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One Tree Reach Wetland Remediation Option Assessment

WRL Technical Report 2016/09
July 2016

By W G Glamore, J E Ruprecht, A J Harrison and C D Drummond

Water Research Laboratory
University of New South Wales
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Executive Summary

The One Tree Reach Wetland is located on the south-west bank of the Hawksbury River at Laughtondale near Wisemans Ferry. The site has previously been identified as an acid sulfate soil (ASS) hot-spot, with highly acidic soils, surface and groundwaters. Draining of the landscape over the past century exposed an insidious acid problem that has been severely impacting the wider estuary. Despite recent remediation efforts undertaken by Council in 2012 to retain water within the wetland at a higher level through the installation of a weir system, the wetland remains severely degraded and impacted by ASS. Indeed, a water balance assessment of the wetland suggests that the system is a largely stagnant, acid pond discharging to the Hawkesbury River estuary. This study has shown that the wetland ecosystem health would benefit from more efficient tidal flushing and increased connectivity to the wider Hawkesbury River estuary.

The key outcomes of the study are:

- Ground survey data of the wetland was combined with LiDAR of the wider catchment to create a robust Digital Elevation Model (DEM) of the study region;
- A stage-volume relationship was developed from the site topography to assess the hydrologic response of the site to various environmental conditions, including rainfall and tidal inflows;
- An aerial photographic assessment has provided high-resolution aerial photos and video footage, near-infrared data of wetland vegetation, baseline vegetation classifications, and high-resolution photogrammetric digital elevation data of the site;
- Field investigations have confirmed the presence of a submerged concrete culvert in the Northern Channel that restricts tidal flushing of the wetland and reduces fish passage;
- There were minimal variations in the wetland water level data during the monitoring period between March and April 2016. The median level observed was 0.58 m AHD;
- A soil assessment at the One Tree Reach Wetland indicates the presence of AASS at or near (within 400 mm) the ground surface (i.e. ranged from 0.65 to 1.05 m AHD);
- Tidal flows enter the wetland when levels in the Northern Channel exceed 0.67 m AHD versus the previously stated invert level of 0.4 m AHD (WEW, 2013); and
- Small tidal fluctuations and evaporation drive the water balance at the One Tree Reach Wetland.

Several recommendations to improve the water quality in One Tree Reach Wetland, included:

- Modification/removal of the existing culvert at the confluence of the Northern Channel and the Hawkesbury River to increase the tidal exchange within the wetland;
- Redesign/modification of the current weir system to increase tidal flushing of the wetland;
- Management/removal of dense vegetation that currently restricts flow into the wetland; and
- Continued water level and water quality monitoring to ensure remediation outcomes are achieved.

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1. Introduction

The Water Research Laboratory (WRL) of the School of Civil and Environmental Engineering at UNSW Australia was commissioned by Hornsby Shire Council (Council) to undertake field and desktop investigations to quantify the hydrology and extent of acid sulfate soils (ASS) across the One Tree Reach Wetland (Figure 1.1). The wetland is located on the south-west bank of the Hawkesbury River at Laughtondale near Wisemans Ferry. The presence of highly acidic soils at the wetland has been observed by previous studies (Dragonfly Environmental, 2011; Ward, 2012). Surface soil and surface water acidity has been measured below pH 4 across many areas of the site, with some measurements below pH 3 observed. Despite recent remediation efforts undertaken by Council in 2012 to retain water within the wetland at a higher level (through the installation of a weir system within the Northern Channel), the wetland remains severely degraded and impacted by ASS. This study aims to provide Council with an evidence-based, on-ground action plan to address the land and water impacts of ASS across the One Tree Reach Wetland.

1.1 About this Report

The terms hydrology and remediation are used regularly throughout this report. The term 'hydrology' is used in the broader sense relating to the interaction of surface water, groundwater and the contributing climate, as well as catchment characteristics which drive the water cycle. The term 'remediation' means to remedy a symptom of damage, and is often used in the context of reducing pollution from degraded ASS areas.

The report is composed of the following sections:

- **Section 2** provides background information on previous studies and the aims of the present study;
- **Section 3** provides details of the catchment properties of the One Tree Reach Wetland;
- **Section 4** provides a summary of the acid sulfate soil assessment completed at the One Tree Reach Wetland;
- **Section 5** provides a summary of the water level and quality monitoring undertaken during the field program;
- **Section 6** presents a water balance carried out to quantify and assess the hydrological response of the One Tree Reach Wetland for a representative tidal flushing regime in March 2016; and
- **Section 7** provides a summary of the study investigations and provides feasible recommendations to manage the One Tree Reach Wetland.

This report has been structured to highlight the key findings of the study. Significant tasks that do not form the core of the priority assessment outcomes have been documented as appendices, rather than in the main body of the report. Specifically, a summary of the soil profile data collected during the field investigations is provided in **Appendix A**. For readers unfamiliar with UAV technology, some background information is provided in **Appendix B**. **Appendix C** provides an empirical weir equation used to estimate the flow over a rectangular weir.

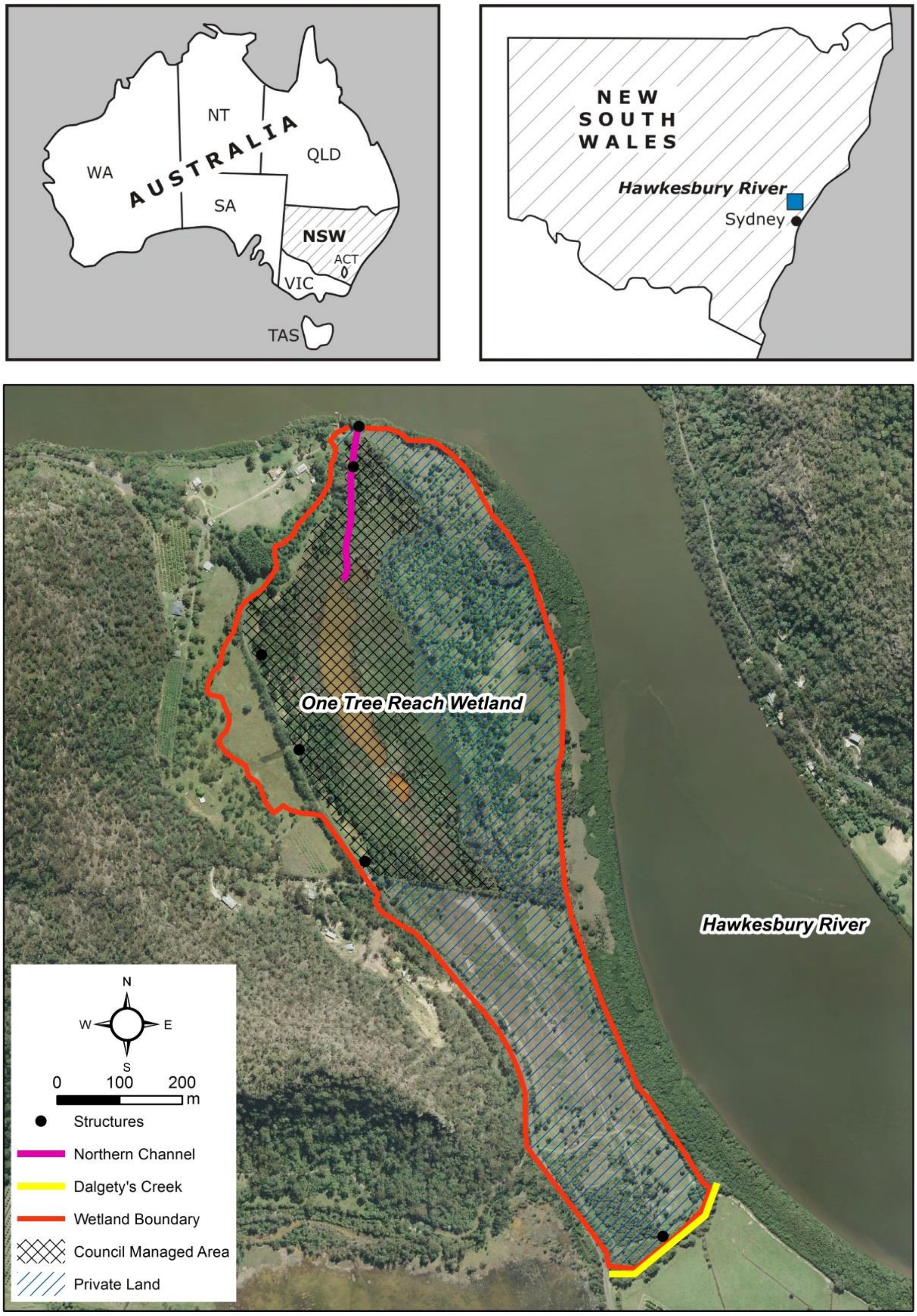

Figure 1.1: Location of One Tree Reach Wetland

2. Background Information

2.1 Preamble

This chapter provides background information on previous work undertaken at One Tree Reach Wetland, which involved surface soil and surface water quality assessments, and/or an understanding of site hydrology. Previous studies that were found to be directly relevant to this investigation included:

- Dragonfly Environmental (2011) – *One Tree Reach Wetland Acid Sulfate Soil Study*;
- Hornsby Shire Council (2011) – *One Tree Reach Wetland File Note*;
- Ward (2012) – *One Tree Reach Wetland Acid Sulfate Soil Restoration Project: Monitoring Protocol*; and
- Waratah Eco Works (WEW) (2013) – *One Tree Reach Wetland Plan of Management*.

2.2 Previous Studies

2.2.1 Dragonfly Environmental (2011)

In 2011, Dragonfly Environmental prepared a report for Council investigating the presence of acid sulfate soils and suitable remediation measures to improve the health of the wetland. The report provided results of surface soil acidity and surface water quality sampling (pH, dissolved oxygen (DO), temperature, turbidity) that identified the presence of highly acidic soils across the wetland. The report indicated that surface sediments were sampled to a depth of 10 cm from several acid scalded sites across the wetland. The report also provided a general discussion on the wetland management issues and identified several factors that influenced the wetland hydrology.

Key outcomes from the study include:

- Highly acidic soils were identified across the wetland;
- Surface waters were being impacted by soil acidification;
- Areas with low pH were accompanied by stunted vegetation;
- Previous land drainage had lowered wetland water levels and exposed acidic soils;
- The northern water body of the wetland was noted to be tidally influenced;
- Several management recommendations, including infilling drains across the whole wetland, and installing a weir that stops water flowing from the southern (private) portion to the Council managed portion of the wetland; and
- Two (2) identified knowledge gaps, including a limited understanding of the distribution of acid sulfate soils across the wetland and the site hydrology.

