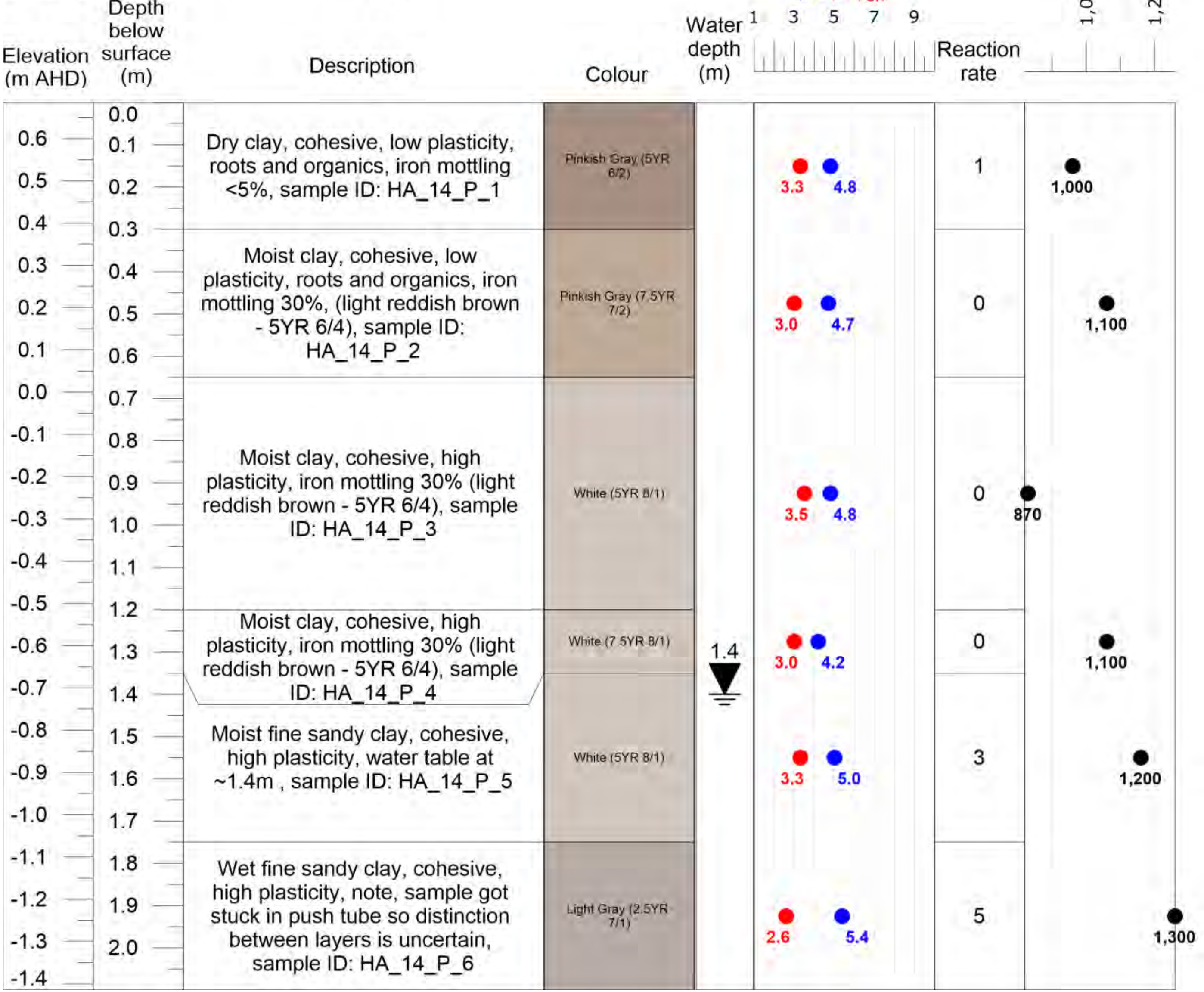
Soil profile details:

Project Number:	2018064	Profile ID:	HA_14_P
River/estuary:	Hastings	Sample date:	19/09/19
Easting:	482496.1	Sampled by:	AJH TAT
Northing:	6523954.3		

Ground elevation (m AHD): 0.69
Hydraulic conductivity (m/d): 2.10

Water quality:

Surface water EC (µS/cm): 42,532
Surface water pH: 6.25
Groundwater EC (µS/cm): 21,282
Groundwater pH: 5.7



Description	Colour	Soil pH	Soil pH$_{FOX}$	Reaction rate	Soil EC (µS/cm)
Dry clay, cohesive, low plasticity, roots and organics, iron mottling <5%, sample ID: HA_14_P_1	Pinkish Gray (5YR 6/2)	4.8	3.3	1	1,000
Moist clay, cohesive, low plasticity, roots and organics, iron mottling 30%, (light reddish brown - 5YR 6/4), sample ID: HA_14_P_2	Pinkish Gray (7.5YR 7/2)	4.7	3.0	0	1,100
Moist clay, cohesive, high plasticity, iron mottling 30% (light reddish brown - 5YR 6/4), sample ID: HA_14_P_3	White (5YR 8/1)	4.8	3.5	0	870
Moist clay, cohesive, high plasticity, iron mottling 30% (light reddish brown - 5YR 6/4), sample ID: HA_14_P_4	White (7.5YR 8/1)	4.2	3.0	0	1,100
Moist fine sandy clay, cohesive, high plasticity, water table at ~1.4m , sample ID: HA_14_P_5	White (5YR 8/1)	5.0	3.3	3	1,200
Wet fine sandy clay, cohesive, high plasticity, note, sample got stuck in push tube so distinction between layers is uncertain, sample ID: HA_14_P_6	Light Gray (2.5YR 7/1)	5.4	2.6	5	1,300

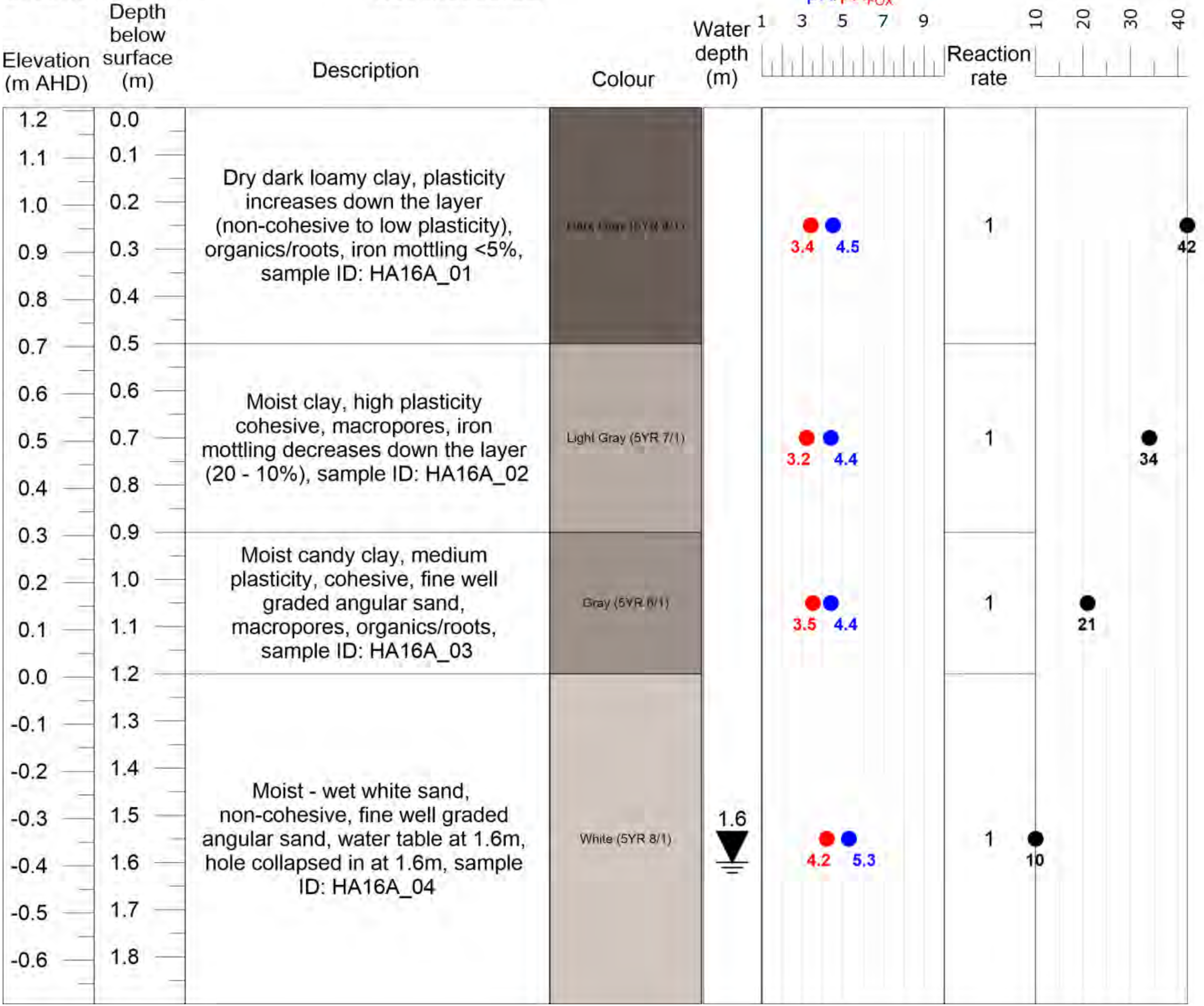
Soil profile details:

Project Number:	2018064	Profile ID:	HA_16_A
River/estuary:	Hastings	Sample date:	19/11/19
Easting:	483502	Sampled by:	DWJ TAT
Northing:	6525931.8		

Ground elevation (m AHD): 1.21
Hydraulic conductivity (m/d): Not measured

Water quality:

Surface water EC (µS/cm): 50,427
Surface water pH: 6.65
Groundwater EC (µS/cm): Not measured
Groundwater pH: Not measured



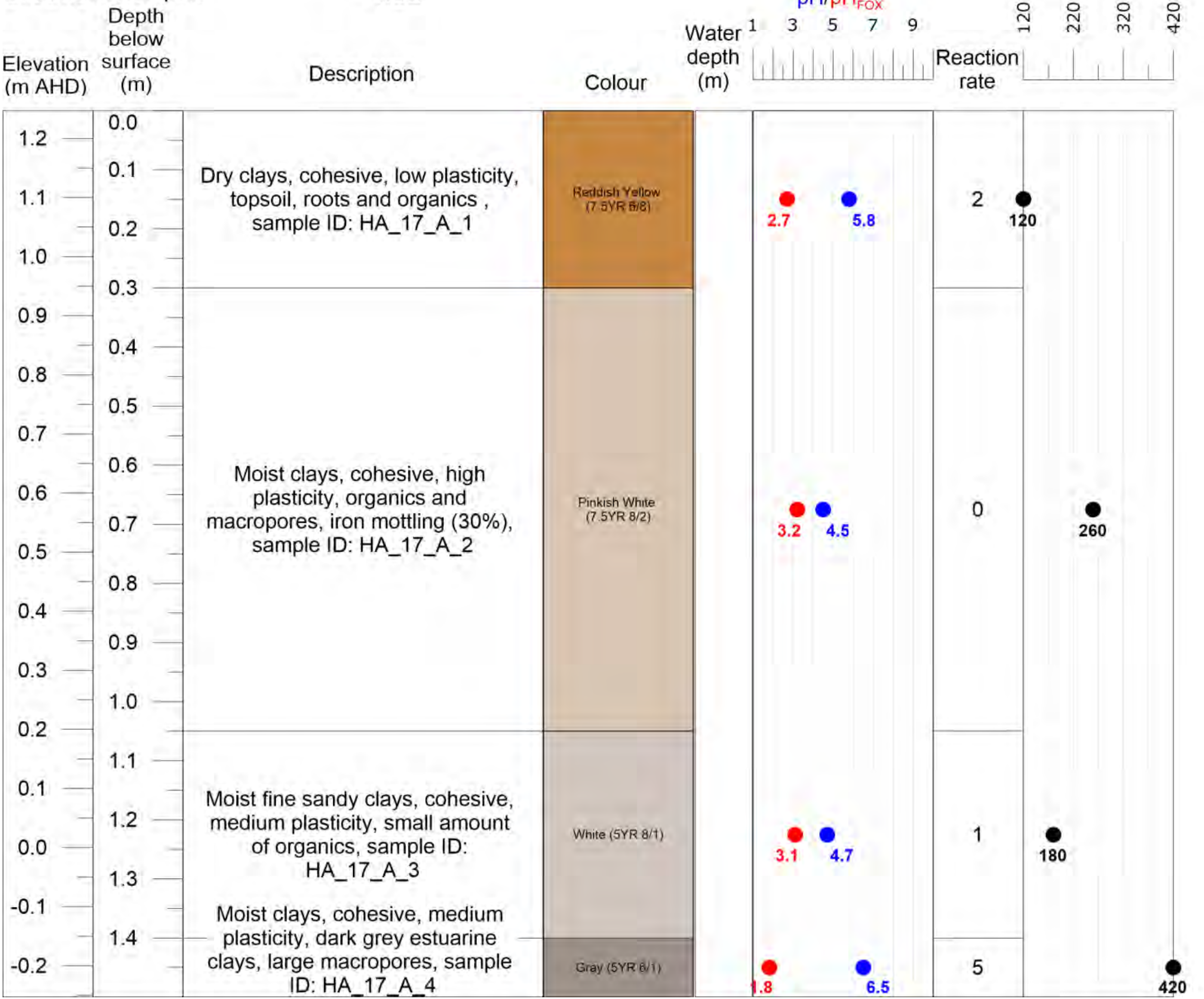
Description	Colour	pH$_{FOX}$	pH	Reaction rate	Soil EC (µS/cm)
Dry dark loamy clay, plasticity increases down the layer (non-cohesive to low plasticity), organics/roots, iron mottling <5%, sample ID: HA16A_01	Dark Gray (5YR 4/1)	3.4	4.5	1	42
Moist clay, high plasticity cohesive, macropores, iron mottling decreases down the layer (20 - 10%), sample ID: HA16A_02	Light Gray (5YR 7/1)	3.2	4.4	1	34
Moist candy clay, medium plasticity, cohesive, fine well graded angular sand, macropores, organics/roots, sample ID: HA16A_03	Gray (5YR 6/1)	3.5	4.4	1	21
Moist - wet white sand, non-cohesive, fine well graded angular sand, water table at 1.6m, hole collapsed in at 1.6m, sample ID: HA16A_04	White (5YR 8/1)	4.2	5.3	1	10

Soil profile details:

Project Number: 2018064
River/estuary: Hastings
Easting: 486145.4
Northing: 6524156.5
Profile ID: HA_17_A
Sample date: 19/09/19
Sampled by: AJH TAT
Ground elevation (m AHD): 1.25
Hydraulic conductivity (m/d): Not measured

Water quality:

Surface water EC (µS/cm): 55,700
Surface water pH: 7.6
Groundwater EC (µS/cm): 2,485
Groundwater pH: 4.52



Dry clays, cohesive, low plasticity, topsoil, roots and organics , sample ID: HA_17_A_1

Moist clays, cohesive, high plasticity, organics and macropores, iron mottling (30%), sample ID: HA_17_A_2

Moist fine sandy clays, cohesive, medium plasticity, small amount of organics, sample ID: HA_17_A_3

Moist clays, cohesive, medium plasticity, dark grey estuarine clays, large macropores, sample ID: HA_17_A_4

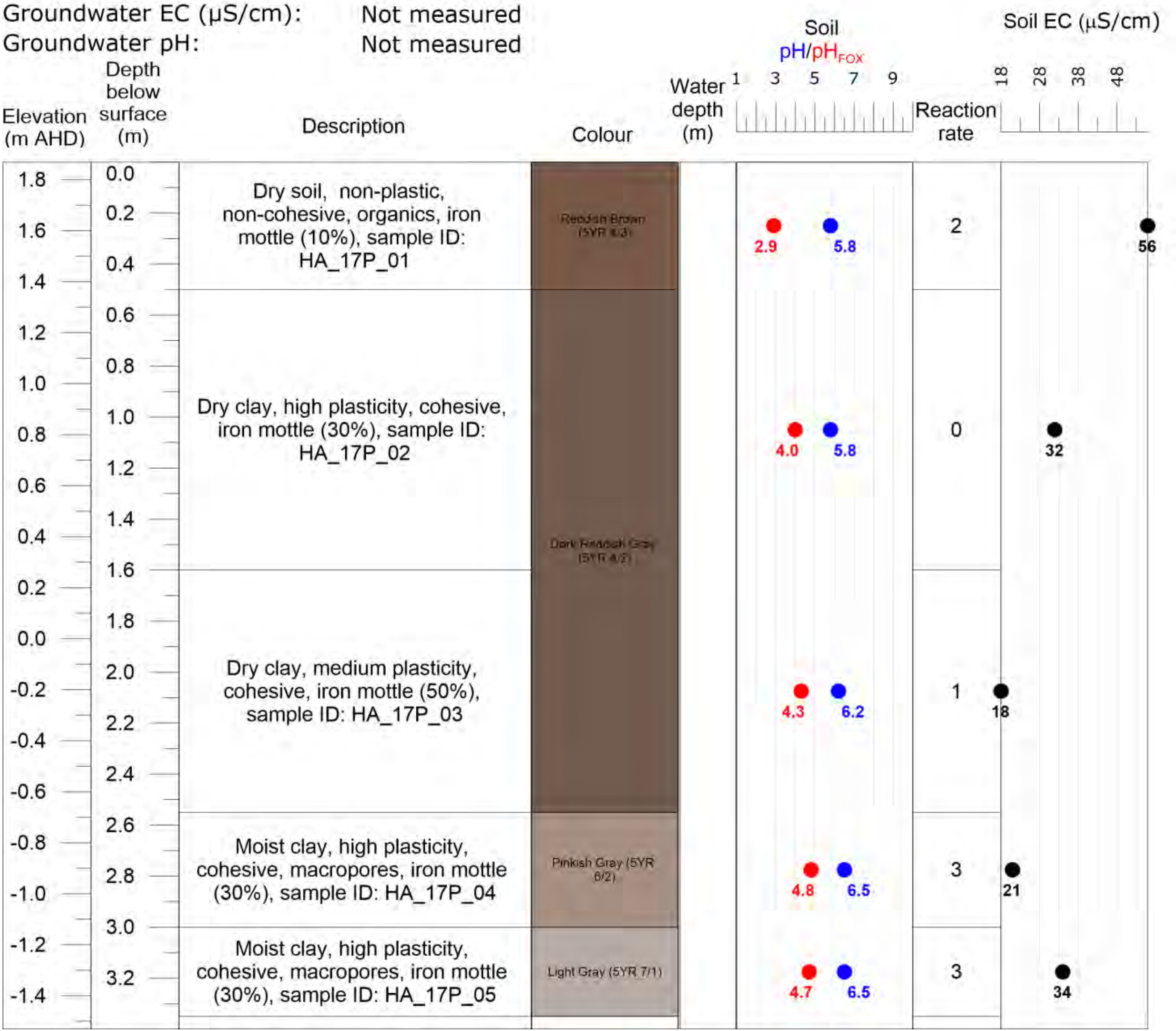
Soil profile details:

Project Number:	2018064	Profile ID:	HA_17_P
River/estuary:	Hastings	Sample date:	24/09/19
Easting:	477052.5	Sampled by:	DWJ TAT
Northing:	6523672.5		