2.2.2 Council (2011)

Following the study completed by Dragonfly Environmental, Council completed two (2) site investigations at One Tree Reach to assess factors influencing its hydrology. The investigations focused on the impact of tidal flows to the northern and southern portions of the wetland, flooding due to localised rainfall, and nearby groundwater extractions. The site inspections were undertaken at high tide on 18 February (1.93 m) and 18 March (1.83 m) in 2011.

Key outcomes from the investigations include:

- The southern (private) portion of the wetland drains to Dalgety's Creek via a constructed drainage channel approximately 100 m east of Singleton Road;
- A timber weir structure with a one-way floodgate prevents tidal water ingress from Dalgety's Creek on to the adjacent private land;
- The Council managed portion of the wetland appeared to be predominately freshwater with a tidal influence apparent from the river via the Northern Channel;
- At low tide, the Northern Channel restricted fish passage between the river and the wetland;
- Tidal flushing had benefited the Council managed portion of the wetland with increased biodiversity when compared to adjacent private land;
- Nearby groundwater extraction bores were unlikely to influence local groundwater levels across the wetland; and
- A recommendation to install a weir in the Northern Channel to maintain a higher water level within the Council managed portion of the wetland.

At the completion of the study, a detailed understanding of the site hydrology was still unknown. As the site inspections were undertaken at high tide, Council was unable to determine if there was any structure(s) controlling river flows entering the Council managed portion of the wetland via the Northern Channel. There was also uncertainty around the magnitude and timing of inter-catchment flows between the Council managed portion of the wetland and the adjacent private land.

2.2.3 Ward (2012)

In 2012, Southern Cross Geoscience was engaged by Council to assess water quality throughout the wetland prior to the installation of the weir, and to prepare monitoring protocols to measure the land and water impacts following the weir installation. The report (Ward, 2012) provided results of surface water quality monitoring, including temperature, pH, electrical conductivity (EC), DO, and redox potential (Eh) at 15 sites across the wetland, as well as surface soil acidity at one (1) of the water quality monitoring sites. The field monitoring was conducted on 26 July 2012. The report compared the new findings with previous studies.

Key findings from the study include:

- The current extent of the wetland represents less than half of its historical extent;
- Surface water quality across the wetland was still being impacted by soil acidification. However, the results of this study showed a slight improvement in the water quality within the wetland compared to the two previous studies;
- Surface water salinities within the wetland were approximately 12% seawater. The Northern Channel and Dalgety's Creek had salinities lower than those measured in the wetland. Note it is unclear from the report if the Northern Channel and Dalgety's Creek were sampled on a rising or falling tide which would have impacted the reported salinities;
- Surface soils (0 – 10 cm) from a scalded site at approximately 0.7 m AHD were highly acidic. However, the distribution of acid sulfate soils within the wetland was still unknown;
- The height of the weir was restricted to approximately 0.4 m AHD due to the ground levels along the southern boundary of the Council managed portion of the wetland;
- A monitoring protocol was developed that provided details of the potential water quality sampling locations, assessment frequency, water quality parameters and included guidelines for collection, preservation and transportation of samples. Note that monitoring water levels in the wetland was not recommended from this study.

2.2.4 Waratah Eco Works (2013)

In 2013, WEW prepared a report (WEW, 2013) for Council investigating options to manage land and water impacts associated with acid sulfate soils at the One Tree Reach Wetland. The WEW report provided a general overview of the changes to the wetland and the present values and threats to its ecology, water quality and hydrology. The area considered in this plan of management covered the Council managed portion of the wetland and not the adjacent private land.

Key outcomes from the study include:

- Historical surveys showed that a drain was located between the wetland and river from the late 1870s. The form of the open water areas within the wetland indicated that they were once a subsidiary channel and possibly part of the main river channel;
- WEW determined the catchment area of the wetland draining to the river is approximately 50 hectares;
- The wetland exhibits high conservation values with five (5) endangered ecological communities (EECs), including Swamp Mahogany, Floodplain Paperback Scrub, Floodplain Redland, Forest Red-Gum, Swamp Oak, and Coastal Saltmarsh;
- The invert of the Northern Channel is at -0.3 m AHD;
- The top of the weir was set at the natural ground level on either side of the Northern Channel, which is approximately equal to mean High Water Springs (0.7 m AHD), while the lowest section of the weir is at approximately Mean High Water Neaps (0.4 m AHD);
- Removable drop-boards in increments of 100 mm were fitted between the lowest section and the top of the weir to artificially control the water level in the wetland;
- Scouring of the weir invert had occurred immediately downstream of the weir and undercut the cut off wall causing a sink hole to form upstream of the weir and low flows to divert beneath rather than through the weir;
- The water levels within the wetland were noted to vary on almost a daily basis depending on the number of drop-boards in place within the weir, the height of the tide, and the rainfall within the catchment; and
- WEW noted that the wetland was brackish with the possibility of the formation of a halocline during period of low rainfall and high tides.

The study recommends that water quality monitoring of key parameters (salinity, acidity, temperature, DO) should continue on a monthly basis (as per Ward, 2012), until it is possible to develop seasonal trends. It recommends monitoring water levels to assess the efficacy of the weir at maintaining a higher water level and improving water quality across the wetland. The report provided an assessment of the condition of the weir and recommended several actions to improve its performance, including options to improve fish passage. Note that WEW highlighted that the previous studies have not considered the likely extent of the inundation caused by the increased water levels within the wetland and the likelihood of this increase in further land and water impacts from soil acidification. It was recommended that this data gap be further investigated.

2.3 Study Aims

Based on the findings of the previous studies and a review of their recommendations, this study aimed to:

- Construct a Digital Elevation Model (DEM) and develop a stage-volume relationship of the site;
- Perform an aerial photographic assessment and provide baseline information of key estuarine vegetation communities;
- Complete a soil and water quality assessment;
- Assess water balance relationships and determine the hydrologic water balance of the site; and
- Provide management recommendations to optimise the hydrological conditions in the wetland.

This report reviews the previous management recommendations through the analysis of field data and by using direct measurements to calculate the hydrologic properties of the wetland.

3. Catchment Properties

3.1 Preamble

This chapter provides details of the topography and flow control structures of the One Tree Reach Wetland. Ground survey data of the wetland was combined with LiDAR data of the wider catchment to create a Digital Elevation Model (DEM) of the study region. An aerial survey completed using a drone was used to validate the DEM and provide baseline information on wetland vegetation. The DEM was subsequently used to determine catchment boundaries, flow paths and to develop a stage-volume relationship of the One Tree Reach Wetland.

3.2 Survey Data

3.2.1 LiDAR Ground-Truthing and DEM Construction

WRL received LiDAR data from Council for the One Tree Reach Wetland and surrounding catchment that was collected in May 2011. While the LiDAR data has an accuracy of ±0.8 m and ±0.3 m in the horizontal and vertical direction, respectively, vegetation and open water influence the accuracy of the laser returns locally. Indeed, LiDAR data poorly penetrates dense vegetation or water, providing false-positive readings for a ground level at standing water locations. As such, the accuracy of the LiDAR data must be verified since the One Tree Reach Wetland has dense shrubs surrounding the wetland and substantial areas of permanent open water.

Ground surface elevations were measured and related to AHD using a Trimble 5800/R10 RTK-GPS (Real-Time Kinematic Global Positioning System) and offset using the NSW CorsNET network to an accuracy of ± 20 mm vertically and horizontally. Onsite ground survey measurements (Figure 3.1) were plotted against the interpolated LiDAR returns at the same locations as provided in Figure 3.2. Figure 3.2 shows that LiDAR returns are generally higher in elevation than the ground survey points. This is likely due to open water areas, ground cover and dense vegetation at the time of the LiDAR survey. Based on the ground-truthing exercise (Figure 3.1), the areas of the swamp underwater or densely vegetated at the time of the LiDAR survey were removed and updated with the ground survey points to create the revised bathymetry and DEM of the site. GIS techniques were used to produce a DEM of the study region at a 1 m horizontal resolution, as shown in Figure 3.3.