Ground elevation (m AHD): 1.87
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$_{FOX}$	pH	Reaction rate	Soil EC (µS/cm)
Dry soil, non-plastic, non-cohesive, organics, iron mottle (10%), sample ID: HA_17P_01	Reddish Brown (5YR 4/3)	2.9	5.8	2	56
Dry clay, high plasticity, cohesive, iron mottle (30%), sample ID: HA_17P_02	Dark Reddish Gray (5YR 4/2)	4.0	5.8	0	32
Dry clay, medium plasticity, cohesive, iron mottle (50%), sample ID: HA_17P_03		4.3	6.2	1	18
Moist clay, high plasticity, cohesive, macropores, iron mottle (30%), sample ID: HA_17P_04	Pinkish Gray (5YR 6/2)	4.8	6.5	3	21
Moist clay, high plasticity, cohesive, macropores, iron mottle (30%), sample ID: HA_17P_05	Light Gray (5YR 7/1)	4.7	6.5	3	34

Soil profile details:

Project Number:	2018064	Profile ID:	HA_19_P
River/estuary:	Hastings	Sample date:	17/09/19
Easting:	478183.4	Sampled by:	AJH TAT
Northing:	6518799.5		

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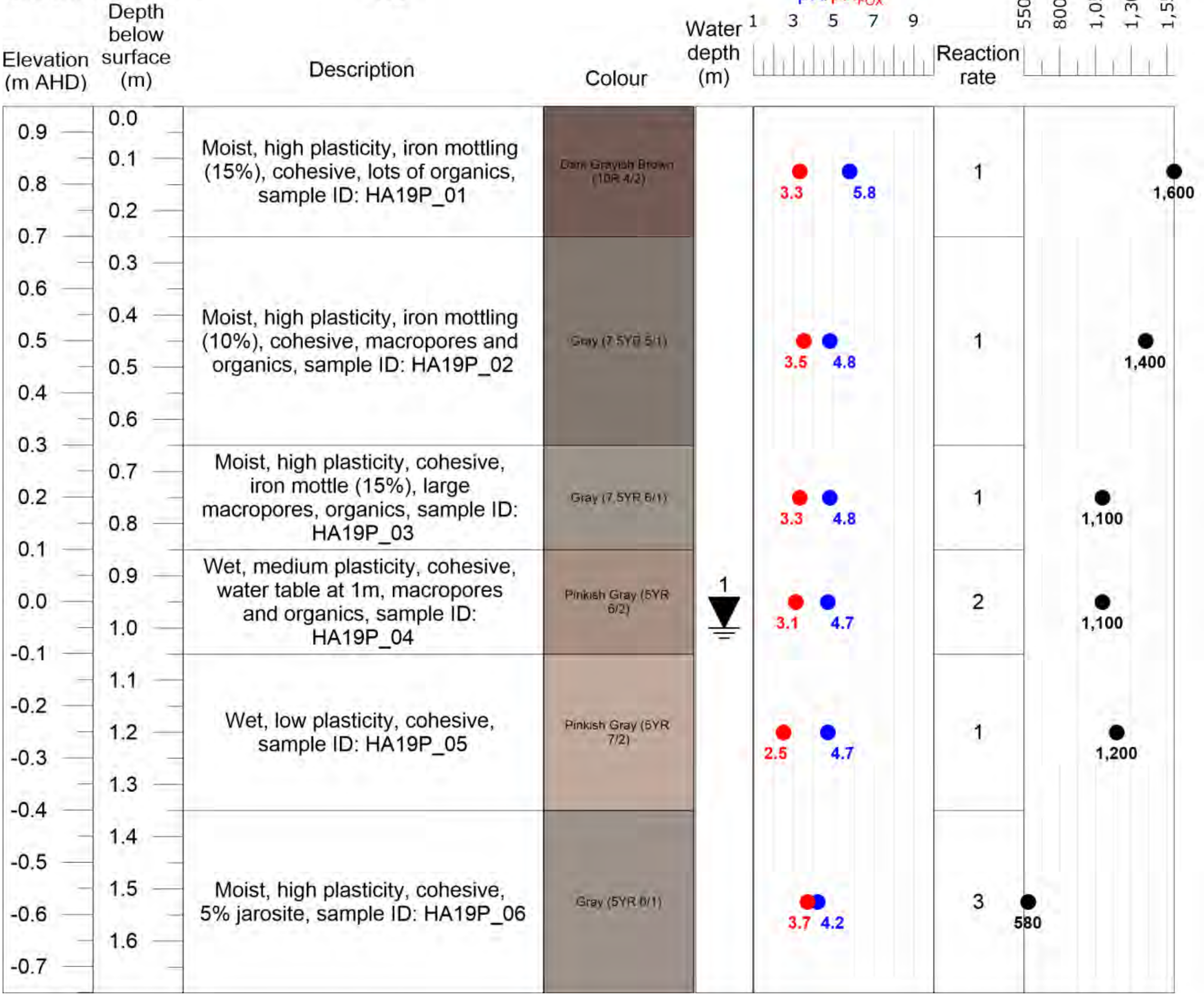
Ground elevation (m AHD): 0.95
Hydraulic conductivity (m/d): 4.61

Water quality:

Surface water EC (µS/cm): 39,100
Surface water pH: 6.8
Groundwater EC (µS/cm): 20,600
Groundwater pH: 4.1



Moist, high plasticity, iron mottling (15%), cohesive, lots of organics, sample ID: HA19P_01	Dark Grayish Brown (10R 4/2)		3.3	5.8	1	1,600
Moist, high plasticity, iron mottling (10%), cohesive, macropores and organics, sample ID: HA19P_02	Gray (7.5YR 5/1)		3.5	4.8	1	1,400
Moist, high plasticity, cohesive, iron mottle (15%), large macropores, organics, sample ID: HA19P_03	Gray (7.5YR 6/1)		3.3	4.8	1	1,100
Wet, medium plasticity, cohesive, water table at 1m, macropores and organics, sample ID: HA19P_04	Pinkish Gray (5YR 6/2)	1	3.1	4.7	2	1,100
Wet, low plasticity, cohesive, sample ID: HA19P_05	Pinkish Gray (5YR 7/2)		2.5	4.7	1	1,200
Moist, high plasticity, cohesive, 5% jarosite, sample ID: HA19P_06	Gray (5YR 6/1)		3.7	4.2	3	580

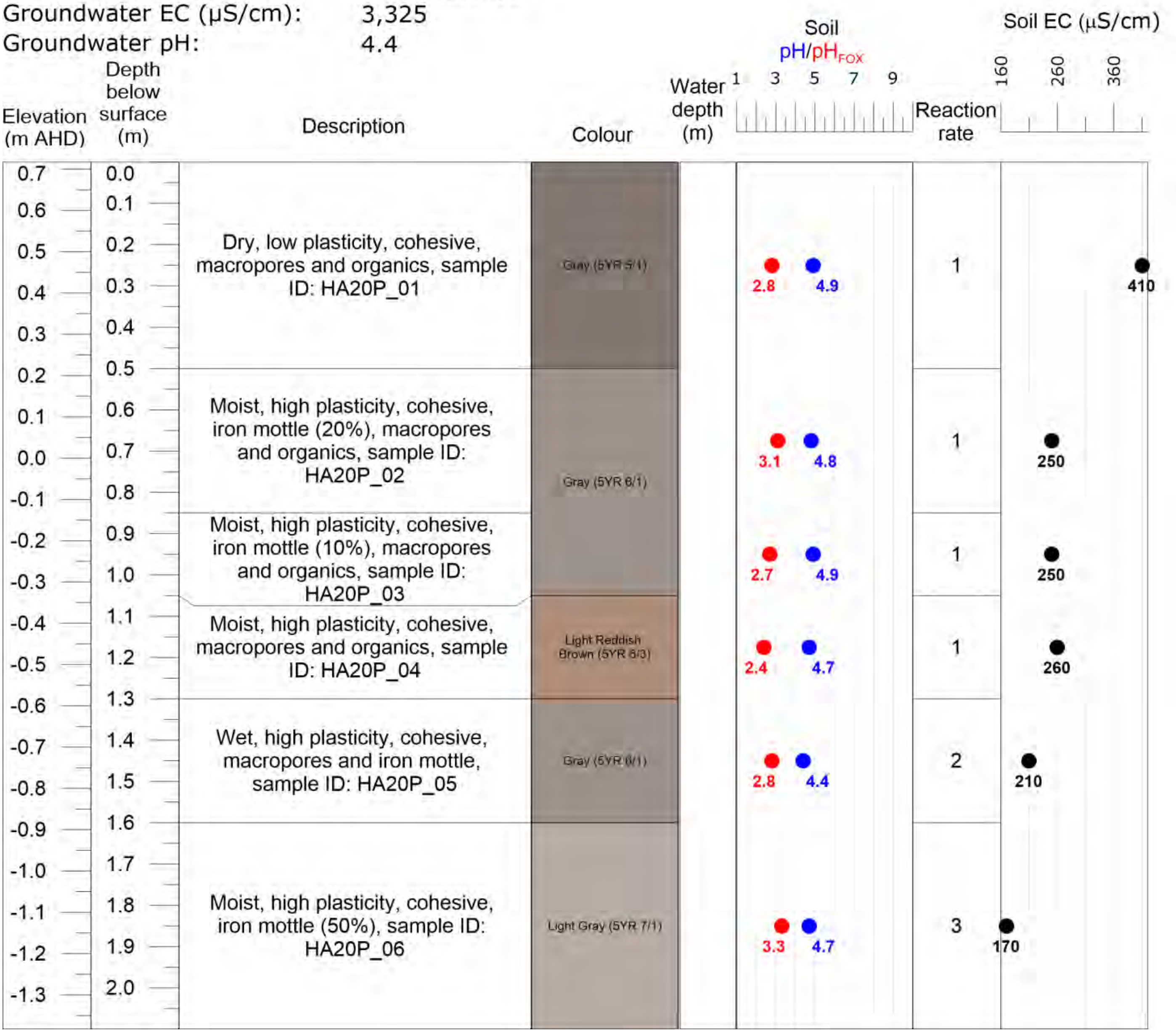
Soil profile details:

Project Number:	2018064	Profile ID:	HA_20_P
River/estuary:	Hastings	Sample date:	17/09/19
Easting:	475869	Sampled by:	AJH TAT
Northing:	6518358.0		

Ground elevation (m AHD):	0.72
Hydraulic conductivity (m/d):	3.55

Water quality:

Surface water EC (μS/cm):	Not measured
Surface water pH:	Not measured
Groundwater EC (μS/cm):	3,325
Groundwater pH:	4.4



Description	Colour	Soil pH_FOX	Soil pH	Reaction rate	Soil EC (μS/cm)
Dry, low plasticity, cohesive, macropores and organics, sample ID: HA20P_01	Gray (5YR 5/1)	2.8	4.9	1	410
Moist, high plasticity, cohesive, iron mottle (20%), macropores and organics, sample ID: HA20P_02	Gray (5YR 6/1)	3.1	4.8	1	250
Moist, high plasticity, cohesive, iron mottle (10%), macropores and organics, sample ID: HA20P_03		2.7	4.9	1	250
Moist, high plasticity, cohesive, macropores and organics, sample ID: HA20P_04	Light Reddish Brown (5YR 6/3)	2.4	4.7	1	260
Wet, high plasticity, cohesive, macropores and iron mottle, sample ID: HA20P_05	Gray (5YR 6/1)	2.8	4.4	2	210
Moist, high plasticity, cohesive, iron mottle (50%), sample ID: HA20P_06	Light Gray (5YR 7/1)	3.3	4.7	3	170

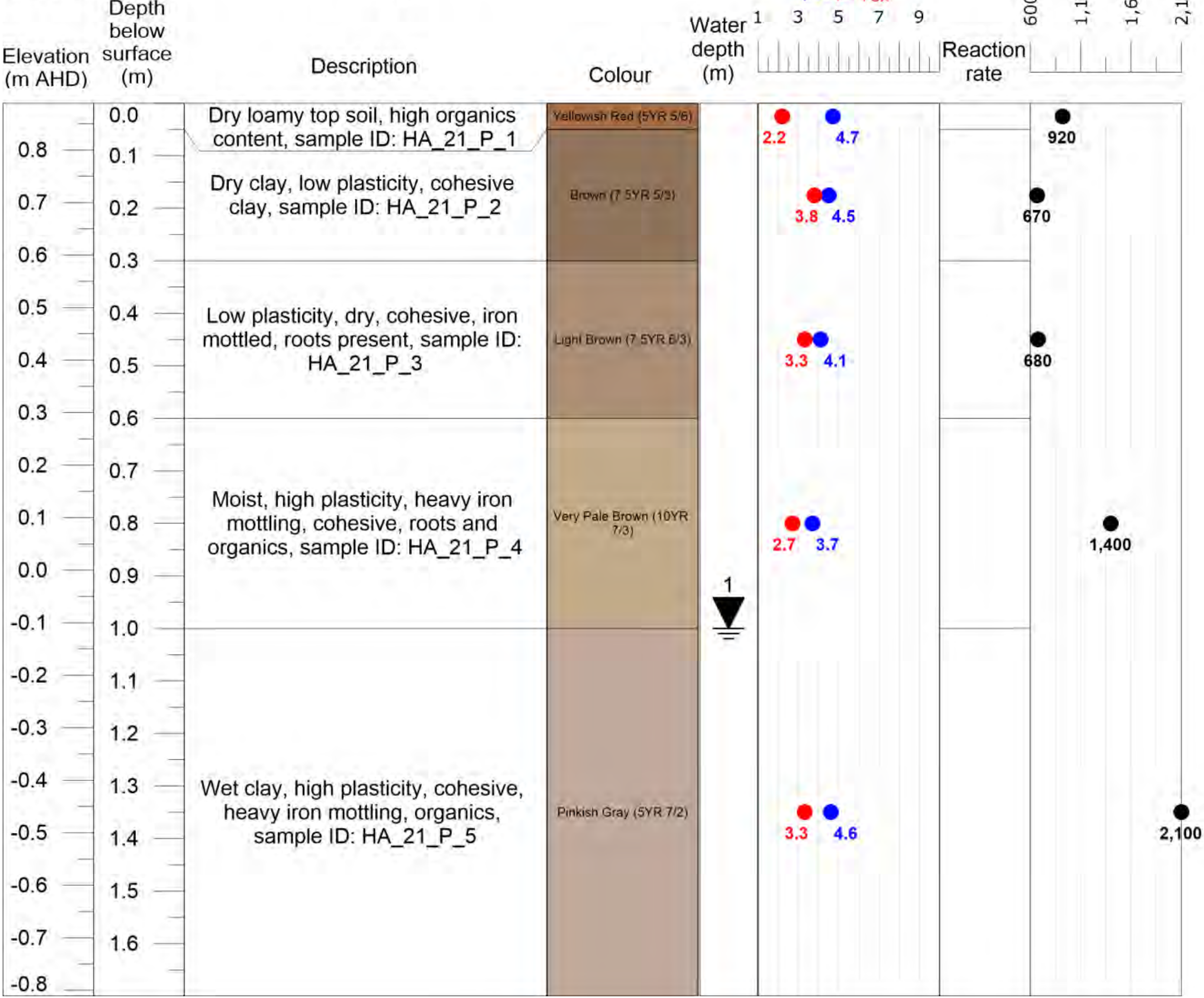
Soil profile details:

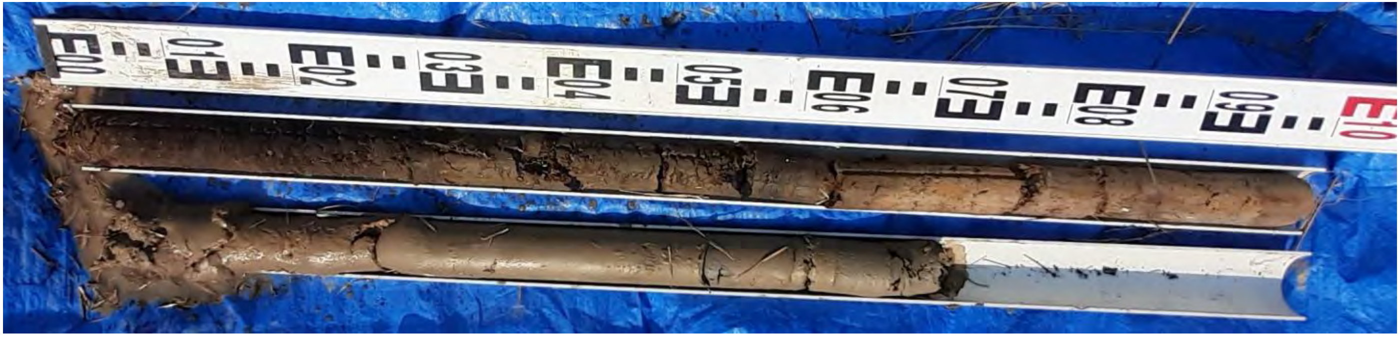
Project Number:	2018064	Profile ID:	HA_21_P
River/estuary:	Hastings	Sample date:	16/09/19
Easting:	480493.9	Sampled by:	AJH TAT
Northing:	6524799.8		

Ground elevation (m AHD):	0.89
Hydraulic conductivity (m/d):	0.13

Water quality:

Surface water EC (µS/cm):	Not measured
Surface water pH:	Not measured
Groundwater EC (µS/cm):	25,500
Groundwater pH:	3.3





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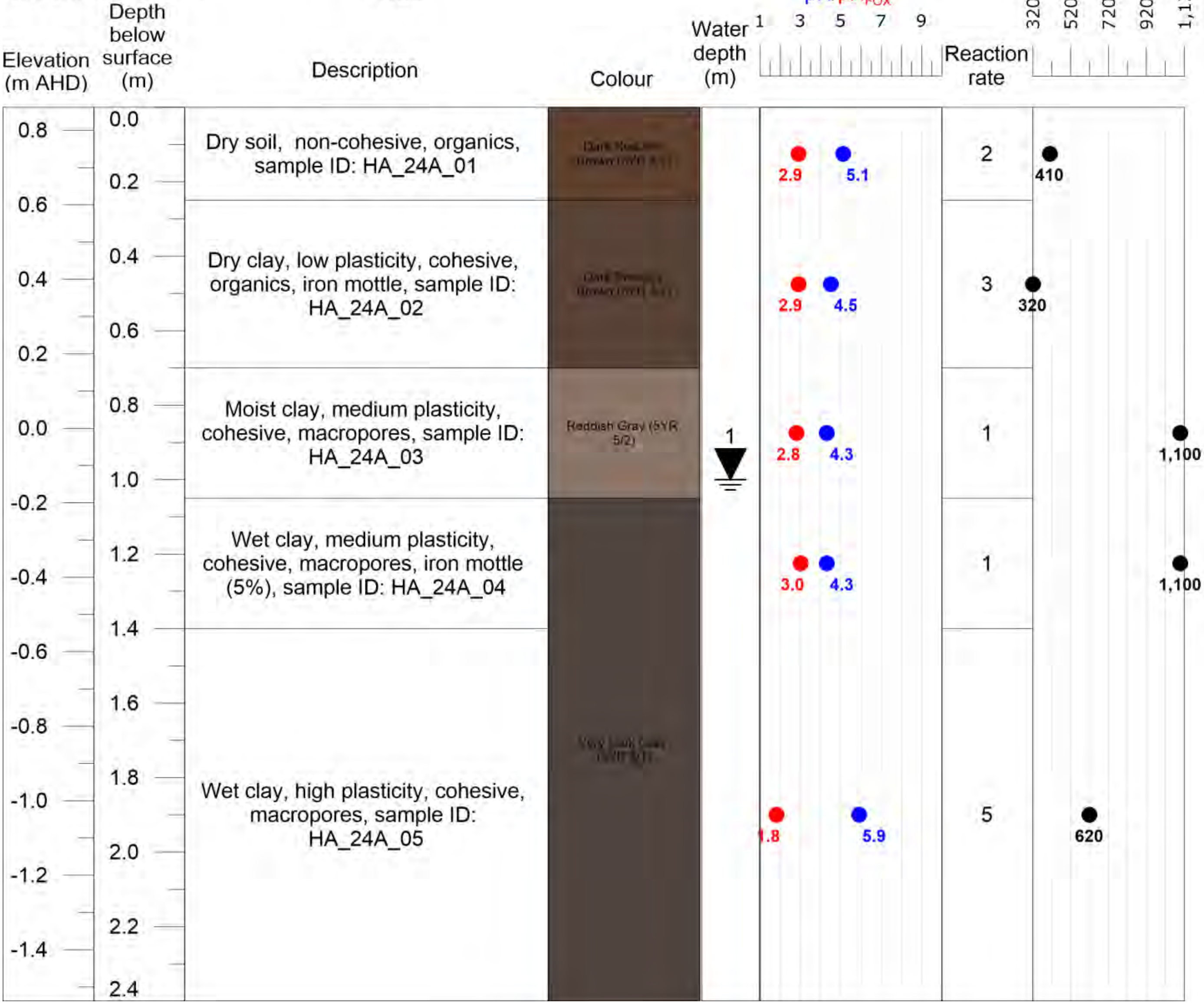
Soil profile details:

Project Number:	2018064	Profile ID:	HA_24_A
River/estuary:	Hastings	Sample date:	24/09/19
Easting:	479170.4	Sampled by:	DWJ TAT
Northing:	6523079.4		

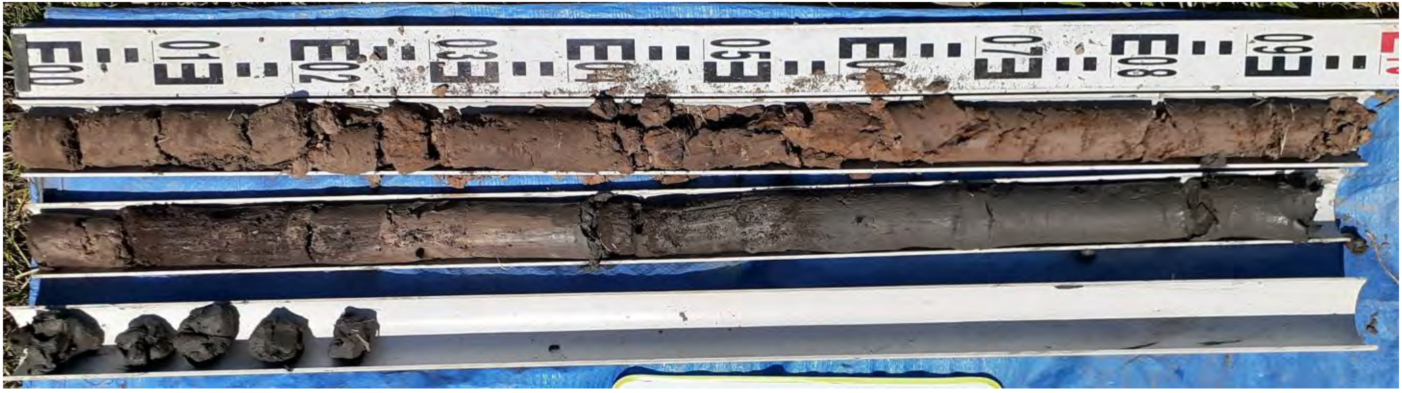
Ground elevation (m AHD):	0.86
Hydraulic conductivity (m/d):	4.03

Water quality:

Surface water EC (µS/cm):	29,564
Surface water pH:	4.4
Groundwater EC (µS/cm):	3,463
Groundwater pH:	4.23



Description	Colour	Soil pH	Soil pH_FOX	Reaction rate	Soil EC (µS/cm)
Dry soil, non-cohesive, organics, sample ID: HA_24A_01	Dark Reddish Brown (5YR 3/3)	5.1	2.9	2	410
Dry clay, low plasticity, cohesive, organics, iron mottle, sample ID: HA_24A_02	Dark Reddish Brown (5YR 3/2)	4.5	2.9	3	320
Moist clay, medium plasticity, cohesive, macropores, sample ID: HA_24A_03	Reddish Gray (5YR 5/2)	4.3	2.8	1	1,100
Wet clay, medium plasticity, cohesive, macropores, iron mottle (5%), sample ID: HA_24A_04		4.3	3.0	1	1,100
Wet clay, high plasticity, cohesive, macropores, sample ID: HA_24A_05	Very Dark Gray (5YR 3/1)	5.9	1.8	5	620



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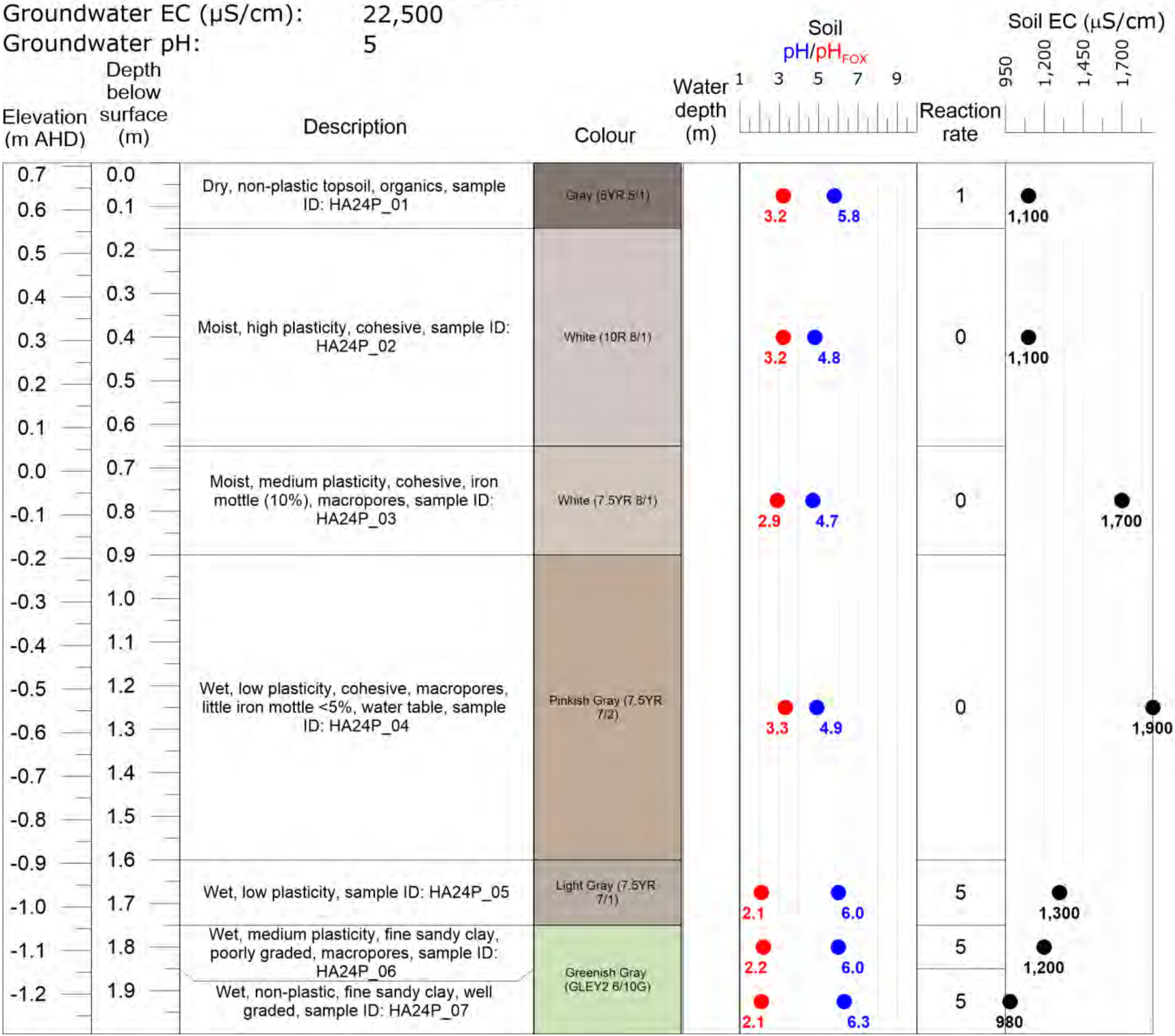
Soil profile details:

Project Number:	2018064	Profile ID:	HA_24_P
River/estuary:	Hastings	Sample date:	18/09/19
Easting:	485547.9	Sampled by:	AJH TAT
Northing:	6524685.0		

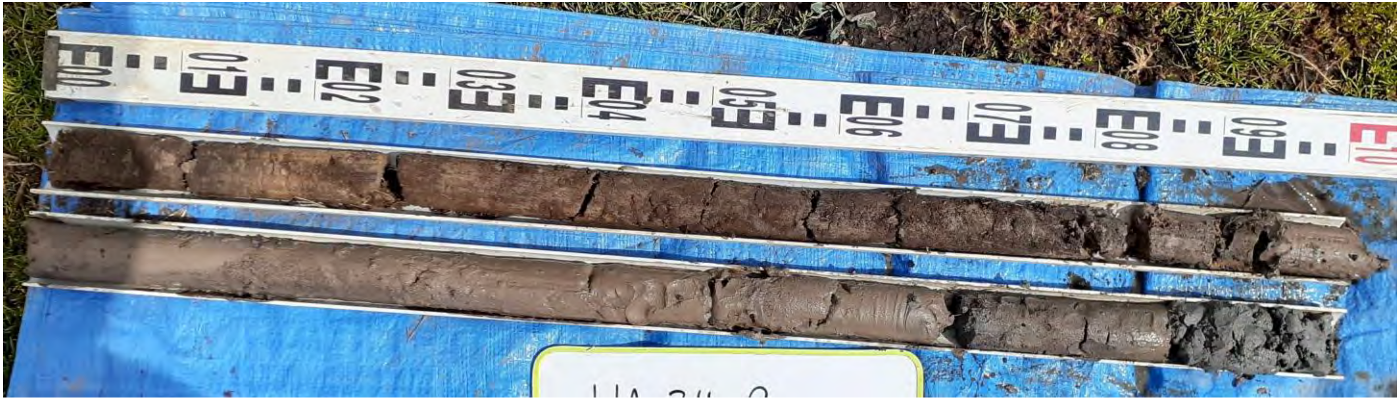
Ground elevation (m AHD): 0.71
Hydraulic conductivity (m/d): 3.67

Water quality:

Surface water EC (μS/cm): Not measured
Surface water pH: Not measured
Groundwater EC (μS/cm): 22,500
Groundwater pH: 5



Elevation (m AHD)	Depth below surface (m)	Description	Colour	Soil pH	Soil pH_{FOX}	Reaction rate	Soil EC (μS/cm)
0.7 – 0.56	0.0 – 0.15	Dry, non-plastic topsoil, organics, sample ID: HA24P_01	Gray (5YR 5/1)	5.8	3.2	1	1,100
0.56 – 0.06	0.15 – 0.65	Moist, high plasticity, cohesive, sample ID: HA24P_02	White (10R 8/1)	4.8	3.2	0	1,100
0.06 – -0.19	0.65 – 0.9	Moist, medium plasticity, cohesive, iron mottle (10%), macropores, sample ID: HA24P_03	White (7.5YR 8/1)	4.7	2.9	0	1,700
-0.19 – -0.89	0.9 – 1.6	Wet, low plasticity, cohesive, macropores, little iron mottle <5%, water table, sample ID: HA24P_04	Pinkish Gray (7.5YR 7/2)	4.9	3.3	0	1,900
-0.89 – -1.04	1.6 – 1.75	Wet, low plasticity, sample ID: HA24P_05	Light Gray (7.5YR 7/1)	6.0	2.1	5	1,300
-1.04 – -1.17	1.75 – 1.88	Wet, medium plasticity, fine sandy clay, poorly graded, macropores, sample ID: HA24P_06	Greenish Gray (GLEY2 6/10G)	6.0	2.2	5	1,200
-1.17 – -1.3	1.88 – 2.0	Wet, non-plastic, fine sandy clay, well graded, sample ID: HA24P_07		6.3	2.1	5	980



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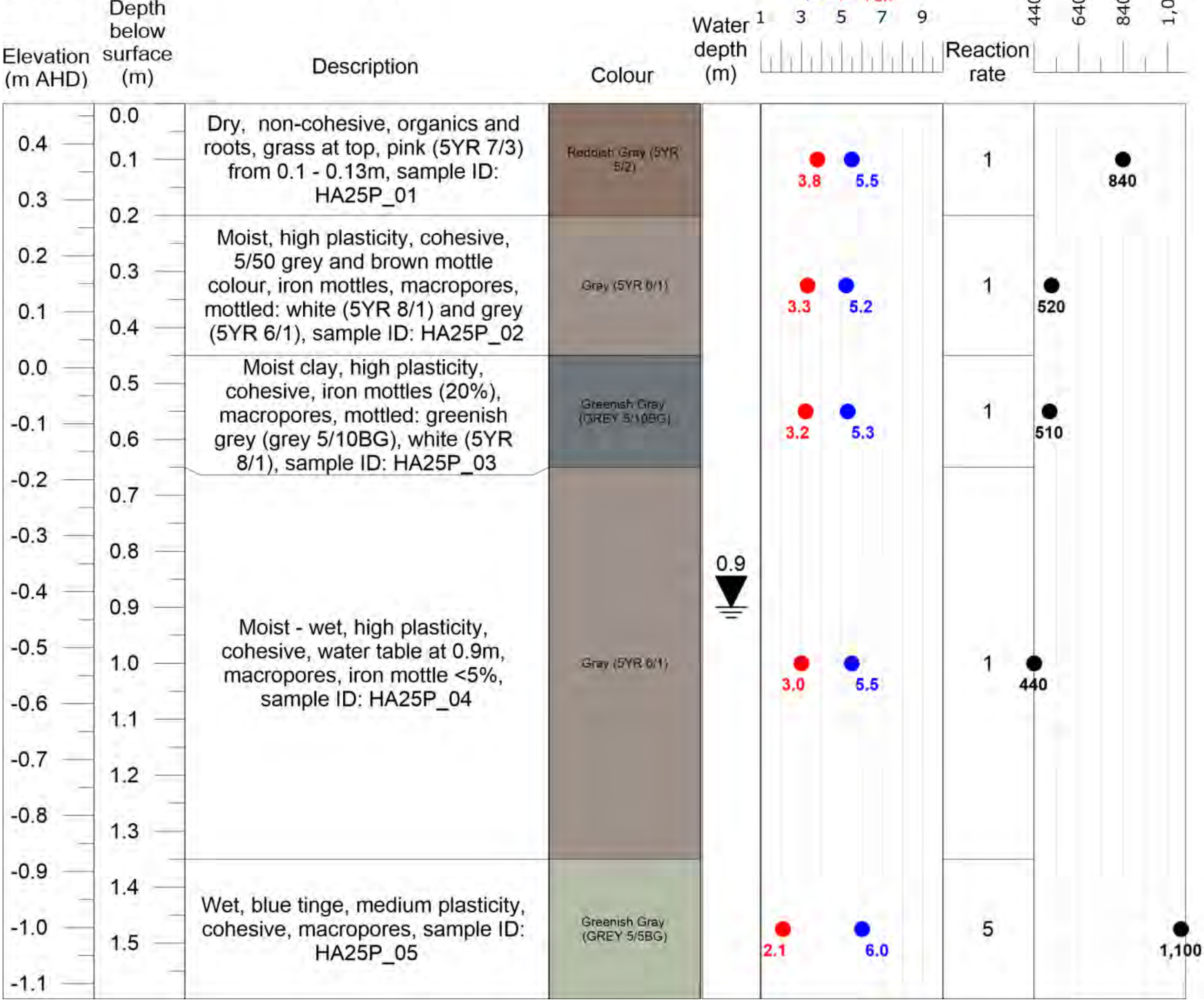
Soil profile details:

Project Number:	2018064	Profile ID:	HA_25_P
River/estuary:	Hastings	Sample date:	19/09/19
Easting:	484935.4	Sampled by:	AJH TAT
Northing:	6523852.7		

Ground elevation (m AHD):	0.47
Hydraulic conductivity (m/d):	0.37

Water quality:

Surface water EC (µS/cm):	Not measured
Surface water pH:	Not measured
Groundwater EC (µS/cm):	3,160
Groundwater pH:	5.3



Dry, non-cohesive, organics and roots, grass at top, pink (5YR 7/3) from 0.1 - 0.13m, sample ID: HA25P_01

Moist, high plasticity, cohesive, 5/50 grey and brown mottle colour, iron mottles, macropores, mottled: white (5YR 8/1) and grey (5YR 6/1), sample ID: HA25P_02

Moist clay, high plasticity, cohesive, iron mottles (20%), macropores, mottled: greenish grey (grey 5/10BG), white (5YR 8/1), sample ID: HA25P_03

Moist - wet, high plasticity, cohesive, water table at 0.9m, macropores, iron mottle <5%, sample ID: HA25P_04

Wet, blue tinge, medium plasticity, cohesive, macropores, sample ID: HA25P_05

Soil profile details:

Project Number: 2018064
River/estuary: Hastings
Easting: 476496.5
Northing: 6522196.8
Profile ID: HA_29_AA
Sample date: 31/01/20
Sampled by: DWJ TAT

Ground elevation (m AHD): 1.15
Hydraulic conductivity (m/d): 0.45

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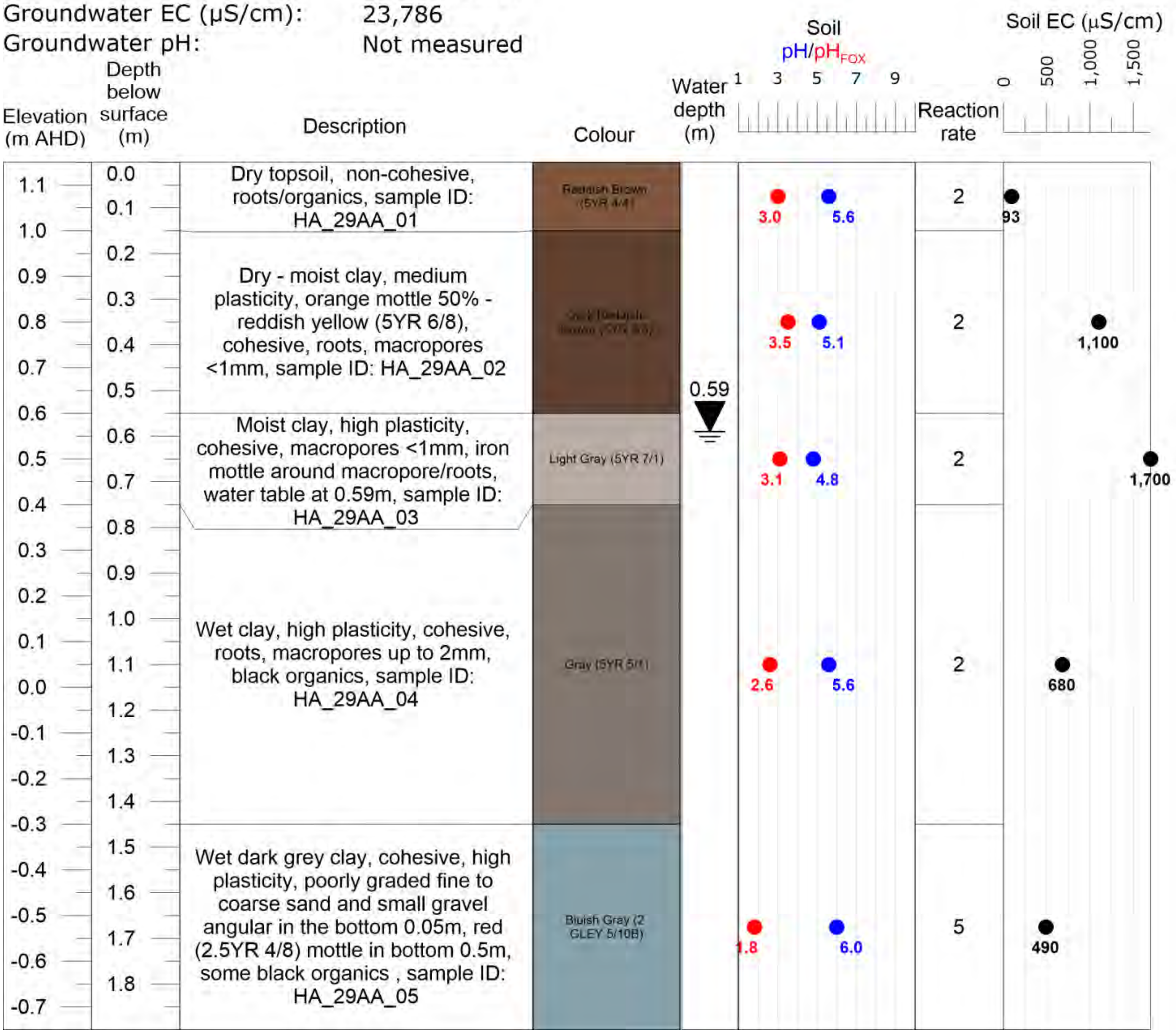
Water quality:

Surface water EC (μS/cm): Not measured
Surface water pH: Not measured
Groundwater EC (μS/cm): 23,786
Groundwater pH: Not measured



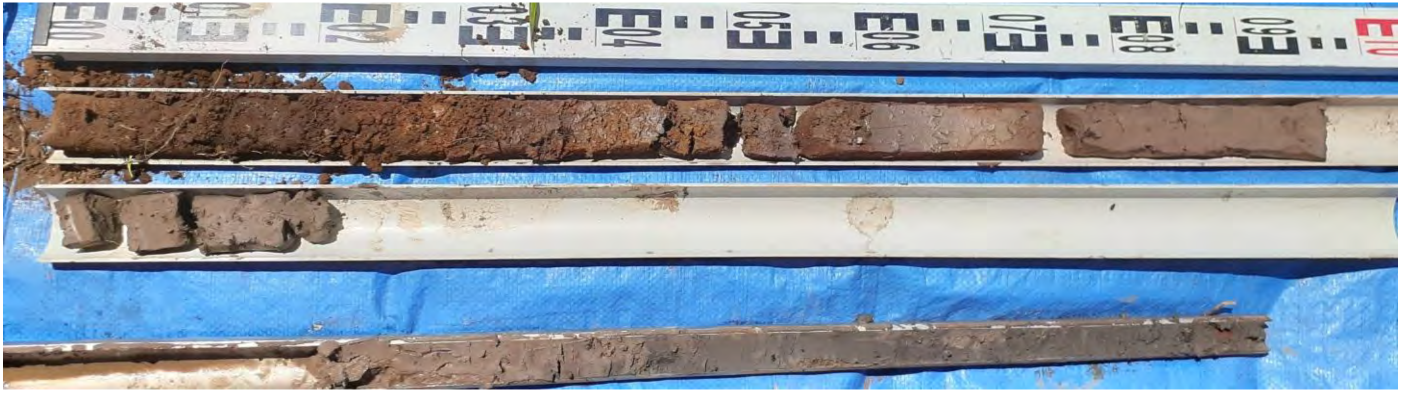
Dry topsoil, non-cohesive, roots/organics, sample ID: HA_29AA_01

Dry - moist clay, medium plasticity, orange mottle 50% - reddish yellow (5YR 6/8), cohesive, roots, macropores <1mm, sample ID: HA_29AA_02

Moist clay, high plasticity, cohesive, macropores <1mm, iron mottle around macropore/roots, water table at 0.59m, sample ID: HA_29AA_03

Wet clay, high plasticity, cohesive, roots, macropores up to 2mm, black organics, sample ID: HA_29AA_04

Wet dark grey clay, cohesive, high plasticity, poorly graded fine to coarse sand and small gravel angular in the bottom 0.05m, red (2.5YR 4/8) mottle in bottom 0.5m, some black organics , sample ID: HA_29AA_05



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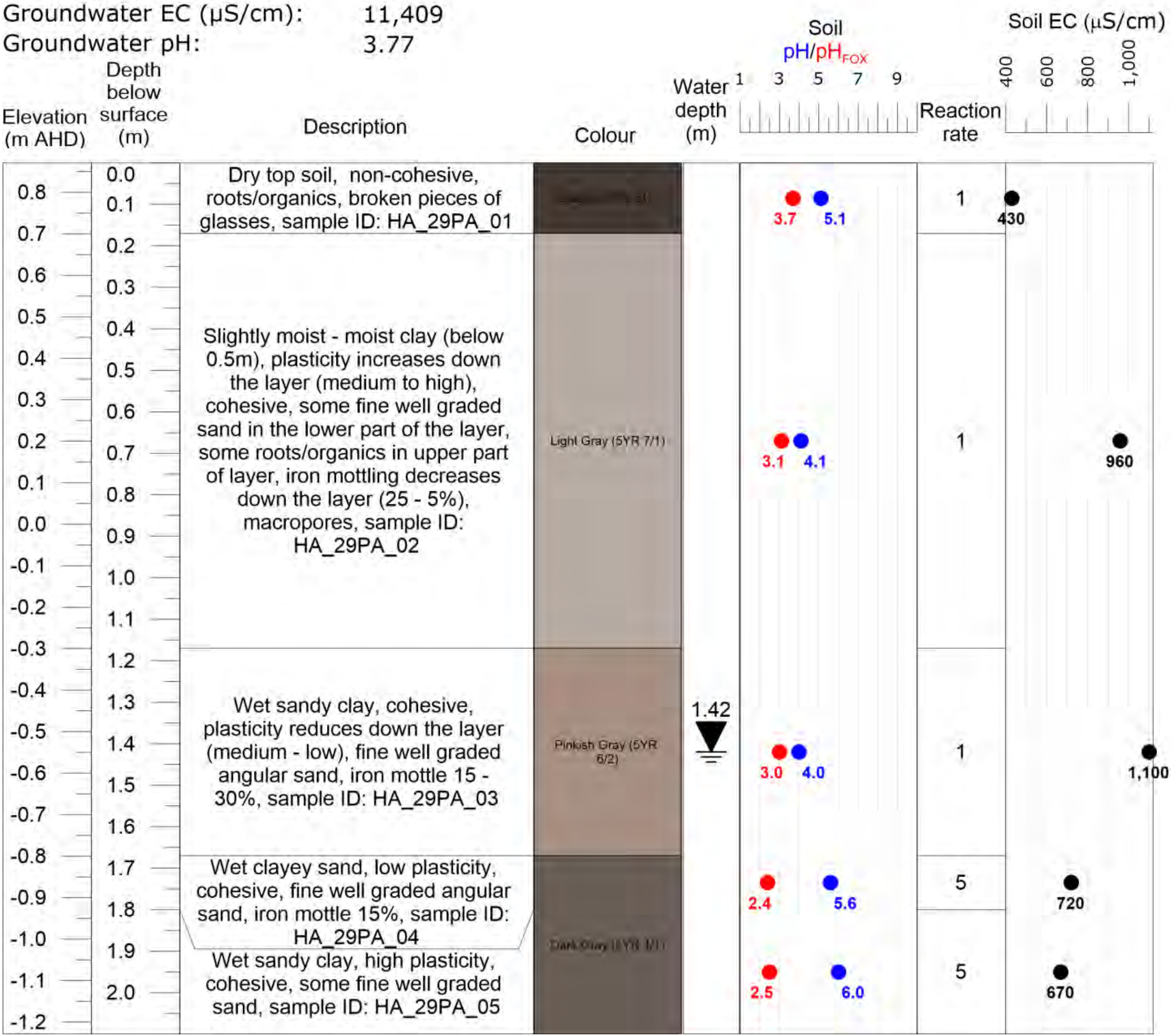
Soil profile details:

Project Number:	2018064	Profile ID:	HA_29_PA
River/estuary:	Hastings	Sample date:	28/01/20
Easting:	483540.1	Sampled by:	DWJ TAT
Northing:	6532060.1		

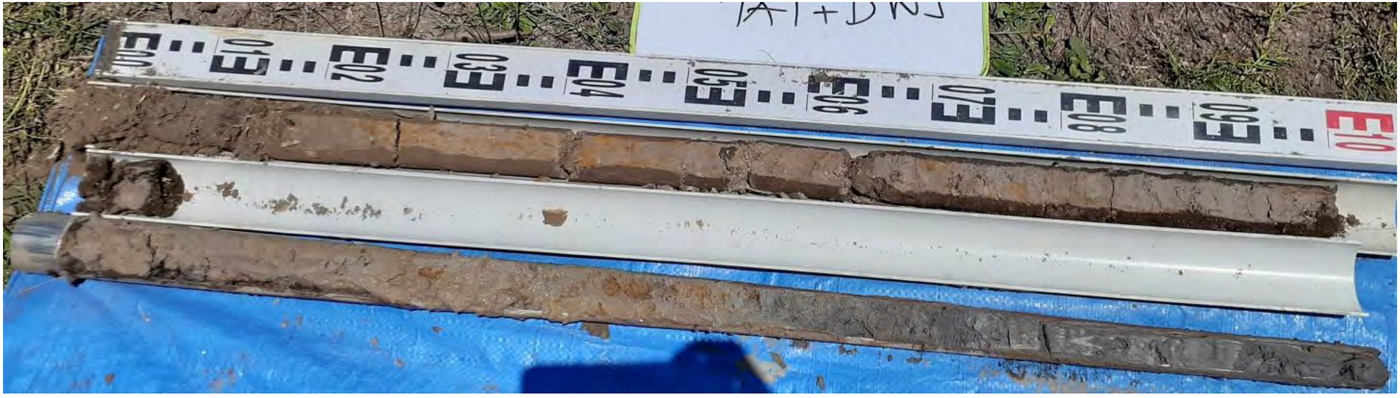
Ground elevation (m AHD):	0.87
Hydraulic conductivity (m/d):	10.52

Water quality:

Surface water EC (μS/cm):	27,541
Surface water pH:	7.67
Groundwater EC (μS/cm):	11,409
Groundwater pH:	3.77



Description	Colour	Water depth (m)	Soil pH	Soil pH$_{FOX}$	Reaction rate	Soil EC (μS/cm)
Dry top soil, non-cohesive, roots/organics, broken pieces of glasses, sample ID: HA_29PA_01	[illegible]		3.7	5.1	1	430
Slightly moist - moist clay (below 0.5m), plasticity increases down the layer (medium to high), cohesive, some fine well graded sand in the lower part of the layer, some roots/organics in upper part of layer, iron mottling decreases down the layer (25 - 5%), macropores, sample ID: HA_29PA_02	Light Gray (5YR 7/1)		3.1	4.1	1	960
Wet sandy clay, cohesive, plasticity reduces down the layer (medium - low), fine well graded angular sand, iron mottle 15 - 30%, sample ID: HA_29PA_03	Pinkish Gray (5YR 6/2)	1.42	3.0	4.0	1	1,100
Wet clayey sand, low plasticity, cohesive, fine well graded angular sand, iron mottle 15%, sample ID: HA_29PA_04	Dark Gray (5YR 4/1)		2.4	5.6	5	720
Wet sandy clay, high plasticity, cohesive, some fine well graded sand, sample ID: HA_29PA_05			2.5	6.0	5	670



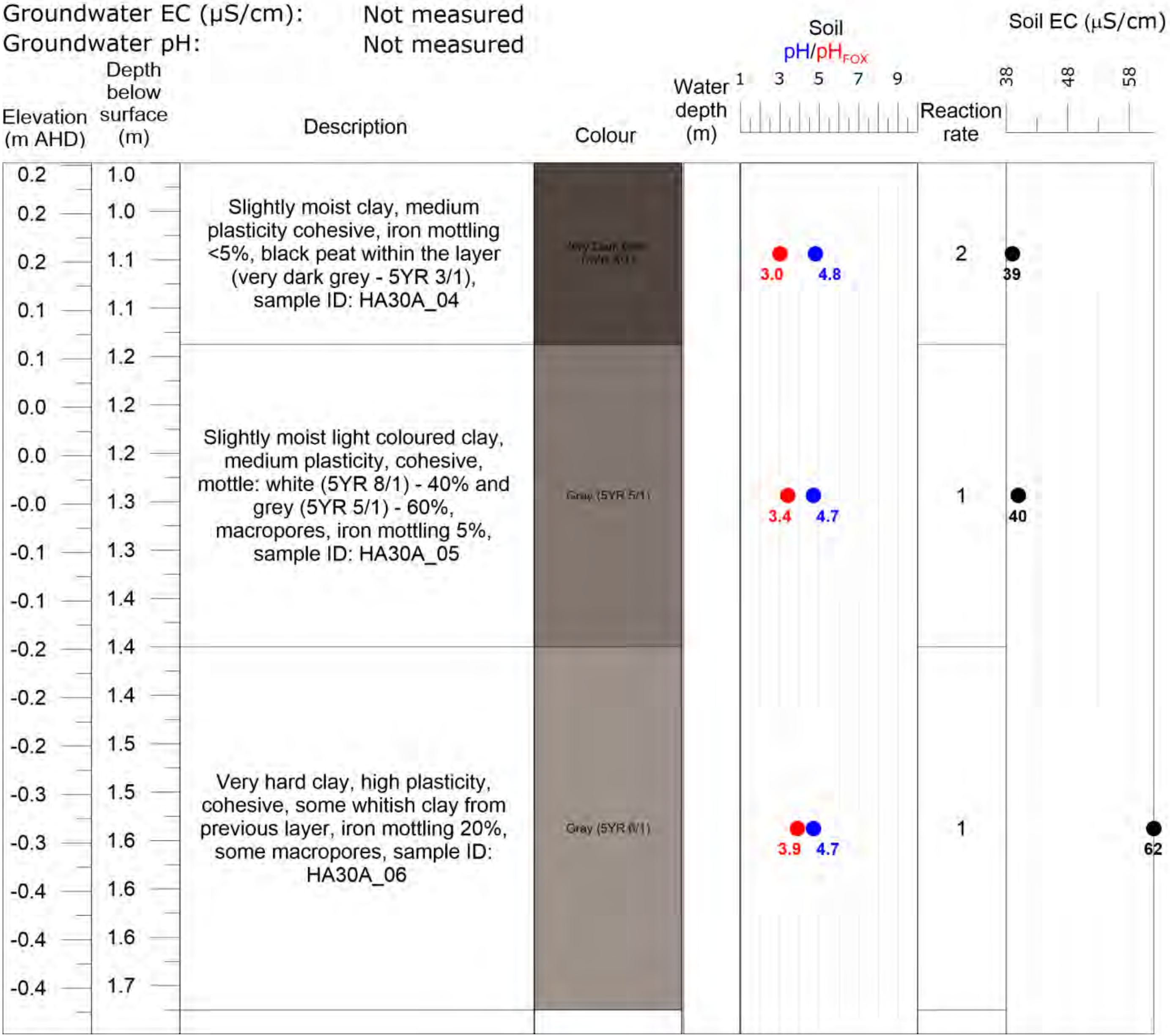
Soil profile details:

Project Number:	2018064	Profile ID:	HA_30_A
River/estuary:	Hastings	Sample date:	19/11/19
Easting:	477781.9	Sampled by:	DWJ TAT
Northing:	6523377.4		

Ground elevation (m AHD):	1.24
Hydraulic conductivity (m/d):	Not measured

Water quality:

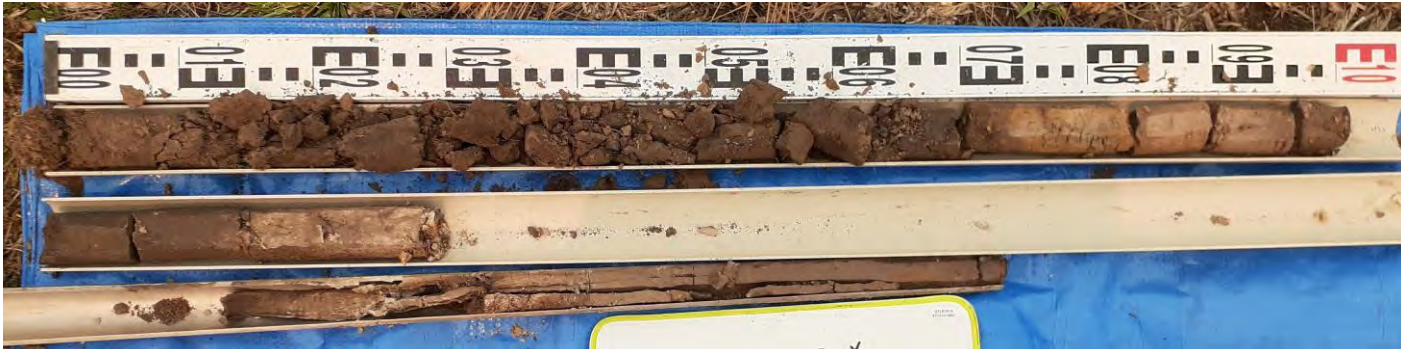
Surface water EC (µS/cm):	Not measured
Surface water pH:	Not measured
Groundwater EC (µS/cm):	Not measured
Groundwater pH:	Not measured



Slightly moist clay, medium plasticity cohesive, iron mottling <5%, black peat within the layer (very dark grey - 5YR 3/1), sample ID: HA30A_04

Slightly moist light coloured clay, medium plasticity, cohesive, mottle: white (5YR 8/1) - 40% and grey (5YR 5/1) - 60%, macropores, iron mottling 5%, sample ID: HA30A_05

Very hard clay, high plasticity, cohesive, some whitish clay from previous layer, iron mottling 20%, some macropores, sample ID: HA30A_06



Soil profile details:

Project Number:	2018064	Profile ID:	HA_31_P
River/estuary:	Hastings	Sample date:	25/09/19
Easting:	482912.2	Sampled by:	DWJ TAT
Northing:	6529005.1		