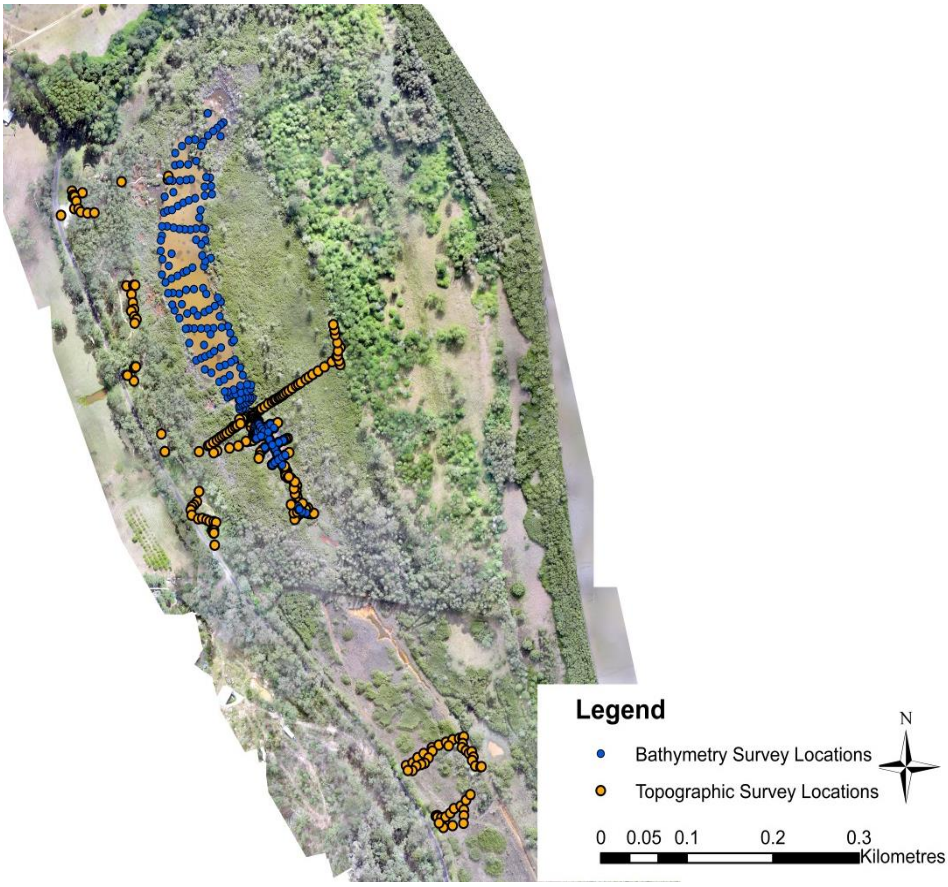

Figure 3.1: Ground Survey Locations

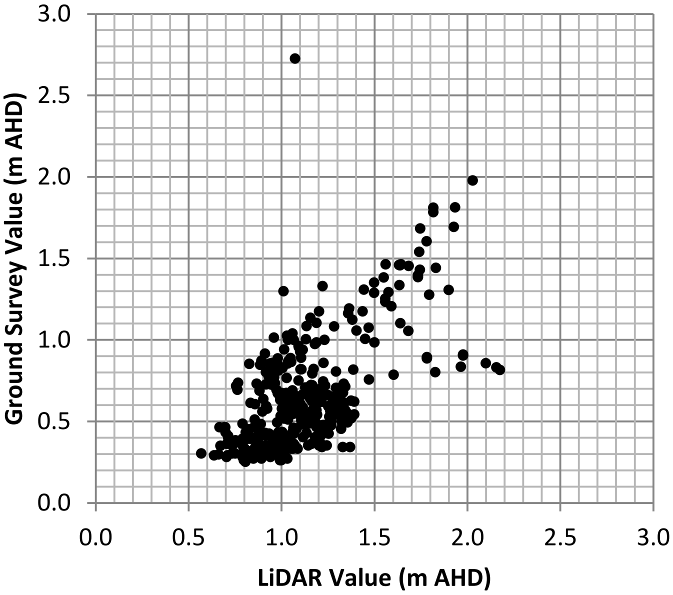

Figure 3.2: Comparison of LiDAR and Ground Survey Elevations

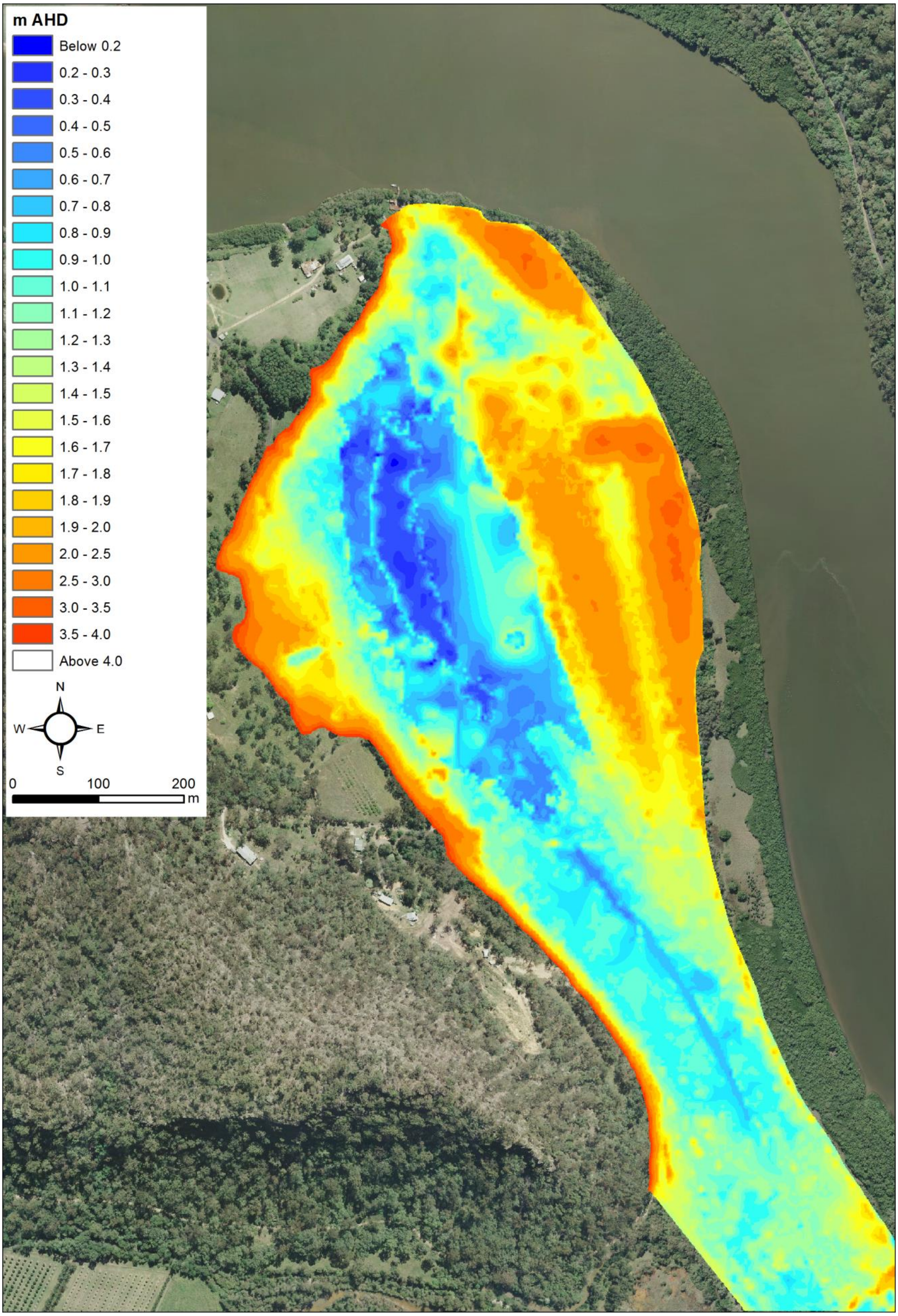

Figure 3.3: Updated DEM of One Tree Reach Wetland

3.2.2 UAV Aerial Survey

An aerial survey of the One Tree Reach Wetland was completed on 27th April 2016 using an Unmanned Aerial Vehicle (UAV) and covered a total area of approximately 85 hectares. The UAV aerial survey provided:

- High-resolution aerial photos (Figure 3.4) and video footage;
- A geo-rectified, orthomosaic image of the wetland (Figure 3.5);
- Near-infrared data of wetland vegetation (Figure 3.6) and baseline vegetation classification (Figure 3.7); and
- High-resolution photogrammetric digital elevation data.

The data collected was georeferenced to the GDA94/MGA Zone 56 datum. Ground control points were surveyed across the site to verify the accuracy of the UAV derived data. Background information on UAV technology is provided in Appendix B.