Ground elevation (m AHD):	0.35
Hydraulic conductivity (m/d):	Not measured

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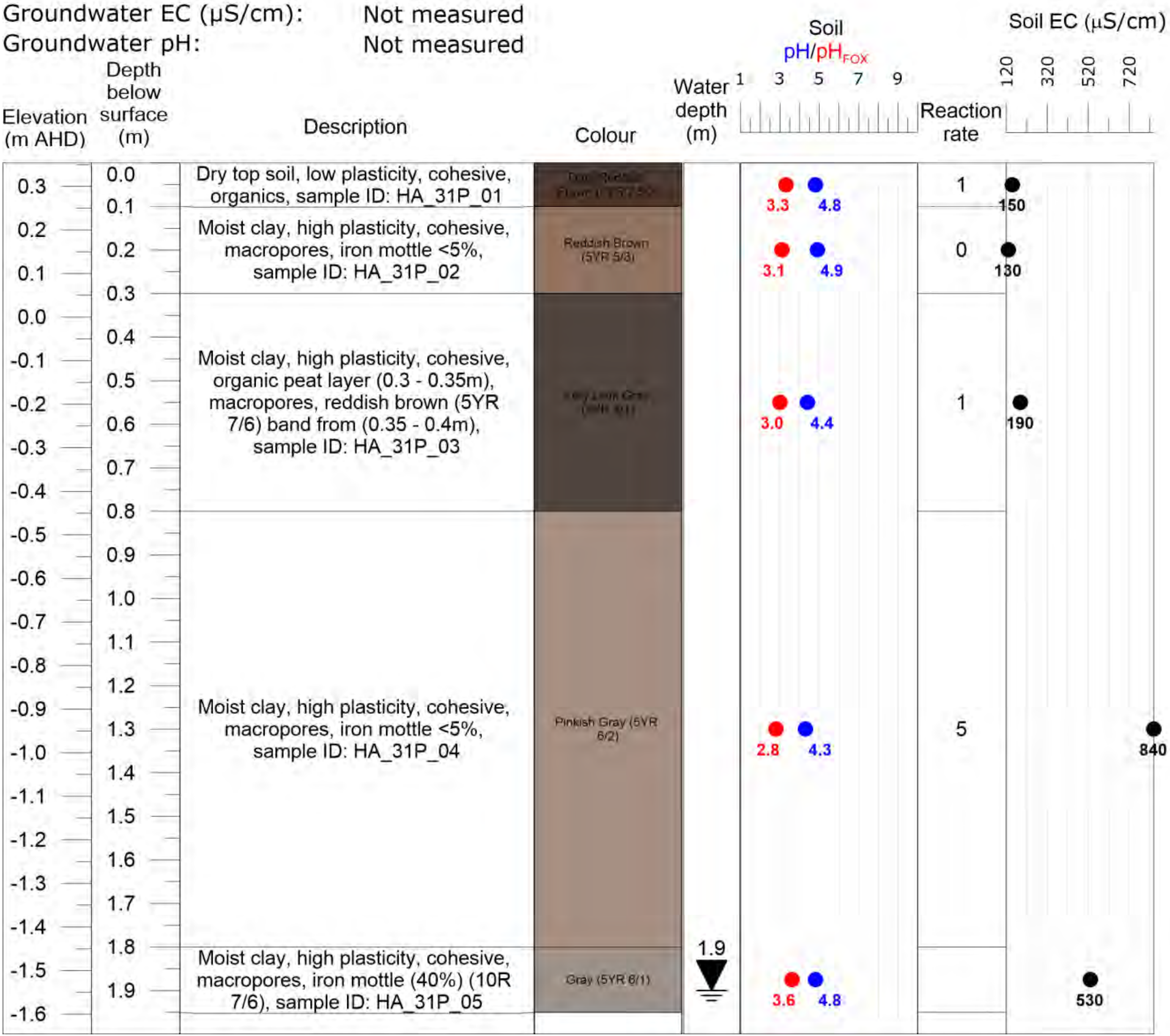
Water quality:

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



Dry top soil, low plasticity, cohesive, organics, sample ID: HA_31P_01	[illegible]		3.3	4.8	1	150
Moist clay, high plasticity, cohesive, macropores, iron mottle <5%, sample ID: HA_31P_02	Reddish Brown (5YR 5/3)		3.1	4.9	0	130
Moist clay, high plasticity, cohesive, organic peat layer (0.3 - 0.35m), macropores, reddish brown (5YR 7/6) band from (0.35 - 0.4m), sample ID: HA_31P_03	[illegible]		3.0	4.4	1	190
Moist clay, high plasticity, cohesive, macropores, iron mottle <5%, sample ID: HA_31P_04	Pinkish Gray (5YR 6/2)		2.8	4.3	5	840
Moist clay, high plasticity, cohesive, macropores, iron mottle (40%) (10R 7/6), sample ID: HA_31P_05	Gray (5YR 6/1)	1.9	3.6	4.8		530

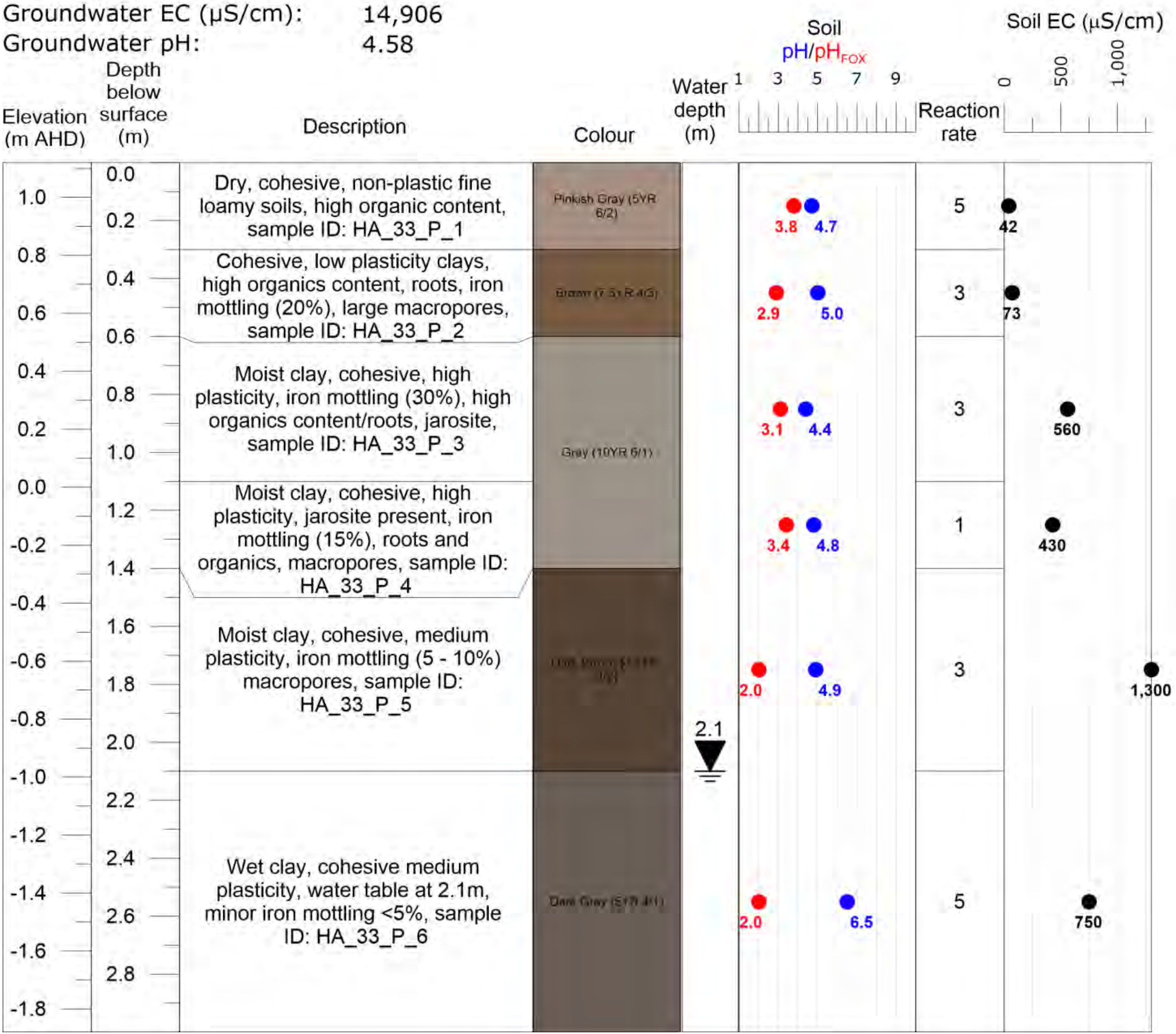
Soil profile details:

Project Number:	2018064	Profile ID:	HA_33_P
River/estuary:	Hastings	Sample date:	17/09/19
Easting:	475859	Sampled by:	AJH TAT
Northing:	6517570.0		

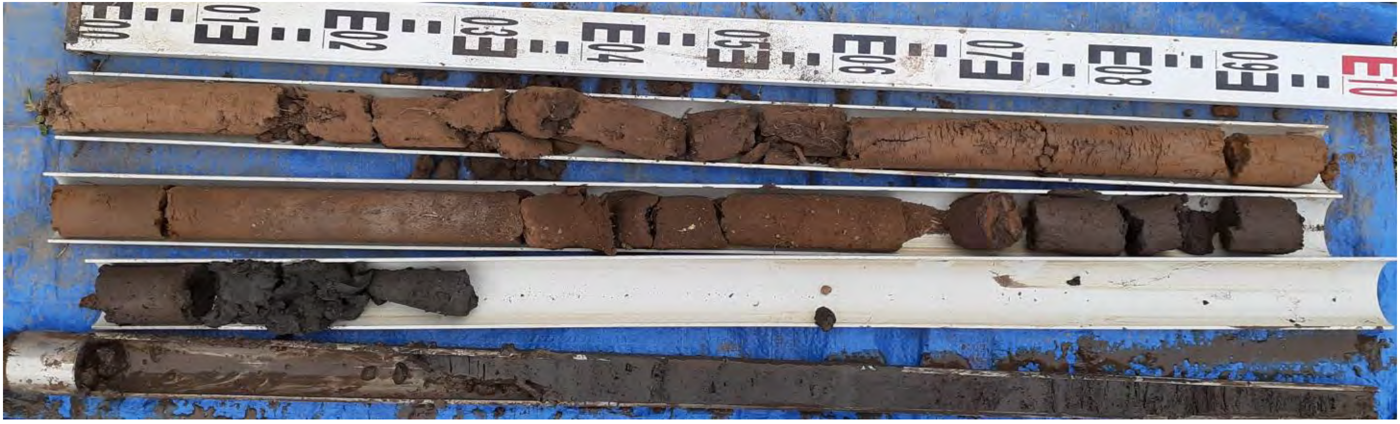
Ground elevation (m AHD):	1.12
Hydraulic conductivity (m/d):	0.54

Water quality:

Surface water EC (µS/cm):	34,000
Surface water pH:	7.6
Groundwater EC (µS/cm):	14,906
Groundwater pH:	4.58



Description	Colour	Soil pH/pH_{FOX}	Reaction rate	Soil EC (µS/cm)
Dry, cohesive, non-plastic fine loamy soils, high organic content, sample ID: HA_33_P_1	Pinkish Gray (5YR 6/2)	4.7/3.8	5	42
Cohesive, low plasticity clays, high organics content, roots, iron mottling (20%), large macropores, sample ID: HA_33_P_2	Brown (7.5YR 4/3)	5.0/2.9	3	73
Moist clay, cohesive, high plasticity, iron mottling (30%), high organics content/roots, jarosite, sample ID: HA_33_P_3	Gray (10YR 6/1)	4.4/3.1	3	560
Moist clay, cohesive, high plasticity, jarosite present, iron mottling (15%), roots and organics, macropores, sample ID: HA_33_P_4		4.8/3.4	1	430
Moist clay, cohesive, medium plasticity, iron mottling (5 - 10%) macropores, sample ID: HA_33_P_5	Dark Brown (7.5YR 3/2)	4.9/2.0	3	1,300
Wet clay, cohesive medium plasticity, water table at 2.1m, minor iron mottling <5%, sample ID: HA_33_P_6	Dark Gray (5YR 4/1)	6.5/2.0	5	750



Soil profile details:

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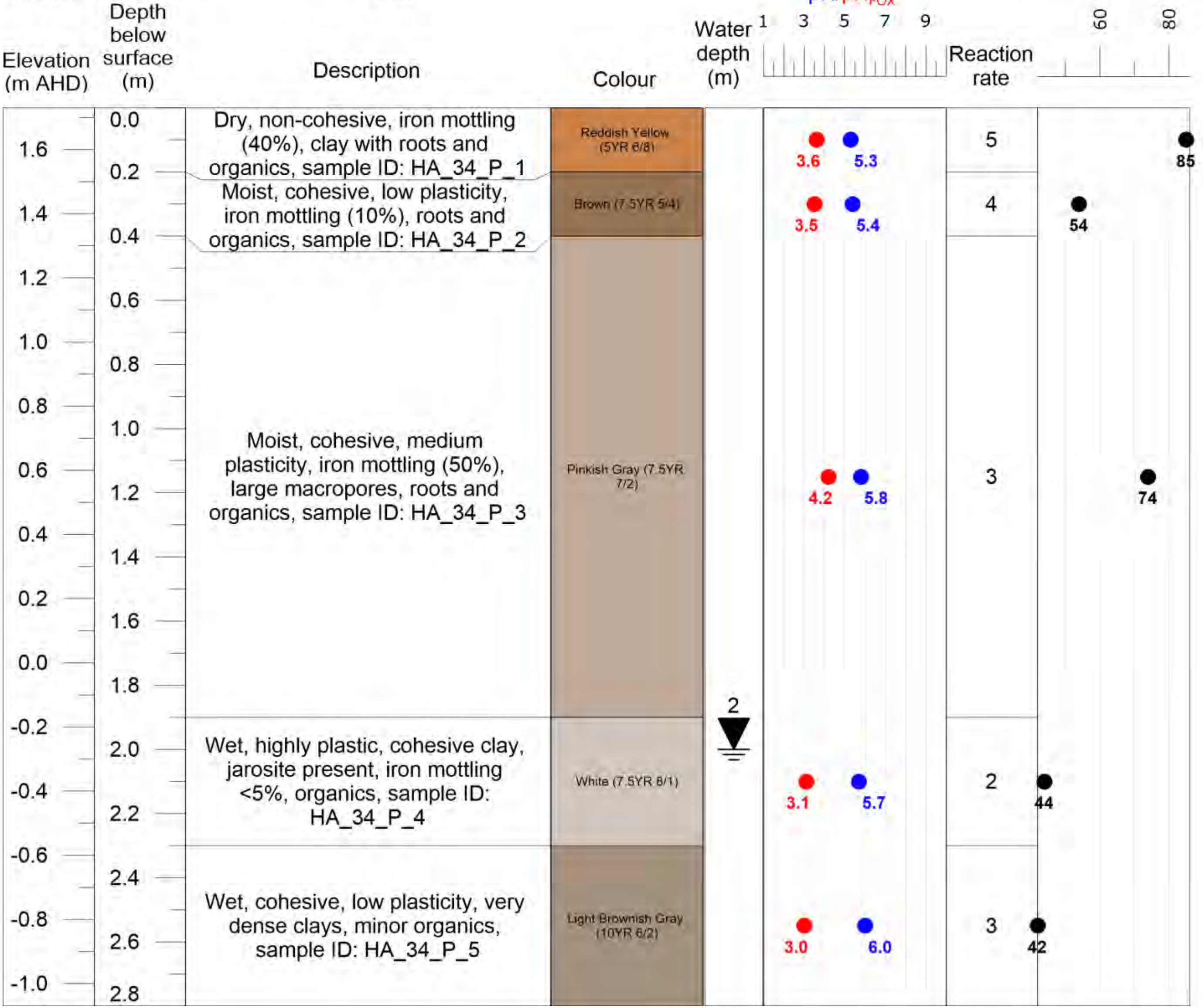
Project Number:	2018064	Profile ID:	HA_34_P
River/estuary:	Hastings	Sample date:	17/09/19
Easting:	476518.5	Sampled by:	AJH TAT
Northing:	6518424.0		

Ground elevation (m AHD):	1.73
Hydraulic conductivity (m/d):	0.15

Water quality:

Surface water EC (μS/cm):	Not measured
Surface water pH:	Not measured
Groundwater EC (μS/cm):	729
Groundwater pH:	6.2



Description	Colour	Soil pH/pH$_{FOX}$	Reaction rate	Soil EC (µS/cm)
Dry, non-cohesive, iron mottling (40%), clay with roots and organics, sample ID: HA_34_P_1	Reddish Yellow (5YR 6/8)	3.6 5.3	5	85
Moist, cohesive, low plasticity, iron mottling (10%), roots and organics, sample ID: HA_34_P_2	Brown (7.5YR 5/4)	3.5 5.4	4	54
Moist, cohesive, medium plasticity, iron mottling (50%), large macropores, roots and organics, sample ID: HA_34_P_3	Pinkish Gray (7.5YR 7/2)	4.2 5.8	3	74
Wet, highly plastic, cohesive clay, jarosite present, iron mottling <5%, organics, sample ID: HA_34_P_4	White (7.5YR 8/1)	3.1 5.7	2	44
Wet, cohesive, low plasticity, very dense clays, minor organics, sample ID: HA_34_P_5	Light Brownish Gray (10YR 6/2)	3.0 6.0	3	42

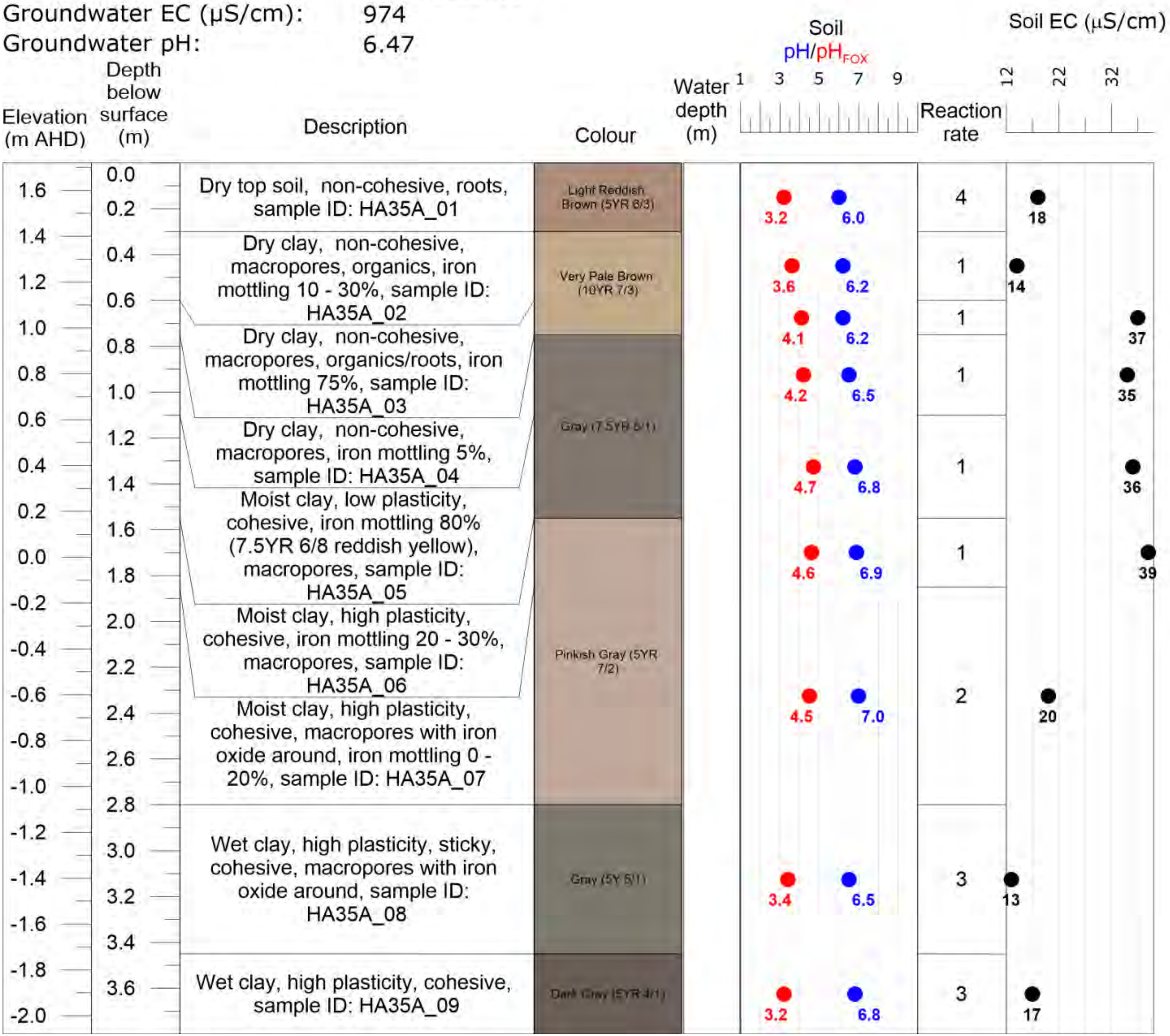
Soil profile details:

Project Number:	2018064	Profile ID:	HA_35_A
River/estuary:	Hastings	Sample date:	19/11/19
Easting:	480540.3	Sampled by:	DWJ TAT
Northing:	6525580.3		

Ground elevation (m AHD): 1.72
Hydraulic conductivity (m/d): 0.26

Water quality:

Surface water EC (µS/cm):	Not measured
Surface water pH:	Not measured
Groundwater EC (µS/cm):	974
Groundwater pH:	6.47



Description	Colour	Soil pH	Soil pH$_{FOX}$	Reaction rate	Soil EC (µS/cm)
Dry top soil, non-cohesive, roots, sample ID: HA35A_01	Light Reddish Brown (5YR 6/3)	6.0	3.2	4	18
Dry clay, non-cohesive, macropores, organics, iron mottling 10 - 30%, sample ID: HA35A_02	Very Pale Brown (10YR 7/3)	6.2	3.6	1	14
Dry clay, non-cohesive, macropores, organics/roots, iron mottling 75%, sample ID: HA35A_03	Gray (7.5YR 6/1)	6.2	4.1	1	37
Dry clay, non-cohesive, macropores, iron mottling 5%, sample ID: HA35A_04		6.5	4.2	1	35
Moist clay, low plasticity, cohesive, iron mottling 80% (7.5YR 6/8 reddish yellow), macropores, sample ID: HA35A_05	Pinkish Gray (5YR 7/2)	6.8	4.7	1	36
Moist clay, high plasticity, cohesive, iron mottling 20 - 30%, macropores, sample ID: HA35A_06		6.9	4.6	1	39
Moist clay, high plasticity, cohesive, macropores with iron oxide around, iron mottling 0 - 20%, sample ID: HA35A_07		7.0	4.5	2	20
Wet clay, high plasticity, sticky, cohesive, macropores with iron oxide around, sample ID: HA35A_08	Gray (5Y 5/1)	6.5	3.4	3	13
Wet clay, high plasticity, cohesive, sample ID: HA35A_09	Dark Gray (5YR 4/1)	6.8	3.2	3	17

Soil profile details:

Project Number:	2018064	Profile ID:	HA_35_P
River/estuary:	Hastings	Sample date:	16/09/19
Easting:	479088.2	Sampled by:	AJH TAT
Northing:	6525549.9		

Ground elevation (m AHD):	0.65
Hydraulic conductivity (m/d):	2.94

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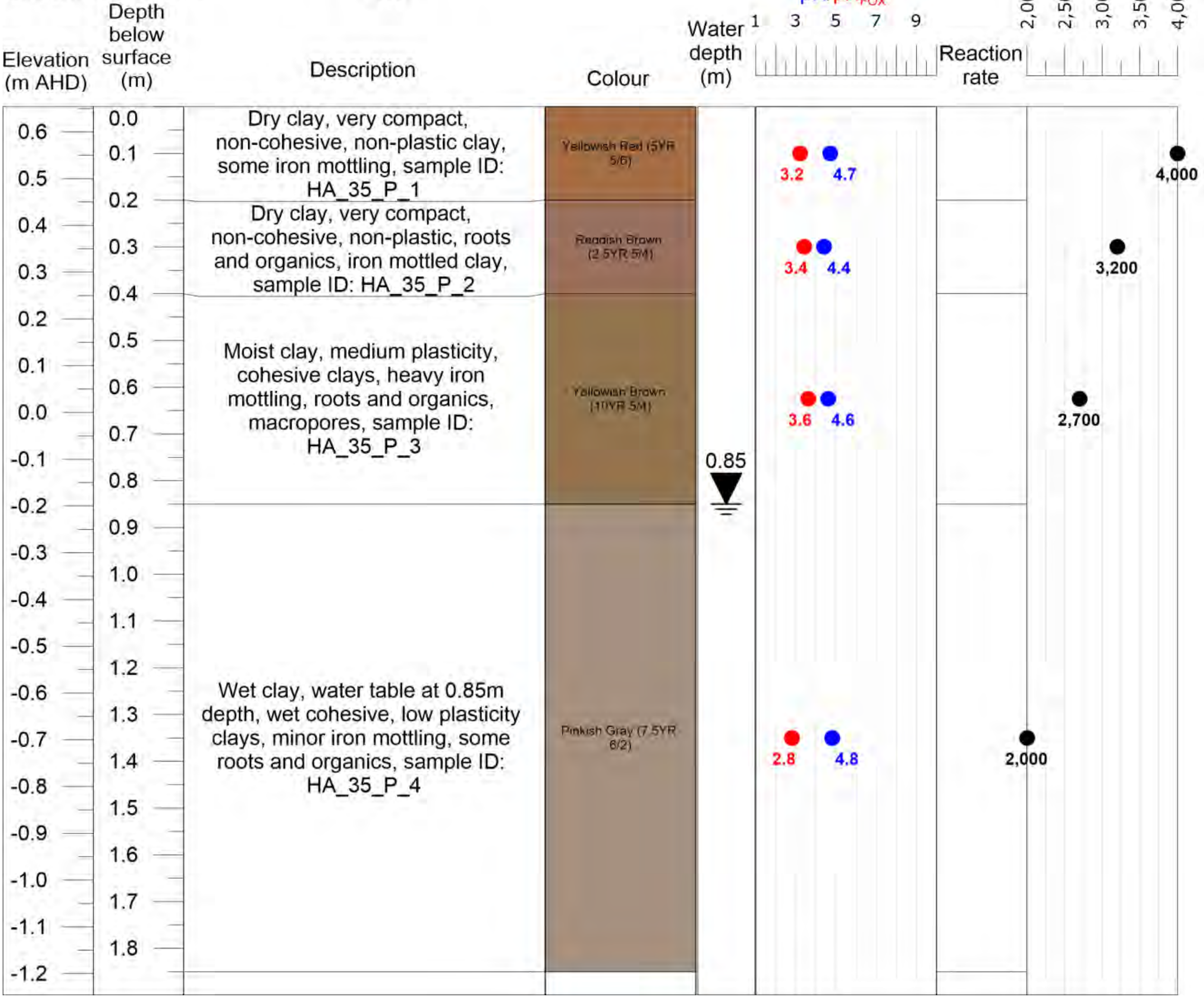
Water quality:

Surface water EC (µS/cm):	Not measured
Surface water pH:	Not measured
Groundwater EC (µS/cm):	25,400
Groundwater pH:	4.7



Dry clay, very compact, non-cohesive, non-plastic clay, some iron mottling, sample ID: HA_35_P_1

Dry clay, very compact, non-cohesive, non-plastic, roots and organics, iron mottled clay, sample ID: HA_35_P_2

Moist clay, medium plasticity, cohesive clays, heavy iron mottling, roots and organics, macropores, sample ID: HA_35_P_3

Wet clay, water table at 0.85m depth, wet cohesive, low plasticity clays, minor iron mottling, some roots and organics, sample ID: HA_35_P_4

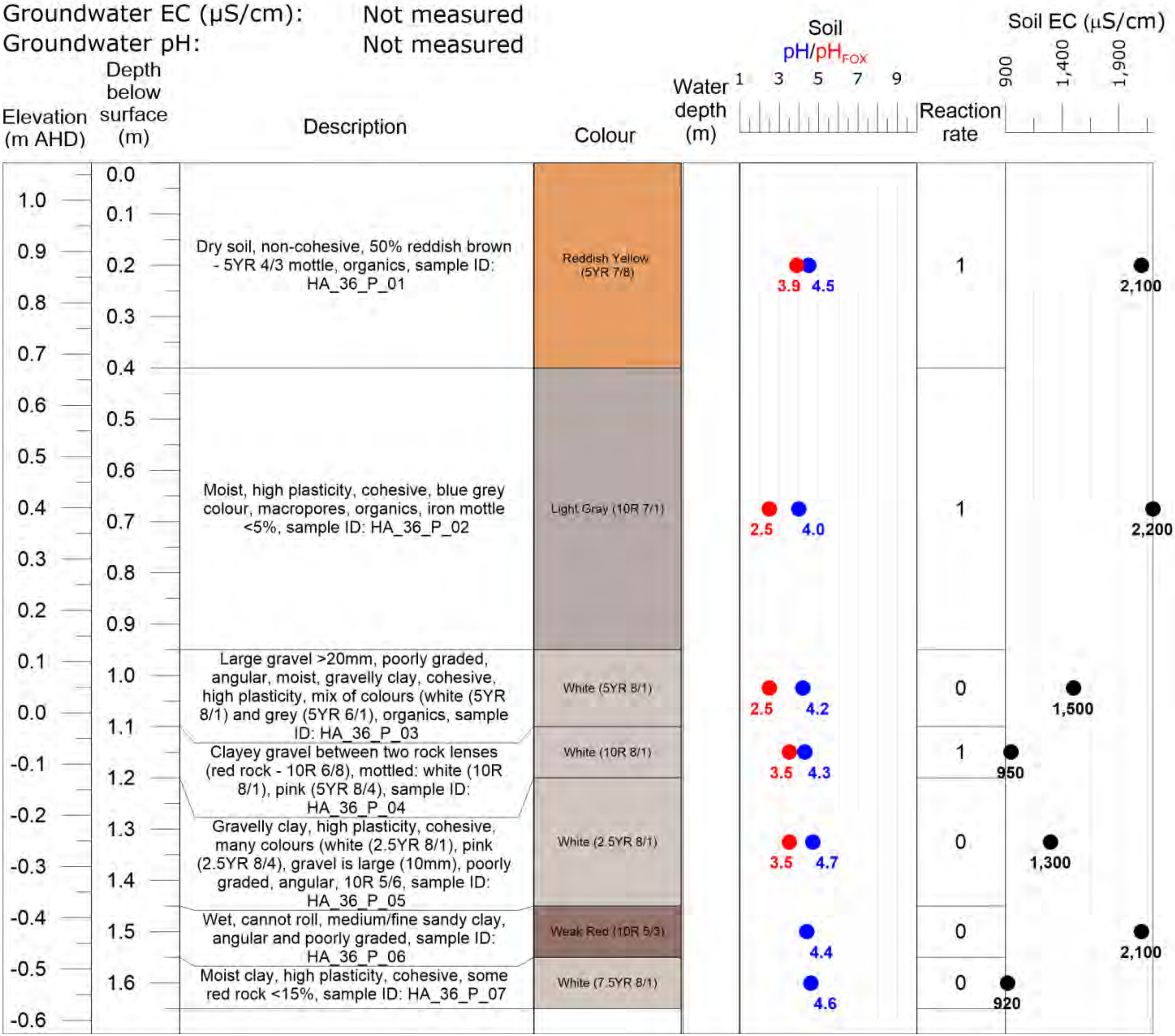
Soil profile details:

Project Number:	2018064	Profile ID:	HA_36_P
River/estuary:	Hastings	Sample date:	20/09/19
Easting:	478246	Sampled by:	AJH TAT
Northing:	6526321.7		

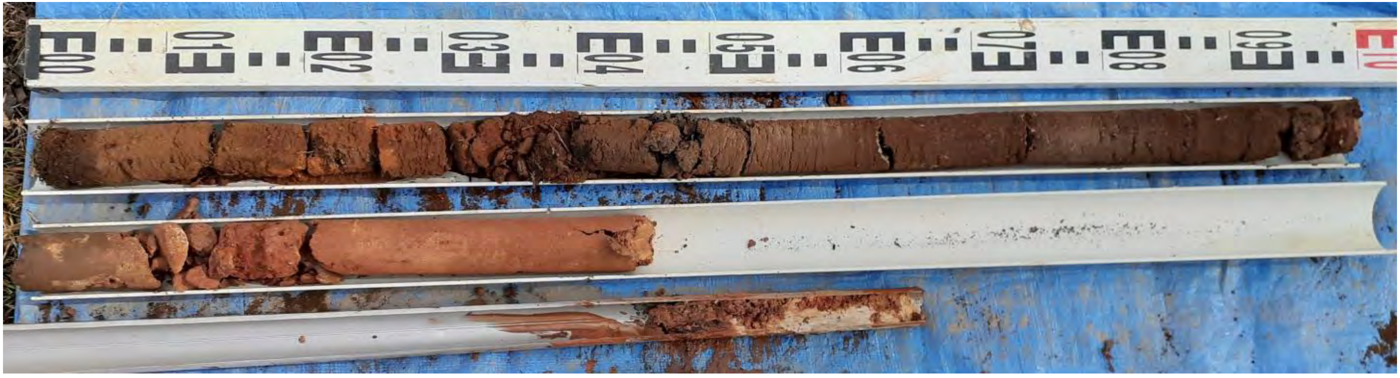
Ground elevation (m AHD):	1.07
Hydraulic conductivity (m/d):	Not measured

Water quality:

Surface water EC (µS/cm):	47,500
Surface water pH:	7.6
Groundwater EC (µS/cm):	Not measured
Groundwater pH:	Not measured



Description	Colour	Soil pH	Soil pH_{FOX}	Reaction rate	Soil EC (µS/cm)
Dry soil, non-cohesive, 50% reddish brown - 5YR 4/3 mottle, organics, sample ID: HA_36_P_01	Reddish Yellow (5YR 7/8)	4.5	3.9	1	2,100
Moist, high plasticity, cohesive, blue grey colour, macropores, organics, iron mottle <5%, sample ID: HA_36_P_02	Light Gray (10R 7/1)	4.0	2.5	1	2,200
Large gravel >20mm, poorly graded, angular, moist, gravelly clay, cohesive, high plasticity, mix of colours (white (5YR 8/1) and grey (5YR 6/1), organics, sample ID: HA_36_P_03	White (5YR 8/1)	4.2	2.5	0	1,500
Clayey gravel between two rock lenses (red rock - 10R 6/8), mottled: white (10R 8/1), pink (5YR 8/4), sample ID: HA_36_P_04	White (10R 8/1)	4.3	3.5	1	950
Gravelly clay, high plasticity, cohesive, many colours (white (2.5YR 8/1), pink (2.5YR 8/4), gravel is large (10mm), poorly graded, angular, 10R 5/6, sample ID: HA_36_P_05	White (2.5YR 8/1)	4.7	3.5	0	1,300
Wet, cannot roll, medium/fine sandy clay, angular and poorly graded, sample ID: HA_36_P_06	Weak Red (10R 5/3)	4.4		0	2,100
Moist clay, high plasticity, cohesive, some red rock <15%, sample ID: HA_36_P_07	White (7.5YR 8/1)	4.6		0	920



Soil profile details:

Project Number:	2018064	Profile ID:	HA_37_C
River/estuary:	Hastings	Sample date:	05/03/20
Easting:	481617.1	Sampled by:	AJH KW
Northing:	6525310.5		

Ground elevation (m AHD):	1.85
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

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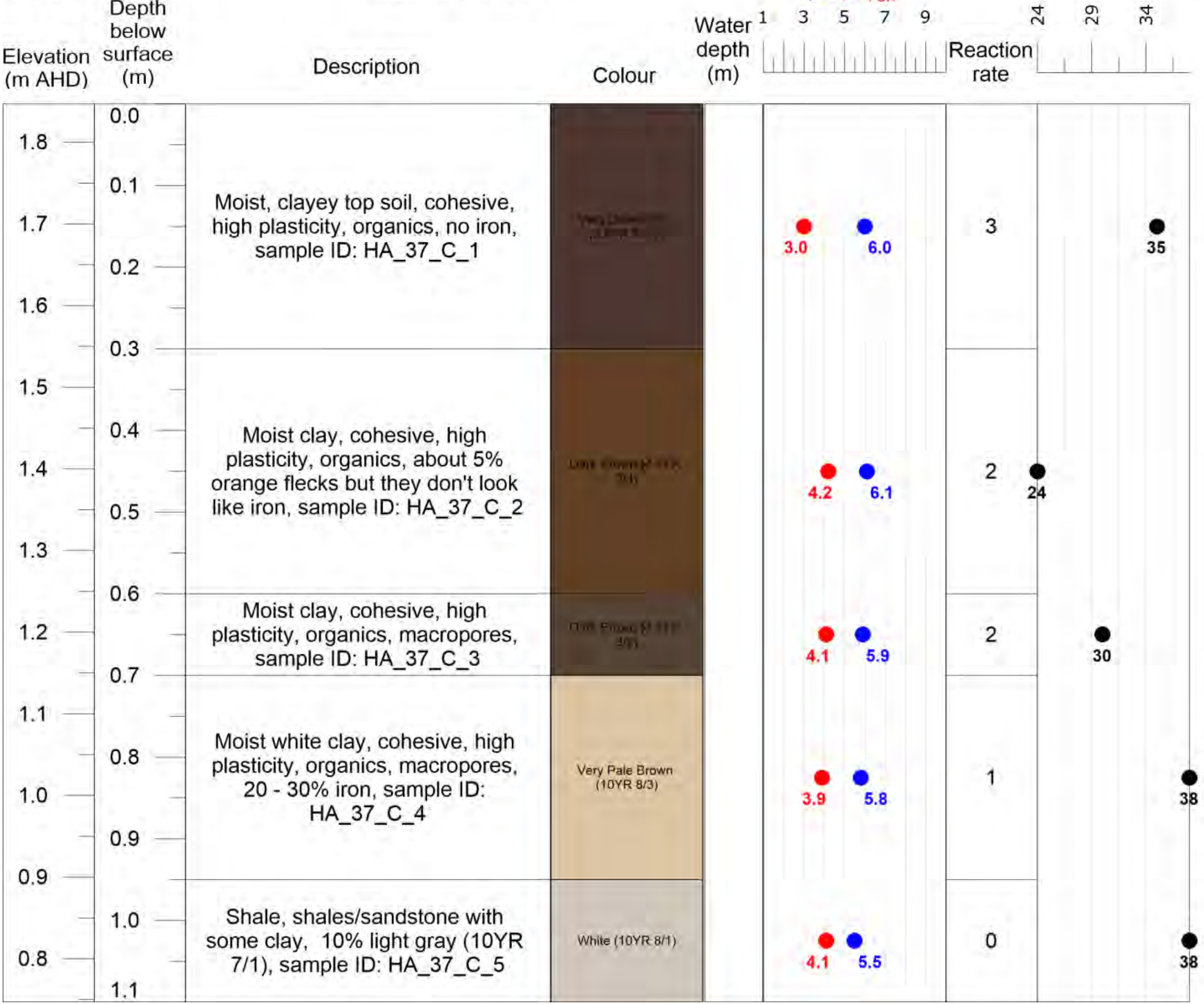