Figure 3.4: UAV Aerial Imagery

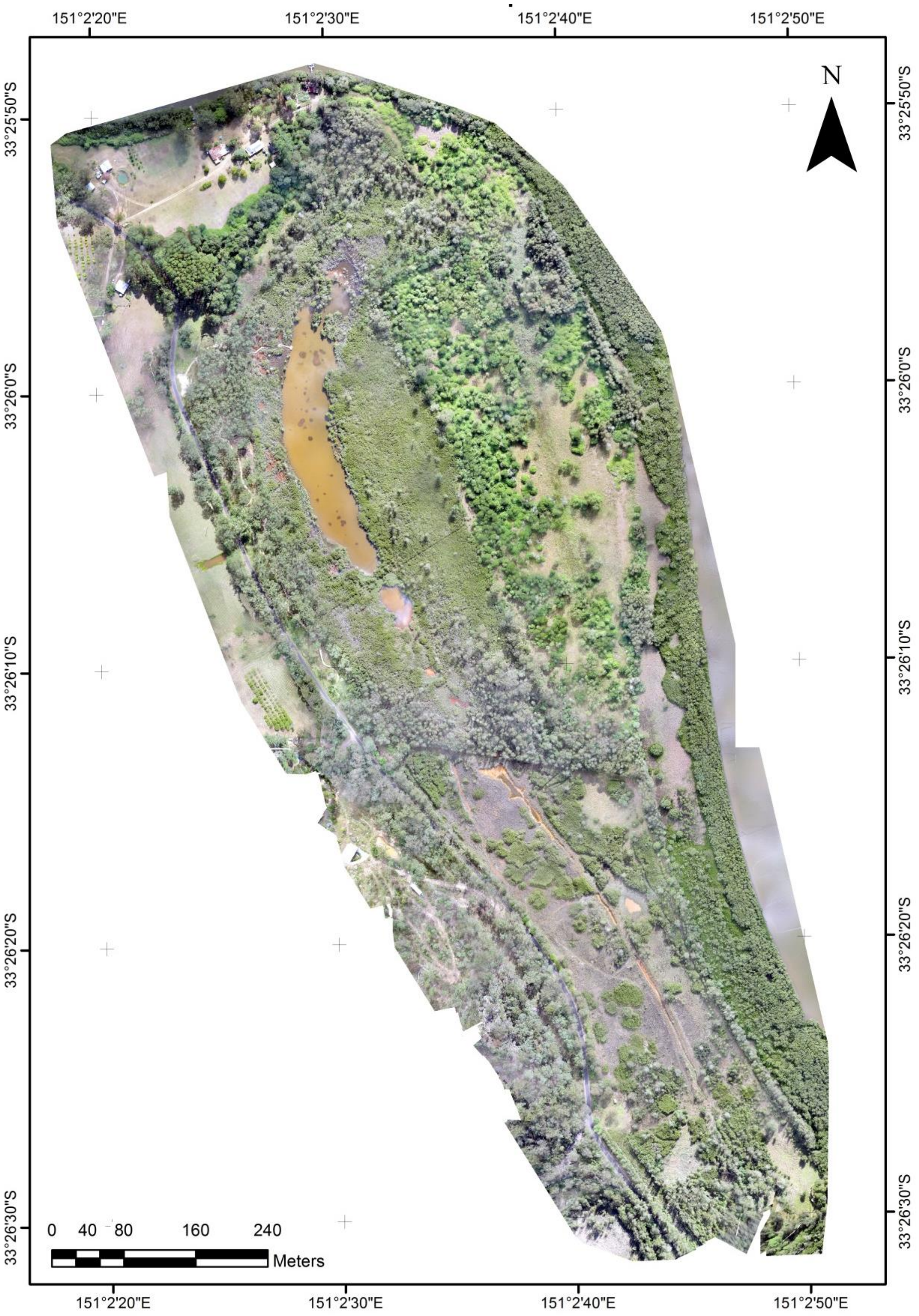

Figure 3.5: Geo-rectified Orthomosaic of One Tree Reach Wetland

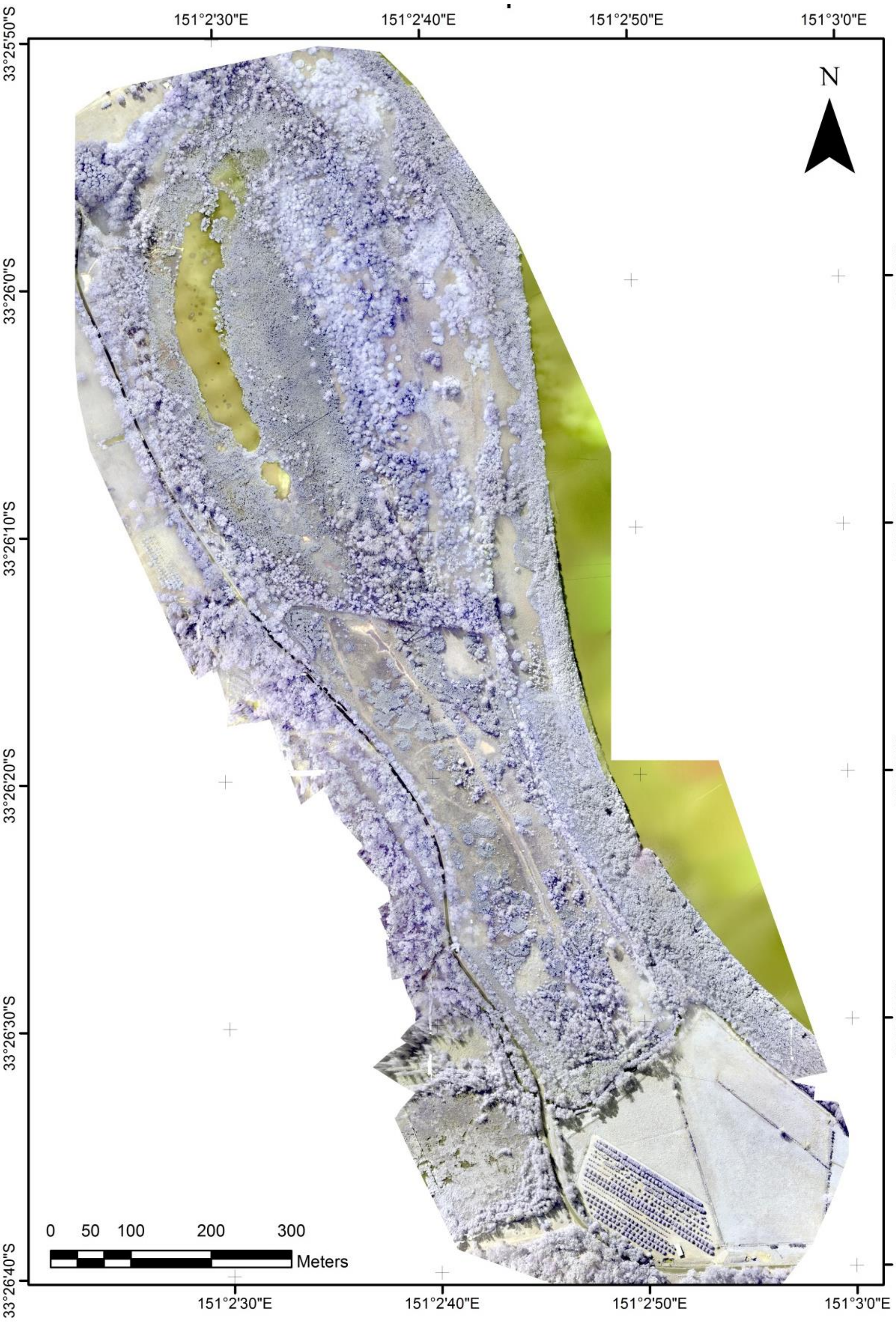

Figure 3.6: UAV Aerial Imagery (Near-Infrared)

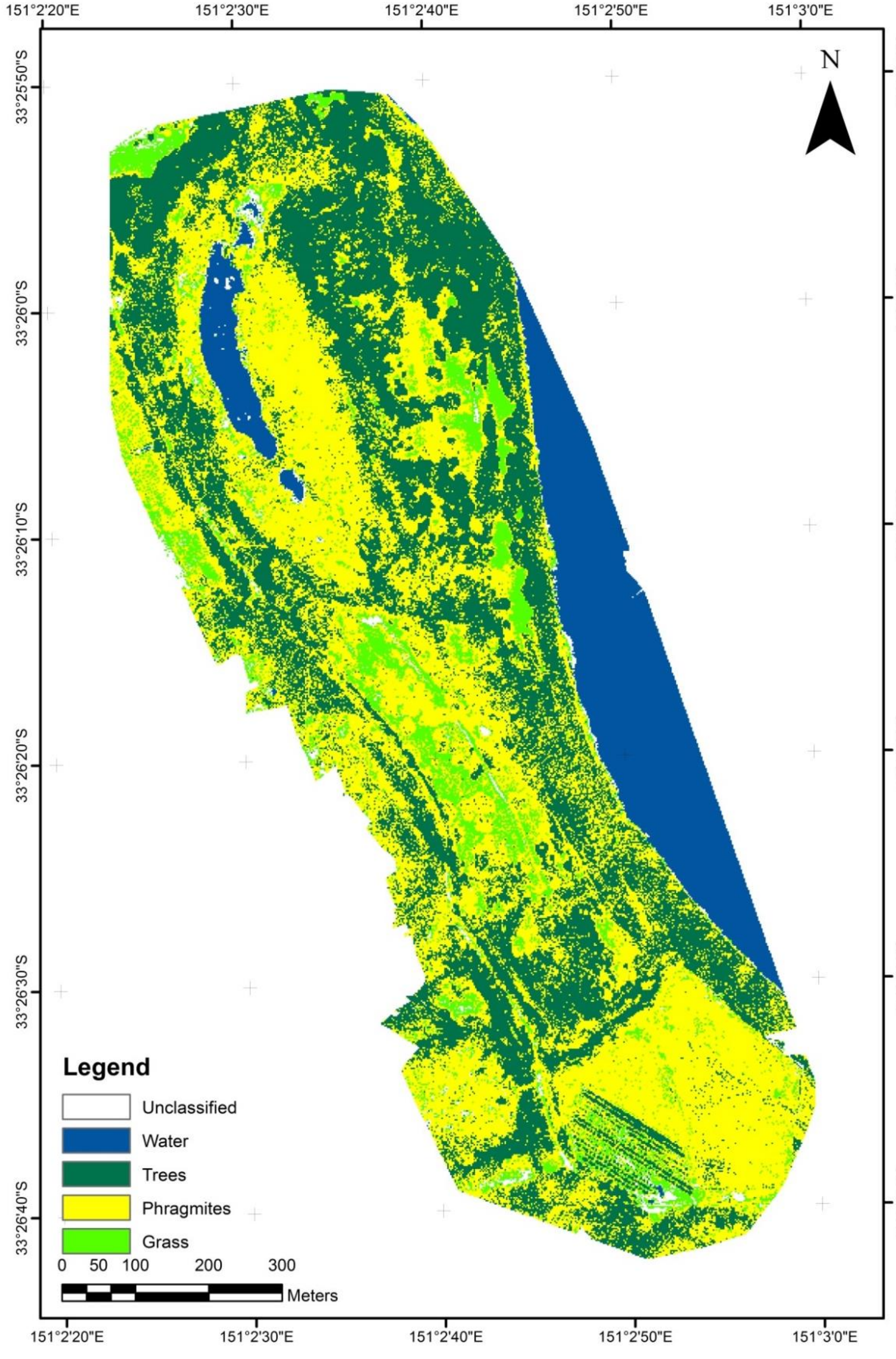

Figure 3.7: UAV Aerial Imagery (Baseline Vegetation Classification)

3.3 Stage-Storage Relationship

A key step in assessing the flooding response of the site was to develop a stage-volume relationship from the site topography. The stage-volume relationship indicates the volume of water below a certain elevation in the DEM. Volume data was extracted for the site using the DEM at a range of water levels as provided in Figure 3.8. The stage-volume relationship for the One Tree Reach Wetland indicates that for the average water level observed during the field study, approximately 4,470 m^3 of water was stored in the wetland.

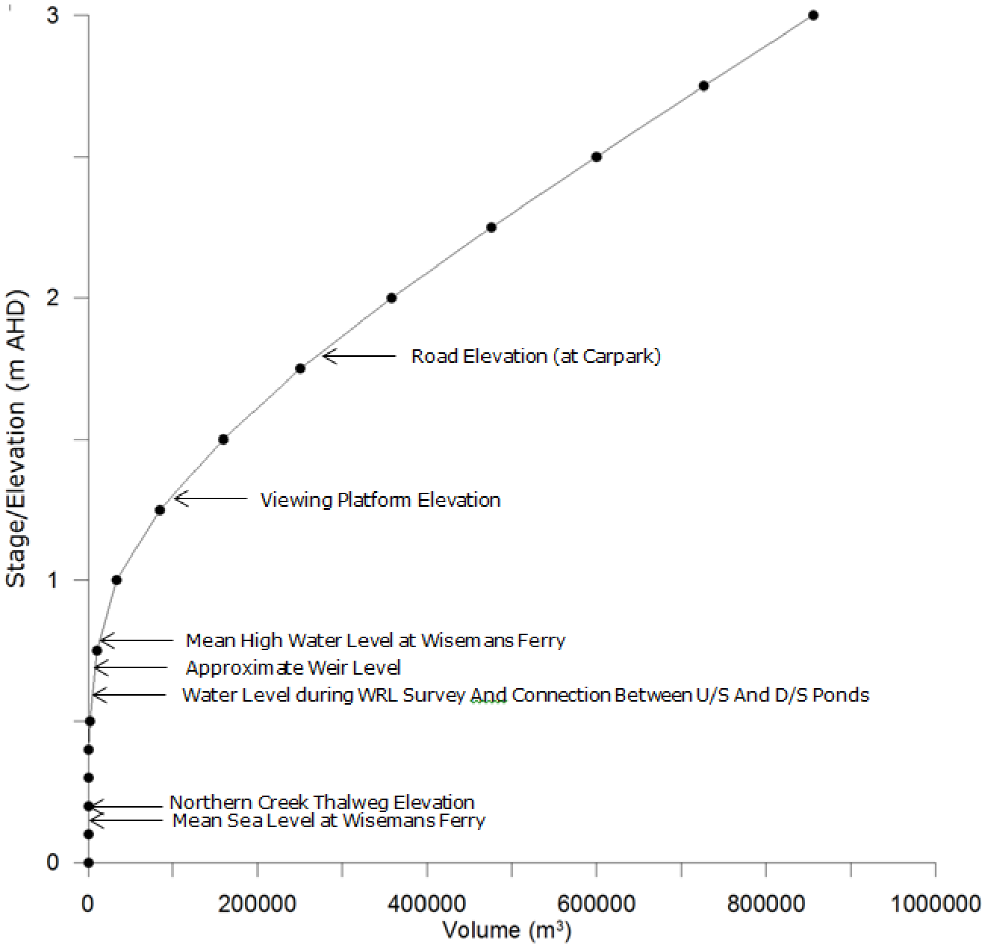

Figure 3.8: One Tree Reach Wetland Stage-Volume Relationship

3.4 Structures

The field survey identified six (6) structures that control flow to and from the One Tree Reach Wetland as shown in Figure 3.9 and Table 3.1. Catchment inflows enter the wetland at 4, 5, and 6 (Figure 3.9) through concrete capped, earthen channels (Figure 3.10). A summary of the key information of the flow control structures collected during the field survey is provided in Table 3.1. Note that the structure inverts were surveyed to AHD using Trimble RTK-GPS survey gear. Flow paths for the wetland were identified during the ground survey and confirmed using the DEM of the site, and are indicated in Figure 3.9 and Table 3.1. Note that inter-catchment flows between the wetland and adjacent private property may occur when water levels exceed approximately 1.0 m AHD, however this is only expected to occur during large catchment floods.

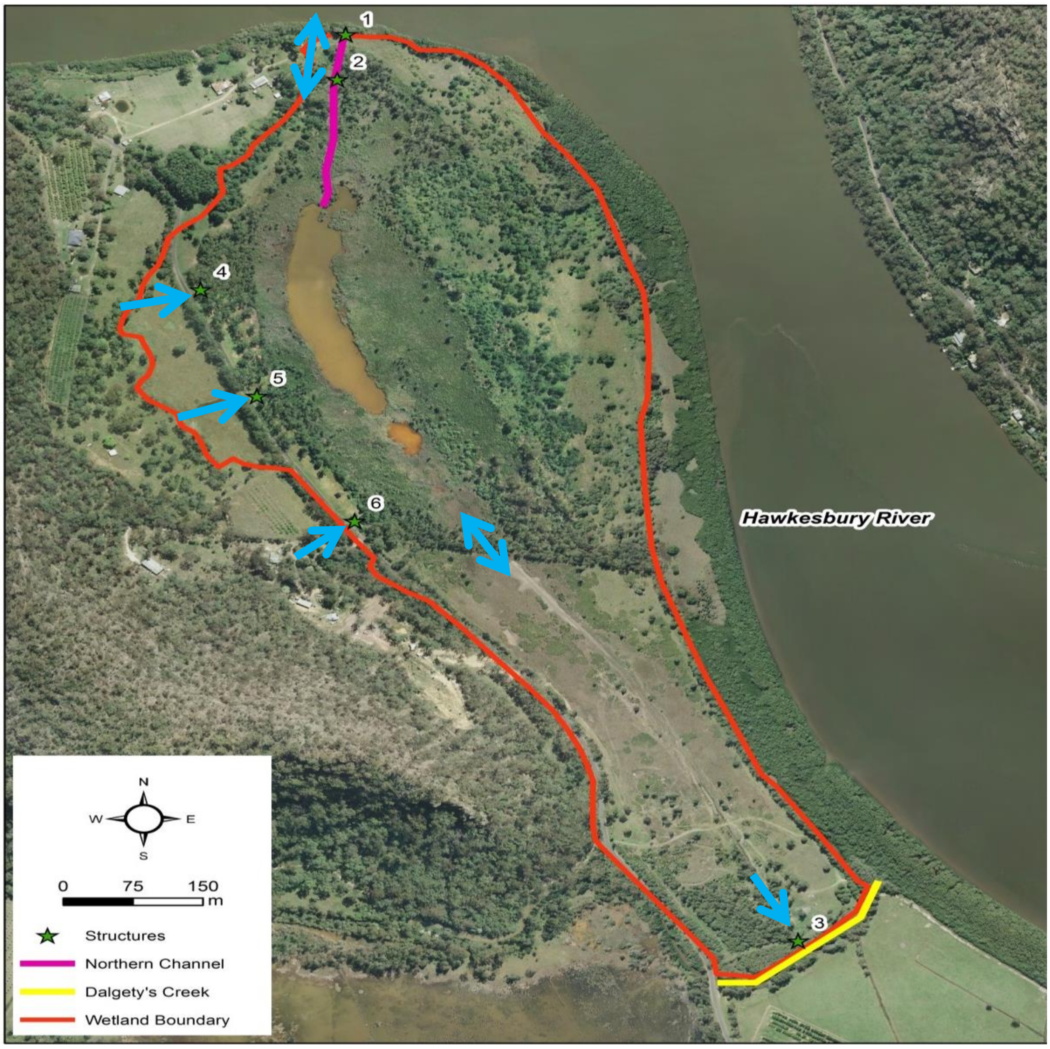

Figure 3.9: Locations of Flow Control Structures (Arrows Indicate Flow Paths)

Table 3.1: Key Features of Flow Control Structures at the One Tree Reach Wetland

ID	Easting (m)	Northing (m)	Invert (m AHD)	Length (m)	Width/ Diameter (m)	Type	Flow Path	Condition
1	317964	6299284	Unknown	~5.0	Unknown	Culvert	Tidal	Good
2	317955	6299247	0.67[2] 0.63 0.67[2]	-	~2.0	Weir 1[1] Weir 2[1] Weir 3[1]	Tidal	Good
3	318456	6297984	Unknown	-	Unknown	Weir + Floodgate	Outflow	Unknown
4	317866	6298784	0.72	2.0	~1.5	Culvert	Inflow	Choked
5	317958	6298619	1.05	2.0	~1.5	Culvert	Inflow	Choked
6	317943	6298606	Unknown	2.0	~1.5	Culvert	Inflow	Choked

[1] Structure 2 is a system of three (3), closely spaced weirs, with varied invert heights. Refer to Figure 3.12 for a distinction between the three weirs.

[2] The invert levels of the "cut-outs" on Weirs 1 and 3 range between 0.67 and 0.77 m AHD. Based on the ground survey, water enters the wetland when it exceeds 0.67 m AHD.

Figure 3.10: Culverts Allowing Catchment Inflows to the Wetland

Two (2) separate structures control the flow to and from the Council managed portion of the wetland and the Hawkesbury River. The following information is known about this infrastructure:

1. As water enters the Northern Channel from the Hawkesbury River, it passes through a submerged concrete culvert that is located on private property near the entrance to the river (Figure 3.11). While there is no available background literature or survey information to characterise this structure, recent observations at low tide (-0.18 m AHD as recorded at Wisemans Ferry) during the ground survey indicated that the invert of the structure must be below the thalweg of the Northern Channel (approximately 0.2 m AHD). However, due to the configuration of the structure, water levels in the Northern Channel are controlled by the upstream/downstream levels of the culvert inflow points which were not surveyed during the field investigation.
2. Upstream of the culvert, Council has erected a system of weirs that consist of three (3) separate structures as shown in Figure 3.12. Details of the original weir (Weir 2) are provided in WEW (2013). Since the installation of Weir 2 in 2012, two (2) additional weirs have been installed by Council to protect Weir 2 from scouring and to improve fish passage into the wetland by creating stilling basins. Weirs 1 and 3 consist of driven plastic sheet piles, with several "cut-outs" to allow water and fish passage below the tops of the weirs. Generally the tops of the weirs have been set at the natural ground level, ranging from 0.93 to 0.99 m AHD, on either side of the channel. The invert levels of the "cut-outs" on Weirs 1 and 3 range between 0.67 and 0.77 m AHD. Based on the ground survey, water enters the wetland when it exceeds 0.67 m AHD ("cut-out" in Weir 3 closest to the Left-Bank). Note that the Left-Bank is defined by an observer looking downstream.

Note that there is a difference in the invert level of Weir 2 calculated in this report (0.63 m AHD) and the invert level of Weir 2 assumed by WEW in the previous study (approximately 0.4 m AHD). There is also a difference in the top level of Weir 2 calculated in this report (0.99 m AHD) and the previous study by WEW (approximately 0.7 m AHD), when all of the drop-boards are in place. This difference has significant implications for the amount of tidal inundation achievable in the wetland. For example, a weir invert height of 0.4 m AHD would allow 44% of high tides to enter the wetland based on observed water levels at Wisemans Ferry from March 8 to April 7 2016, whereas a weir invert height of 0.67 m AHD would allow 28% of high tides to enter the wetland during the same period. This was calculated assuming no head loss due to the culvert downstream of the weirs. Calculations in this report using weir invert levels are based on the invert presented in this section.