Depth below surface (m)	Description	Colour	pH	pH$_{FOX}$	Reaction rate	Soil EC (µS/cm)
0.0 – 0.3	Moist, clayey top soil, cohesive, high plasticity, organics, no iron, sample ID: HA_37_C_1	[illegible]	6.0	3.0	3	35
0.3 – 0.6	Moist clay, cohesive, high plasticity, organics, about 5% orange flecks but they don't look like iron, sample ID: HA_37_C_2	[illegible]	6.1	4.2	2	24
0.6 – 0.7	Moist clay, cohesive, high plasticity, organics, macropores, sample ID: HA_37_C_3	[illegible]	5.9	4.1	2	30
0.7 – 0.95	Moist white clay, cohesive, high plasticity, organics, macropores, 20 - 30% iron, sample ID: HA_37_C_4	Very Pale Brown (10YR 8/3)	5.8	3.9	1	38
0.95 – 1.1	Shale, shales/sandstone with some clay, 10% light gray (10YR 7/1), sample ID: HA_37_C_5	White (10YR 8/1)	5.5	4.1	0	38

Soil profile details:

Project Number:	2018064	Profile ID:	HA_37_X
River/estuary:	Hastings	Sample date:	05/03/20
Easting:	481711.5	Sampled by:	AJH KW
Northing:	6525300.6		

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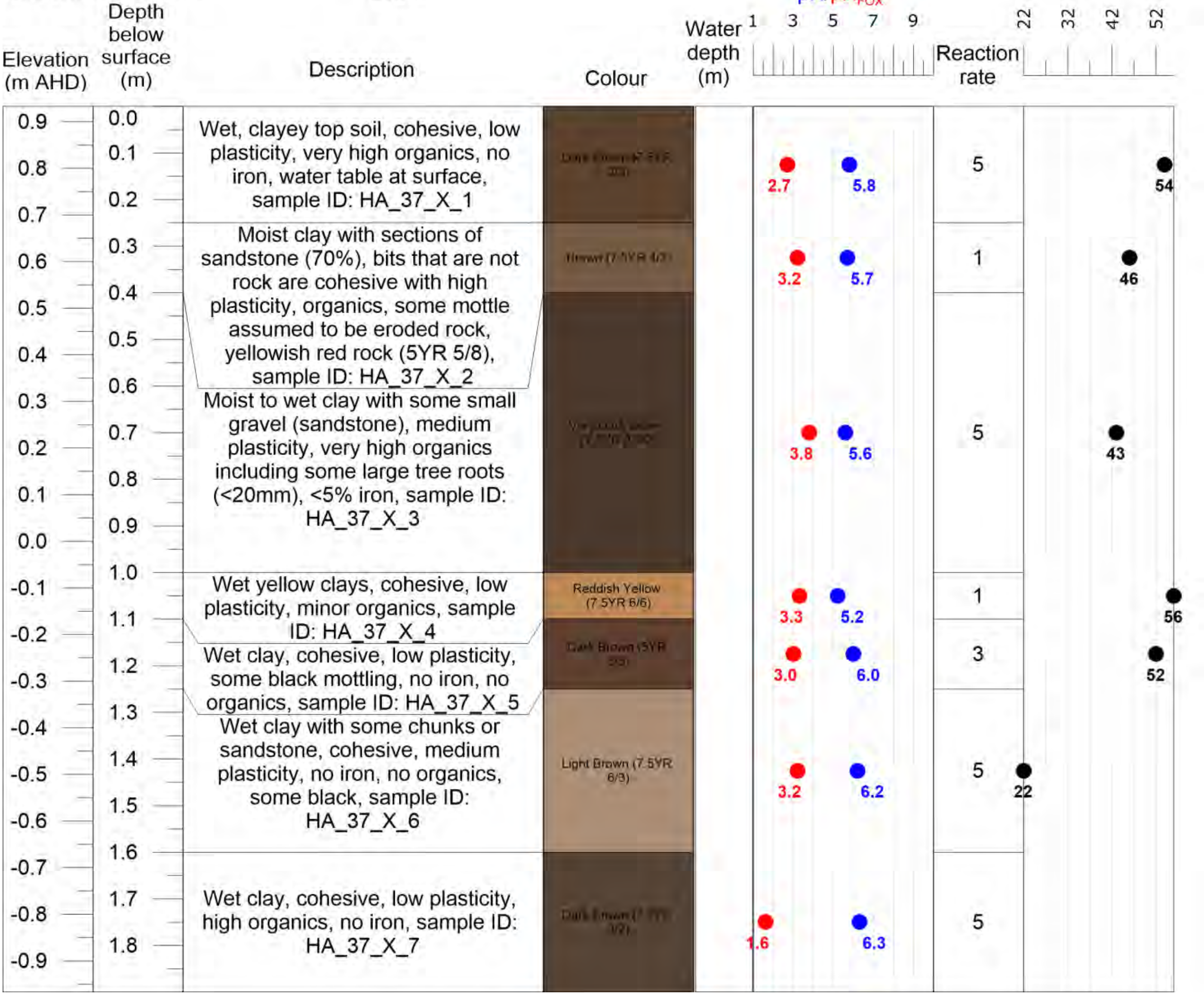
Ground elevation (m AHD):	0.93
Hydraulic conductivity (m/d):	Not measured

Water quality:

Surface water EC (µS/cm):	353
Surface water pH:	5.55
Groundwater EC (µS/cm):	492
Groundwater pH:	5.64



Description	Colour	pH	pH$_{FOX}$	Reaction rate	Soil EC (µS/cm)
Wet, clayey top soil, cohesive, low plasticity, very high organics, no iron, water table at surface, sample ID: HA_37_X_1	Dark Brown (7.5YR 3/3)	5.8	2.7	5	54
Moist clay with sections of sandstone (70%), bits that are not rock are cohesive with high plasticity, organics, some mottle assumed to be eroded rock, yellowish red rock (5YR 5/8), sample ID: HA_37_X_2	Brown (7.5YR 4/3)	5.7	3.2	1	46
Moist to wet clay with some small gravel (sandstone), medium plasticity, very high organics including some large tree roots (<20mm), <5% iron, sample ID: HA_37_X_3	Very dark brown (7.5YR 2.5/2)	5.6	3.8	5	43
Wet yellow clays, cohesive, low plasticity, minor organics, sample ID: HA_37_X_4	Reddish Yellow (7.5YR 6/6)	5.2	3.3	1	56
Wet clay, cohesive, low plasticity, some black mottling, no iron, no organics, sample ID: HA_37_X_5	Dark Brown (5YR 3/3)	6.0	3.0	3	52
Wet clay with some chunks or sandstone, cohesive, medium plasticity, no iron, no organics, some black, sample ID: HA_37_X_6	Light Brown (7.5YR 6/3)	6.2	3.2	5	22
Wet clay, cohesive, low plasticity, high organics, no iron, sample ID: HA_37_X_7	Dark Brown (7.5YR 3/2)	6.3	1.6	5	

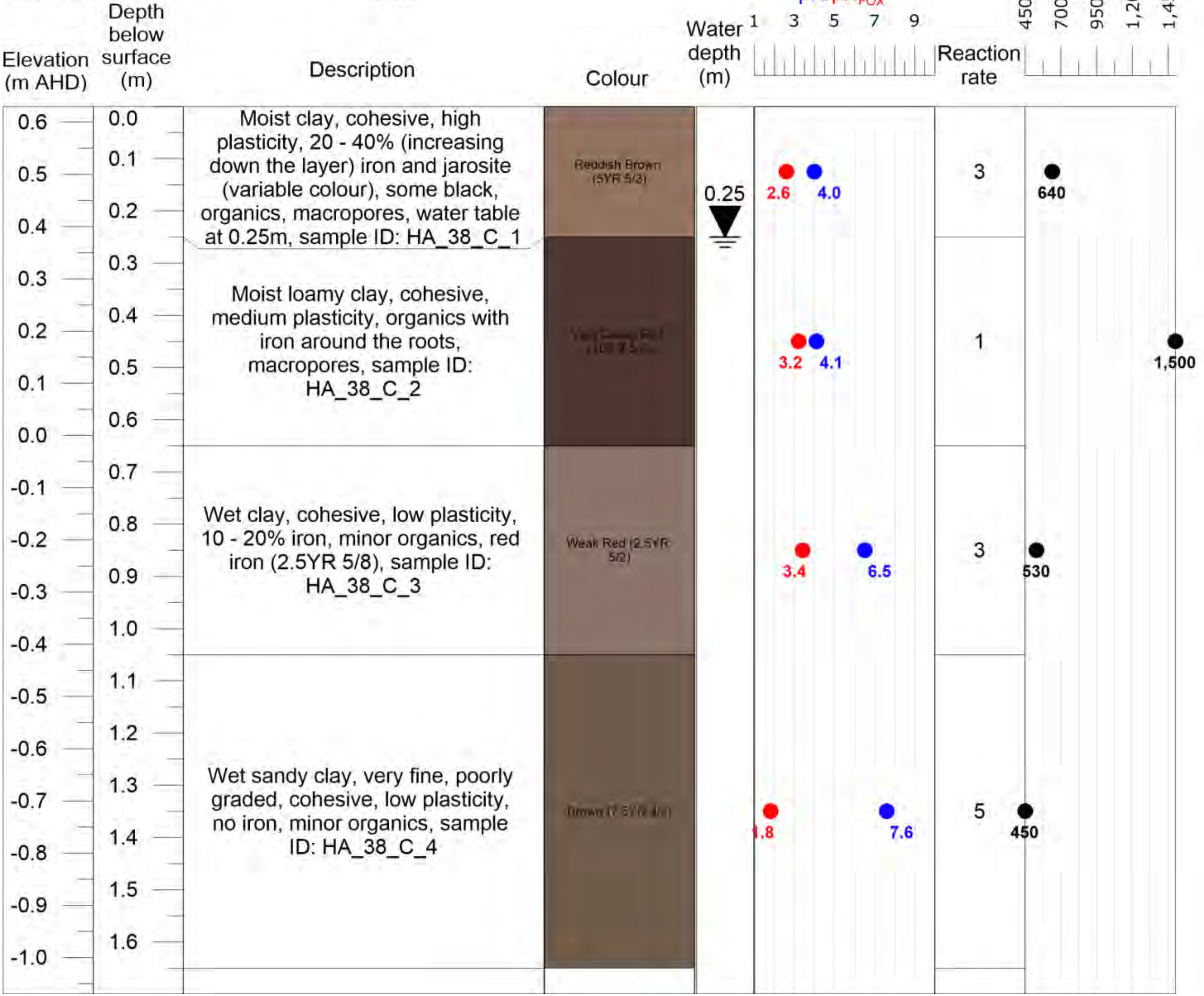
Soil profile details:

Project Number:	2018064	Profile ID:	HA_38_C
River/estuary:	Hastings	Sample date:	04/03/20
Easting:	487710.4	Sampled by:	AJH KW
Northing:	6541316.6		

Ground elevation (m AHD): 0.63
Hydraulic conductivity (m/d): Not measured

Water quality:

Surface water EC (µS/cm):	3,548
Surface water pH:	3.06
Groundwater EC (µS/cm):	19
Groundwater pH:	3.85



Moist clay, cohesive, high plasticity, 20 - 40% (increasing down the layer) iron and jarosite (variable colour), some black, organics, macropores, water table at 0.25m, sample ID: HA_38_C_1

Moist loamy clay, cohesive, medium plasticity, organics with iron around the roots, macropores, sample ID: HA_38_C_2

Wet clay, cohesive, low plasticity, 10 - 20% iron, minor organics, red iron (2.5YR 5/8), sample ID: HA_38_C_3

Wet sandy clay, very fine, poorly graded, cohesive, low plasticity, no iron, minor organics, sample ID: HA_38_C_4

Soil profile details:

Project Number:	2018064
River/estuary:	Hastings
Easting:	485362.6
Northing:	6525339.3
Profile ID:	HA_40_P
Sample date:	18/09/19
Sampled by:	AJH TAT
Ground elevation (m AHD):	0.51
Hydraulic conductivity (m/d):	0.34

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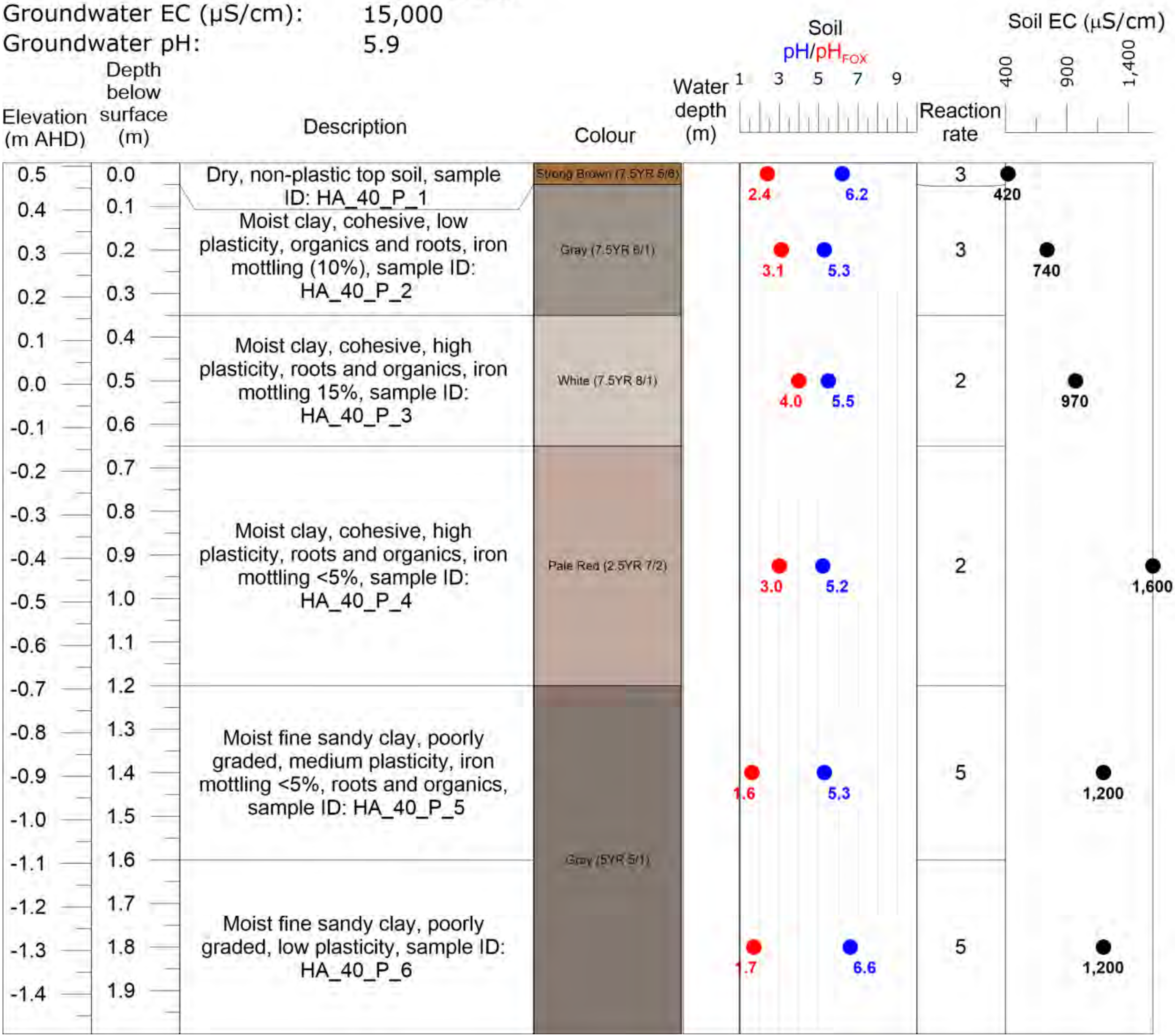
Water quality:

Surface water EC (µS/cm):	Not measured
Surface water pH:	Not measured
Groundwater EC (µS/cm):	15,000
Groundwater pH:	5.9



Description	Colour	pH$_{FOX}$	pH	Reaction rate	Soil EC (µS/cm)
Dry, non-plastic top soil, sample ID: HA_40_P_1	Strong Brown (7.5YR 5/6)	2.4	6.2	3	420
Moist clay, cohesive, low plasticity, organics and roots, iron mottling (10%), sample ID: HA_40_P_2	Gray (7.5YR 6/1)	3.1	5.3	3	740
Moist clay, cohesive, high plasticity, roots and organics, iron mottling 15%, sample ID: HA_40_P_3	White (7.5YR 8/1)	4.0	5.5	2	970
Moist clay, cohesive, high plasticity, roots and organics, iron mottling <5%, sample ID: HA_40_P_4	Pale Red (2.5YR 7/2)	3.0	5.2	2	1,600
Moist fine sandy clay, poorly graded, medium plasticity, iron mottling <5%, roots and organics, sample ID: HA_40_P_5	Gray (5YR 5/1)	1.6	5.3	5	1,200
Moist fine sandy clay, poorly graded, low plasticity, sample ID: HA_40_P_6		1.7	6.6	5	1,200

Soil profile details:

Project Number:	2018064	Profile ID:	HA_43_P
River/estuary:	Hastings	Sample date:	26/09/19
Easting:	486056.5	Sampled by:	DWJ TAT
Northing:	6531276.4		

Ground elevation (m AHD):	0.58
Hydraulic conductivity (m/d):	Not measured

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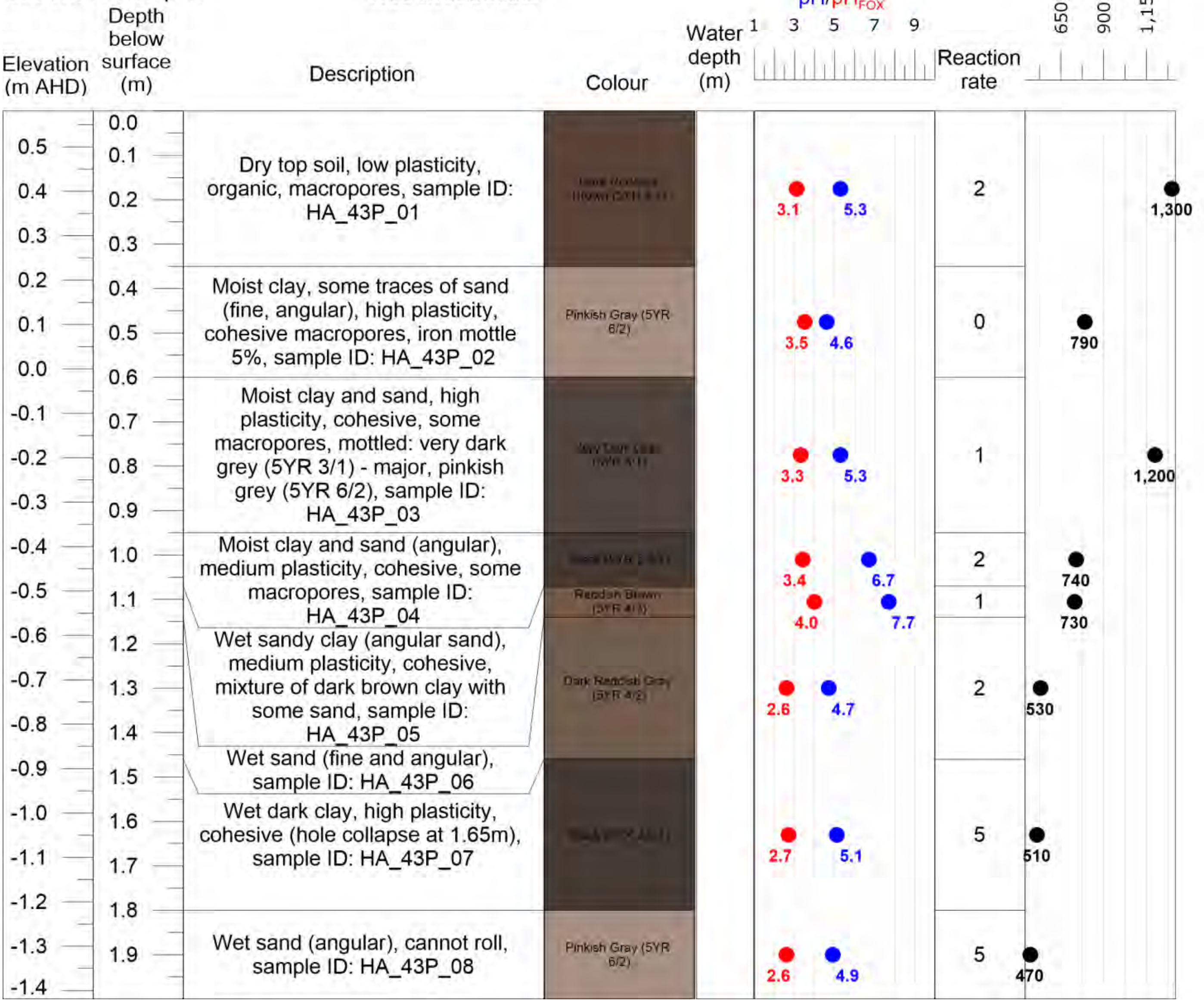
Water quality:

Surface water EC (µS/cm):	7,620
Surface water pH:	6.8
Groundwater EC (µS/cm):	Not measured
Groundwater pH:	Not measured



Description	Colour	pH_{FOX}	pH	Reaction rate	Soil EC (µS/cm)
Dry top soil, low plasticity, organic, macropores, sample ID: HA_43P_01	[illegible]	3.1	5.3	2	1,300
Moist clay, some traces of sand (fine, angular), high plasticity, cohesive macropores, iron mottle 5%, sample ID: HA_43P_02	Pinkish Gray (5YR 6/2)	3.5	4.6	0	790
Moist clay and sand, high plasticity, cohesive, some macropores, mottled: very dark grey (5YR 3/1) - major, pinkish grey (5YR 6/2), sample ID: HA_43P_03	[illegible]	3.3	5.3	1	1,200
Moist clay and sand (angular), medium plasticity, cohesive, some macropores, sample ID: HA_43P_04	[illegible]	3.4	6.7	2	740
	Reddish Brown (5YR 4/[illegible])	4.0	7.7	1	730
Wet sandy clay (angular sand), medium plasticity, cohesive, mixture of dark brown clay with some sand, sample ID: HA_43P_05	Dark Reddish Gray (5YR 4/2)	2.6	4.7	2	530
Wet sand (fine and angular), sample ID: HA_43P_06					
Wet dark clay, high plasticity, cohesive (hole collapse at 1.65m), sample ID: HA_43P_07	[illegible]	2.7	5.1	5	510
Wet sand (angular), cannot roll, sample ID: HA_43P_08	Pinkish Gray (5YR 6/2)	2.6	4.9	5	470

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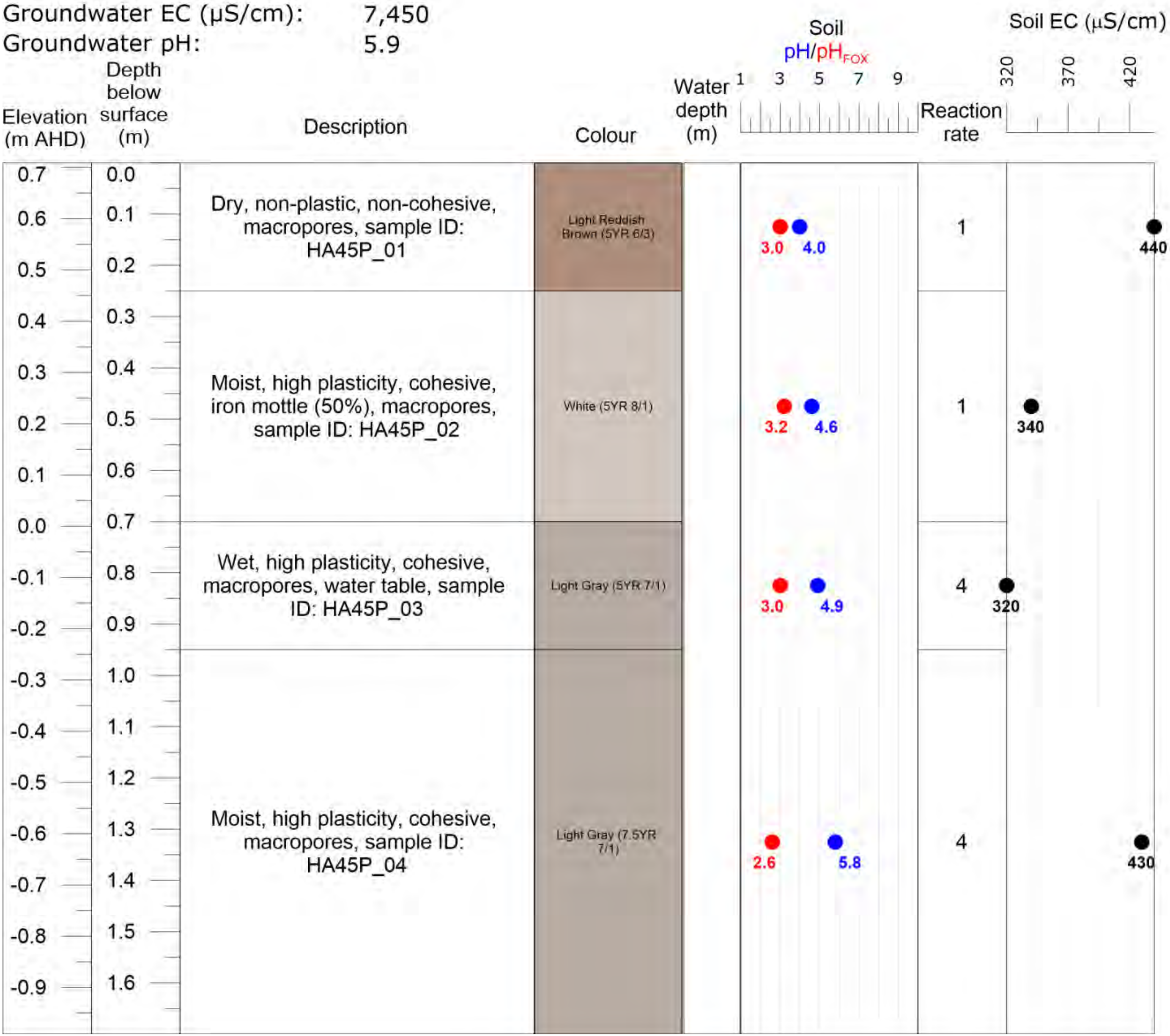
Soil profile details:

Project Number:	2018064	Profile ID:	HA_45_P
River/estuary:	Hastings	Sample date:	18/09/19
Easting:	483853.7	Sampled by:	AJH TAT
Northing:	6523322.0		

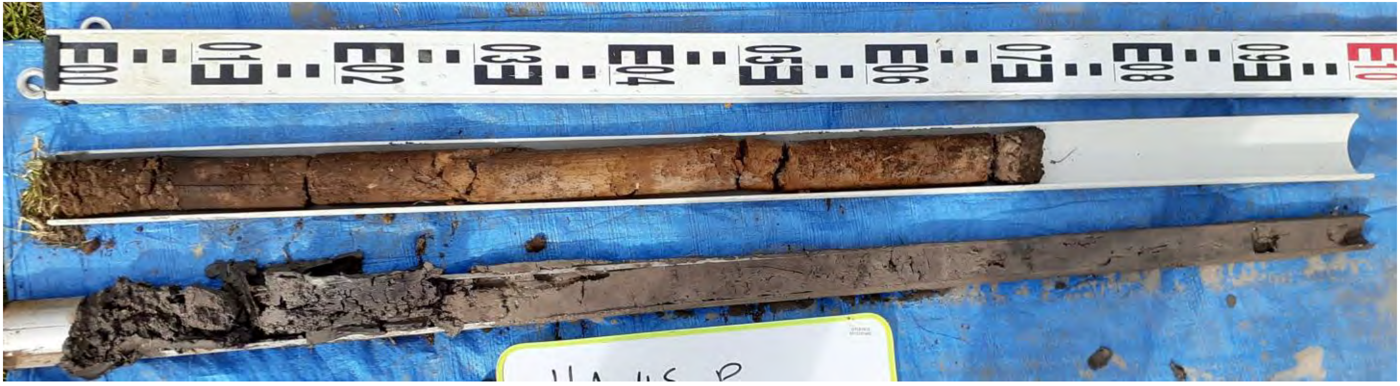
Ground elevation (m AHD):	0.71
Hydraulic conductivity (m/d):	0.42

Water quality:

Surface water EC (µS/cm):	2,200
Surface water pH:	5.2
Groundwater EC (µS/cm):	7,450
Groundwater pH:	5.9



Description	Colour	Soil pH/pH$_{FOX}$	Reaction rate	Soil EC (µS/cm)
Dry, non-plastic, non-cohesive, macropores, sample ID: HA45P_01	Light Reddish Brown (5YR 6/3)	3.0 4.0	1	440
Moist, high plasticity, cohesive, iron mottle (50%), macropores, sample ID: HA45P_02	White (5YR 8/1)	3.2 4.6	1	340
Wet, high plasticity, cohesive, macropores, water table, sample ID: HA45P_03	Light Gray (5YR 7/1)	3.0 4.9	4	320
Moist, high plasticity, cohesive, macropores, sample ID: HA45P_04	Light Gray (7.5YR 7/1)	2.6 5.8	4	430



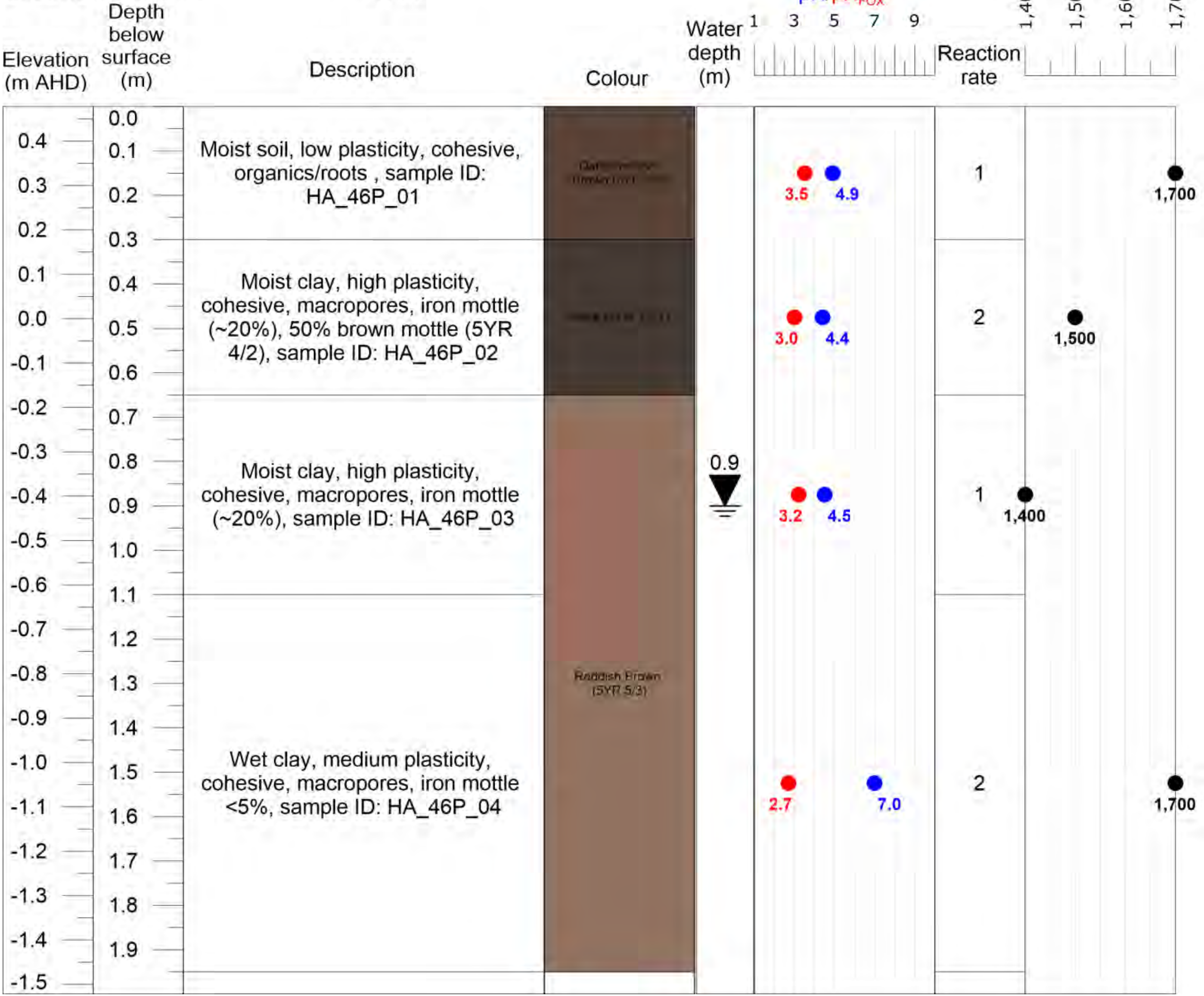
Soil profile details:

Project Number:	2018064	Profile ID:	HA_46_P
River/estuary:	Hastings	Sample date:	25/09/19
Easting:	483783	Sampled by:	DWJ TAT
Northing:	6526230.7		

Ground elevation (m AHD): 0.48
Hydraulic conductivity (m/d): Not measured

Water quality:

Surface water EC (µS/cm):	Not measured
Surface water pH:	Not measured
Groundwater EC (µS/cm):	11,571
Groundwater pH:	4.44



Moist soil, low plasticity, cohesive, organics/roots , sample ID: HA_46P_01

Moist clay, high plasticity, cohesive, macropores, iron mottle (~20%), 50% brown mottle (5YR 4/2), sample ID: HA_46P_02

Moist clay, high plasticity, cohesive, macropores, iron mottle (~20%), sample ID: HA_46P_03

Wet clay, medium plasticity, cohesive, macropores, iron mottle <5%, sample ID: HA_46P_04

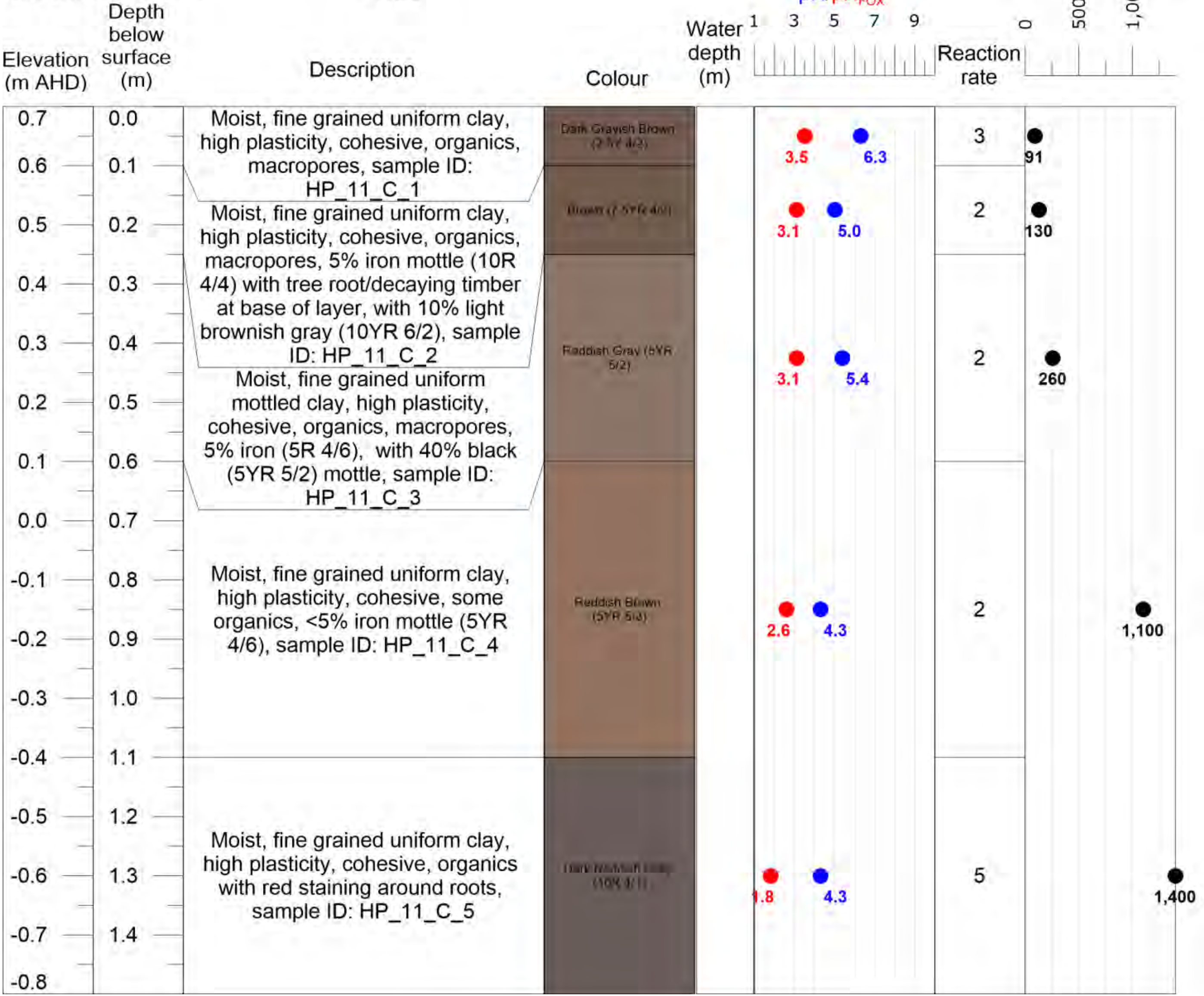
Soil profile details:

Project Number:	2018064	Profile ID:	HP_11_C
River/estuary:	Hastings	Sample date:	04/03/20
Easting:	487046.4	Sampled by:	AJH KW
Northing:	6534686.1		

Ground elevation (m AHD):	0.70
Hydraulic conductivity (m/d):	Not measured

Water quality:

Surface water EC (µS/cm):	1,750
Surface water pH:	5.14
Groundwater EC (µS/cm):	17,070
Groundwater pH:	4.21



Description	Colour	Soil pH/pH$_{FOX}$	Reaction rate	Soil EC (µS/cm)
Moist, fine grained uniform clay, high plasticity, cohesive, organics, macropores, sample ID: HP_11_C_1	Dark Grayish Brown (2.5Y 4/2)	3.5 6.3	3	91
Moist, fine grained uniform clay, high plasticity, cohesive, organics, macropores, 5% iron mottle (10R 4/4) with tree root/decaying timber at base of layer, with 10% light brownish gray (10YR 6/2), sample ID: HP_11_C_2	Brown (7.5YR 4/4)	3.1 5.0	2	130
Moist, fine grained uniform mottled clay, high plasticity, cohesive, organics, macropores, 5% iron (5R 4/6), with 40% black (5YR 5/2) mottle, sample ID: HP_11_C_3	Reddish Gray (5YR 5/2)	3.1 5.4	2	260
Moist, fine grained uniform clay, high plasticity, cohesive, some organics, <5% iron mottle (5YR 4/6), sample ID: HP_11_C_4	Reddish Brown (5YR 5/3)	2.6 4.3	2	1,100
Moist, fine grained uniform clay, high plasticity, cohesive, organics with red staining around roots, sample ID: HP_11_C_5	Dark Reddish Gray (10R 3/1)	1.8 4.3	5	1,400

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