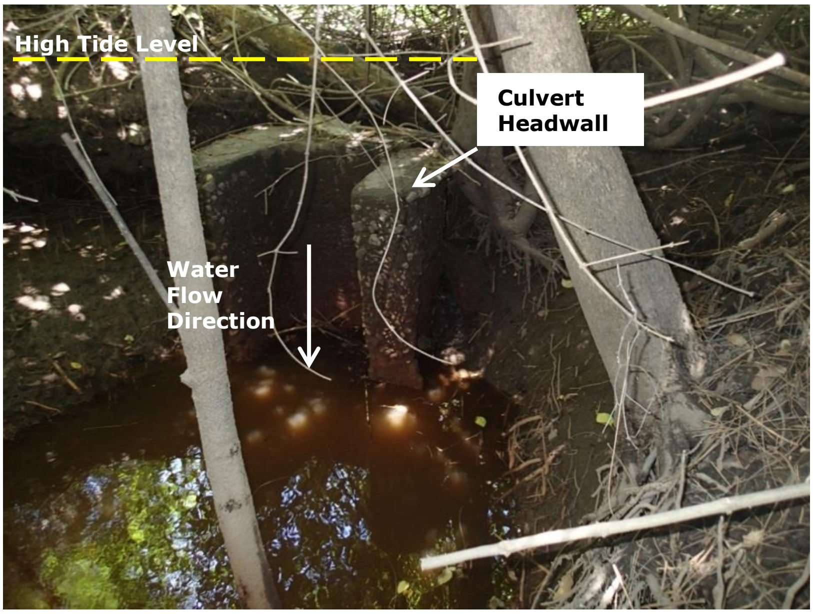

Figure 3.11: Culvert Structure

Figure 3.12: Weir System

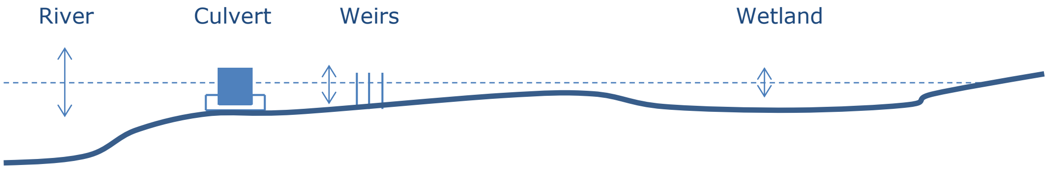

Figure 3.13: Schematic Showing Conceptual Understanding of Site

4. Acid Sulfate Soil Assessment

4.1 Preamble

Acid sulfate soil (ASS) is the common name given to soils and sediments containing iron sulfides, the most common being pyrite (FeS_2). Under most natural conditions, where the soil remains waterlogged, ASS remain innocuous. These soils are commonly referred to as potential acid sulfate soils (PASS). PASS have the 'potential' to produce acid if they dry out. When ASS are exposed to air – by drainage or excavation of the soil, when the water table is lowered artificially, or during droughts or prolonged dry weather – the soil reacts with oxygen (through a process known as oxidation) in the air or water, and can produce large quantities of low pH sulfuric acid (pH <4.5).

The soil structure of coastal floodplains is typically comprised of five (5) distinct zones of varying thickness. On the surface, an organic peat layer exists comprised largely of roots and decomposing matter. This layer transforms into an alluvial/clay zone. An AASS layer commonly exists below this and can be identified by the presence of orange/yellow mottling caused by the oxidation of pyrite. This soil layer often overlies a PASS layer characterised by dark grey, saturated estuarine mud. The PASS layer often has near neutral pH, as pyritic material in the soil is unoxidised. The PASS layer is underlain by non-acidic sub-soil.

This section provides a summary of the soil profile data available for the One Tree Reach Wetland. Data compilation and review identified sources of existing surface soil acidity data and knowledge gaps within the study area (Section 2.2). It is worth noting that the surface soil acidity data collected during previous studies (Dragonfly Environmental, 2011; Ward, 2012) provided an indication of the presence of ASS and did not identify or quantify the extent of ASS across the site, including depths and elevations of AASS/PASS. Field investigations were targeted to fill the identified data gaps. A summary of the soil profile data collected during the field investigations is provided in Appendix A.

4.2 ASS Distribution

WRL staff completed five (5) soil profiles over 2-days at the specified locations within the study area (Figure 4.1) to determine AASS and PASS depth and elevation, and soil acidity. A summary of the soil profile AASS/PASS layer data obtained from the field investigation is provided in Table 4.1. Furthermore, a summary of soil profile data properties, including pH, EC, and oxidation potential is provided in Table 4.2. Detailed data logs of each soil profile is provided in Appendix A.

Soil profiles were collected using a Dormer stainless steel, spiral-tipped, general purpose hand auger and a stainless steel gouge auger. Soil samples from the unsaturated zone were extracted in approximately 250 mm sections using the general purpose hand auger and laid in open PVC piping for logging and sample collection. Soil samples from the saturated zone were extracted using a gouge auger to ensure reliable sample retrieval. All soil profiles were logged in-situ and samples collected from each distinct soil horizon. Profile depths ranged between 1.5 and 2.0 m below ground surface. Ground surface elevations and borehole locations were logged using Trimble RTK-GPS survey gear.

Samples were immediately bagged and cooled during storage. Soil samples were analysed in the WRL soil analysis laboratory. Soil pH and EC were assessed using the methodology (4A1) outlined in Rayment and Higgins (1992). This is a standard method for determination of soil pH and EC, utilising a 1:5 soil to water ratio. Calibration of pH and EC meters was undertaken prior to testing of soil samples.

The presence of ASS was tested using the methodology (4E1) outlined in Rayment and Higginson (1992). Samples were covered with 30% hydrogen peroxide (H_2O_2) and the reaction of any PASS was observed. The strength of the oxidisation reaction is rated on a zero (0) to five (5) scale, with zero (0) reaction indicating absent acidity (no bubbling) and five (5) indicating high levels of acidity (violent bubbling). All soil horizons analysed during the field investigation showed a reaction of at least one (1). A strong oxidation reaction (4) was observed at P1, while moderate reactions (1 to 4) were at observed at all other sites.

The results of the soil assessment at the One Tree Reach Wetland indicate the presence of AASS at or near (within 400 mm) the ground surface. Furthermore, analysis of the collected soil profile data suggests that the distribution of AASS ranges from 0.65 to 1.05 m AHD as provided in Table 4.1. Indeed, the median elevation of AASS across three (3) soil profiles (P1, P4, P5) completed along a transect line from the edge of the wetland (P5) to the northern carpark on Laughtondale Road (P4) was 0.67 m AHD. It is worth noting that this elevation is equivalent to the invert of the weir controlling water levels within the wetland. Note also that the presence of PASS was only identified at one (1) of the five (5) profiles completed and was determined to be within 1 m of the ground surface.

Results of the sub-surface soil properties measured during the field investigation were shown to be fairly similar across all soil profiles. During the field investigations, soil pH ranged between 3.5 and 4.5. This was consistent with the soil sampling done by Ward (2012), but less variable than the soil pH measured in Dragonfly Environmental (2011), which found soil pH between 2.4 and 5.9. The EC of the wetland soils varied between 26.3 µS/cm and 3,230.0 µS/cm, that is, less than 6% seawater (typically 56,000 µS/cm). While there was no baseline data of soil salinity for comparison with data collected in this study, the soil salinities observed here were significantly less than surface water salinities reported in previous studies.

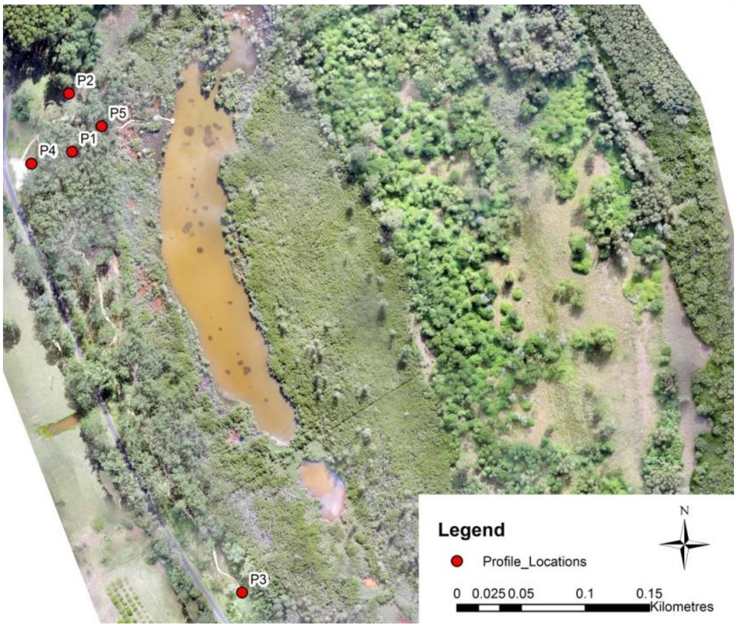

Figure 4.1: Soil Profile Locations

Table 4.1: Summary of Approximate AASS and PASS Depth and Elevation

ID	Depth to AASS (m)	Depth to PASS (m)	Elevation of AASS (m AHD)	Elevation of PASS (m AHD)
1	0.2	-	0.65	-
2	0.3	0.8	0.72	0.22
3	0	-	1.05	-
4	0.4	-	0.68	-
5	0.2	-	0.67	-

Table 4.2: Soil Profile Data Summary

Profile	Sample Depth (m)		pH	EC (μS/cm)	H_2O_2
	From	To			
1	0	0.2	3.59	910.0	1
	0.2	0.6	4.52	376.0	1
	0.6	1.4	4.38	822.0	3
	1.4	2.0	3.85	981.0	4
2	0	0.3	3.95	585.0	2
	0.3	0.6	3.71	3690	2
	0.6	0.8	4.07	229.0	2
	0.8	1.1	4.51	110.1	1
	1.1	1.5	5.03	63.4	2
3	0	0.3	4.34	292.0	2
	0.3	0.5	4.19	108.0	2
	0.5	0.7	4.83	26.3	1
	0.7	1.9	4.82	53.6	1
	1.9	2.3	4.85	88.8	1
4	0	0.4	4.10	317.0	1
	0.4	0.7	3.73	164.8	1
	0.7	1.3	4.58	100.4	1
	1.3	2.0	4.64	163.4	2
5	0	0.2	3.49	3,230.0	2
	0.2	0.6	4.82	722.0	2
	0.6	1.0	4.67	1,114.0	3

5. Water Level and Quality Monitoring

5.1 Preamble

This section provides the results of water level and water quality monitoring that was completed as part of the field investigations undertaken at the One Tree Reach Wetland. Water level/salinity logger(s) were deployed to measure wetland/river levels and conditions to provide further knowledge of the site hydrology and to help develop practical management outcomes. Note that monitoring of water levels in the One Tree Reach Wetland was undertaken between March and April 2016. Surface water quality monitoring was also completed during the ground survey to obtain a greater understanding in the spatial variability in water quality across the wetland.

5.2 Water Levels

The field program involved the installation of two (2) short-term deployable water level devices to measure the site's hydrologic response to various environmental conditions, including rainfall and tidal flows. A Heron dipperLog Nano (L1) was installed at the viewing platform (317908.974 m, 6299006.819 m) within the wetland and a Solnist Levelogger (L2) was installed approximately five (5) m downstream of the weir within the Northern Channel (317953.423 m, 6299250.096 m) as shown in Figure 5.1. Note that all co-ordinates are specified in GDA94/MGA zone 56. The loggers were installed on 7th March 2016 and securely contained within slotted 50 mm PVC pipe.

A continuous time-series of water level data was collected at both sites (Figure 5.1) between March and April 2016. Water level data was referenced to AHD using Trimble RTK-GPS survey gear. Water levels within the wetland were compared with recorded daily rainfall data at Wisemans Ferry Old Post Office (Bureau of Meteorology (BOM) station 061119) as provided in Figure 5.2, and with observed water levels at Wisemans Ferry (NSW Office of Water station 212460) as provided in Figure 5.3.

The data provided in Figure 5.2 shows that the water levels in the wetland were relatively unaffected by the small catchment rainfall events that occurred in March 2016. It is likely that the March 2016 events were small enough that rainfall across the catchment did not contribute to direct runoff reaching the wetland and were intercepted within the larger catchment, or lost due to infiltration and evaporation. Note that the effect of larger catchment rainfall events or backwater flooding from the Hawkesbury River was not assessed during this study, however, it is considered that wetland water levels would be significantly impacted by larger events.

The data in Figure 5.2 shows an abnormal response in the wetland water levels from 18 March to 20 March 2016. While the cause of the anomaly is unknown, the water level logger was calibrated and verified to be functioning properly at the time of the installation. Furthermore, Figure 5.2 shows that the water level in the wetland fell around 6 April to 14 April 2016, when almost no rainfall was recorded for the week, and was most likely attributed to increased evaporation during that period. The wetland water level fell by approximately 0.08 m during this period.

The data provided in Figure 5.3 shows that significant head loss occurs between the river and the wetland as a result of the infrastructure and channel vegetation found within the Northern Channel. While the Northern Channel is tidal, water levels observed within the wetland were less sensitive to tidal flows over the monitoring period. Indeed, peak spring tides in March were observed to exceed 1.3 m AHD in the river, while the water levels in the Northern Channel did not exceed 0.9 m AHD during the monitoring period. Similarly, water levels in the wetland did not exceed 0.7 m AHD during the monitoring period and the tidal amplitude was significantly attenuated compared to water level observations in the Northern Channel.

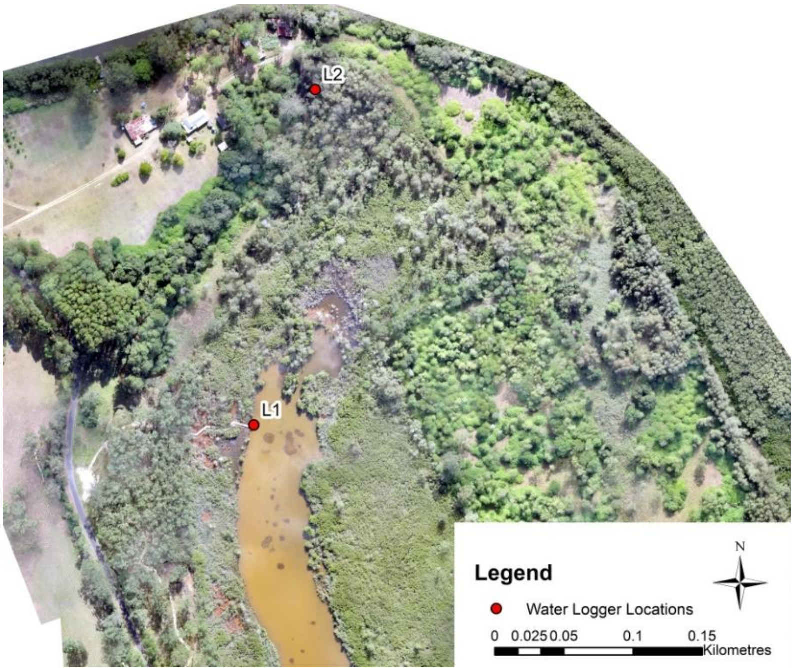

Figure 5.1: Water Logger Locations

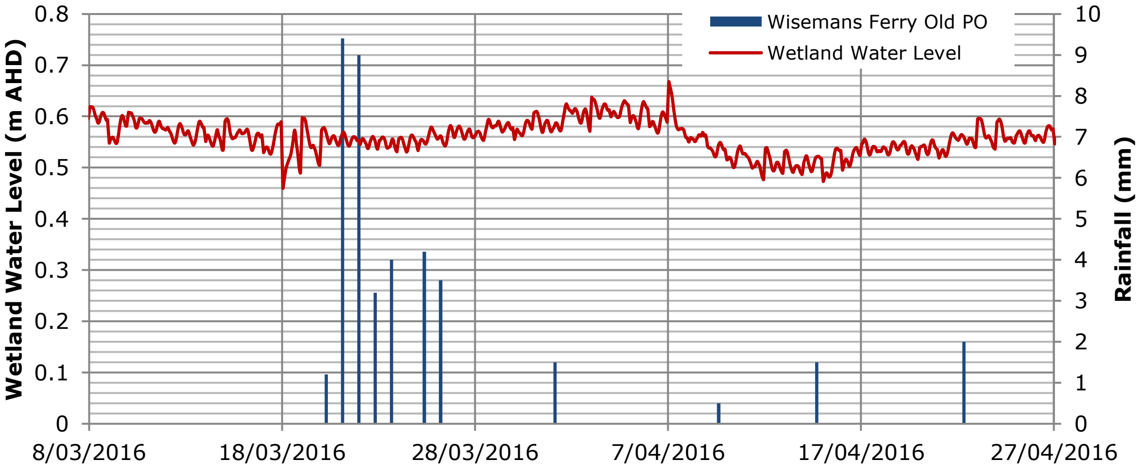

Figure 5.2: Wetland Water Level Response to Rainfall

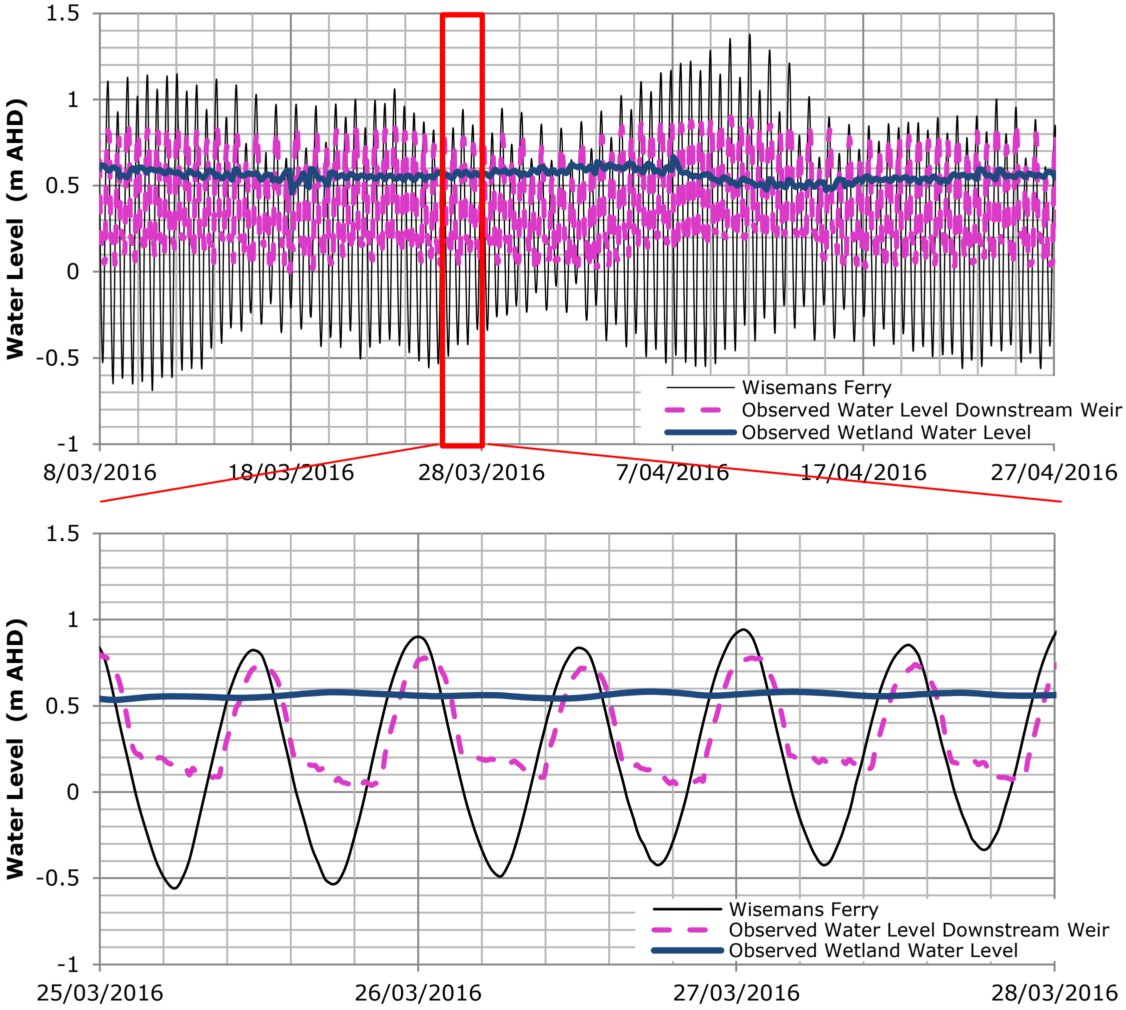

Figure 5.3: Observed Water Levels in Response to Tidal Flows

5.3 Surface Water Quality

Surface water quality monitoring of the open water areas of the wetland (Figure 5.4) was undertaken on 20 January 2016 using a YSI EXO2 multi-parameter water quality sonde. Water quality parameters measured during the ground survey, included pH, EC, DO and temperature are provided in Table 5.1. The median value of surface water acidity observed across the wetland was a pH of 4.3. The pH data clearly indicates that the surface water within the wetland has been affected by acidification and is at toxic levels that can cause fish kills and other environmental issues. DO levels are substantially lower than those measured in Ward (2012), which may also lead to increased mortality of aquatic life within the wetland. The decrease in DO found in this study may be primarily attributed to the high surface water temperatures observed during the monitoring period. Low EC – around 10% of ocean salinity levels – indicate that there is poor tidal flushing within the ponds, which is consistent with the water level response of the site. Similar to previous studies (Ward, 2012; Dragonfly Environmental, 2011), DO and pH are below ANZECC guideline (2000) trigger values for aquatic ecosystems.

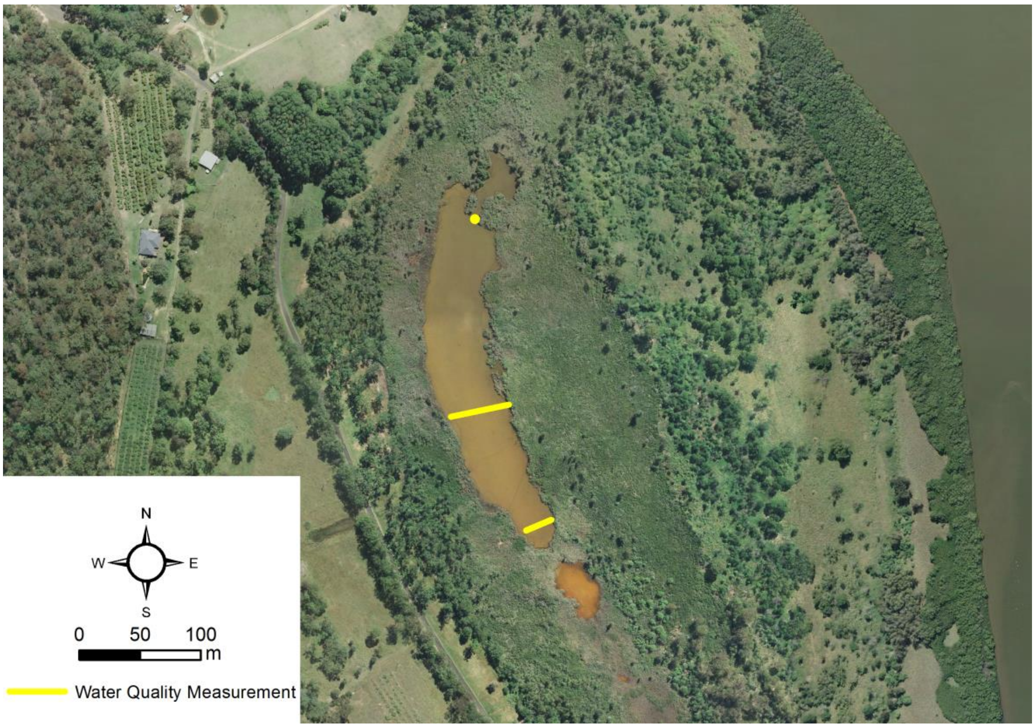

Figure 5.4: Transects and Locations of Surface Water Quality Measurements

Table 5.1: Summary of Field Surface Hydrochemical Properties

Constituent	Unit	Median	Minimum	25th Percentile	75th Percentile	Maximum
Temperature	°C	32	25	31	32	33
Electrical Conductivity	µS/cm	5,492	4,393	5,432	5,563	5,913
Dissolved Oxygen	%	19	15	17	19	48
Acidity	pH	4.28	4.25	4.27	4.29	5.34

A continuous time-series of water quality (EC and temperature) data was also collected at Site L2 (Figure 5.1) between March and April 2016 as shown in Figure 5.5. Figure 5.5 shows that the electrical conductivity in the Northern Channel is typically between 18.5 – 21 mS/cm (i.e. 35 – 40% of seawater). This data suggests that there may be sufficient buffering potential in the Hawkesbury River to neutralise acidity during extended dry periods. Note that "drop-outs" observed in the EC time series is a result of water levels in the Northern Channel falling below the logger.

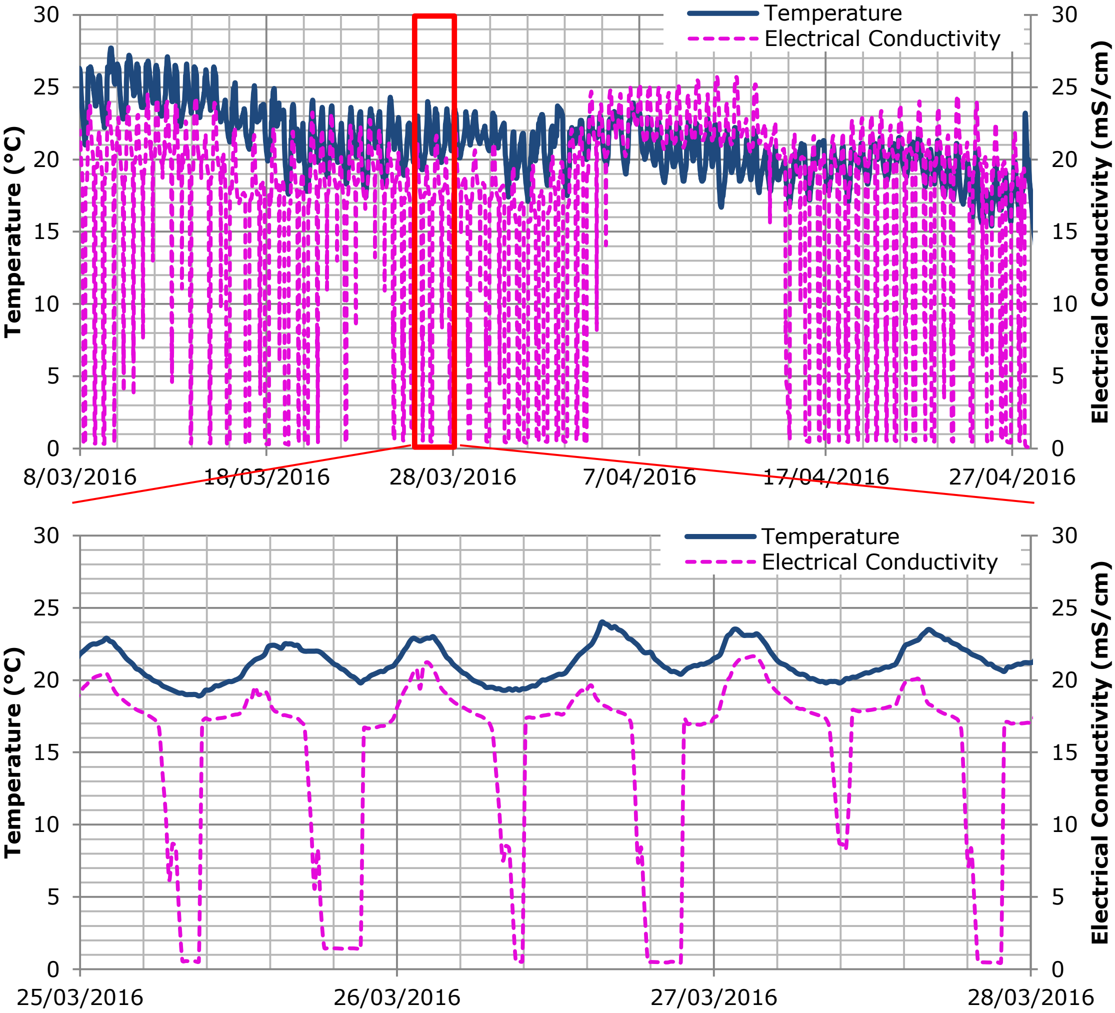

Figure 5.5: Time Series of Temperature and Electrical Conductivity Downstream of Weir

6. One Tree Reach Wetland Water Balance

6.1 Preamble

A water balance was developed to quantify and assess the hydrological response of the One Tree Reach Wetland during a representative dry weather period in March 2016. On the basis of water level observations in the One Tree Reach Wetland and rainfall observations at Wisemans Ferry between March and April 2016, there was not sufficient rainfall during the monitoring period to estimate catchment inflows into the water balance calculations. As such, the water balance of the wetland during the monitoring period was primarily driven by the tidal exchange between the river and wetland. It follows that the volume of water entering the wetland on each tidal cycle should be equal to the change in volume of the wetland, less any losses due to evaporation.

The following section describes the methodology and provides an assessment of the wetland water balance over a tidal flushing regime.

6.2 Water Balance Calculations

6.2.1 Evaporation Loss

Data from the BOM Richmond RAAF station (067105), the nearest station to the site measuring long-term evaporation, indicates an average evaporation of 4.3 mm/day for the month of March. Assuming the surface area of the wetland is approximately equal to 47,000 m^2 (i.e. area of open water and bare soil), the potential evaporation loss over a given tidal cycle is estimated to be 100 m^3.

6.2.2 Tidal Input

As the tide rises in the Hawkesbury River, the Northern Channel fills up and when the system of weirs are operational, water spills into the wetland and causes a change in the volume of the wetland. Tidal flows enter the wetland when levels in the Northern Channel exceed 0.67 m AHD. Indeed, during some neap high tides water levels may not exceed the weir invert and the wetland can sustain a loss of volume due to evaporation. Conversely, during spring high tides, the water level in the creek can overtop the weir completely (0.99 m AHD) and may substantially change the volume of water in the wetland.

The observed tidal input to the wetland was calculated for a representative tidal cycle in March 2016. On the basis of the water levels observed in the Northern Channel and an empirical weir equation used to estimate the flow over the weir (see Appendix C for details), the tidal input to the wetland was estimated to be 390 m^3.

6.2.3 Volume Change in the Wetland

The median water level observed in the wetland during the monitoring period between March and April 2016 was 0.58 m AHD. The stage-volume relationship for the One Tree Reach Wetland indicates that for the average water level observed during the monitoring period, approximately 4,470 m^3 of water was stored in the wetland. This was assumed to be equivalent to the base level of storage in the wetland over the monitoring period. On this basis, the volume change in the wetland for a representative tidal cycle in March 2016 would increase the volume in the wetland by 390 m^3 (i.e. less than 10% of the estimated total volume of water stored in the wetland). Accounting for an evaporation loss of 100 m^3, the new calculated wetland volume is 4,760 m^3. The stage-volume relationship can then be used to back-calculate the new water level in the wetland based on the new wetland volume. This corresponds to approximately 0.01 m increase in water levels over the tidal cycle, which is consistent with the minor changes in water level observed in the water level time series during the monitoring period.

These calculations have shown that the water body has a minimal overturn/flushing rate and is largely a stagnant water body, except for the largest tides. The stagnant water coincides with the low pH, low DO and apparent steady state water level (as also seen by the vegetation lines). Note that as no freshwater flooding of the One Tree Reach Wetland occurred over the monitoring period, the water balance for a large local catchment rainfall event still remains an unknown.

6.2.4 Assumptions and Uncertainty

The following assumptions are pertinent to the water balance calculations of the One Tree Reach Wetland presented above, including:

- The accuracy of the DEM is limited to the regions where ground-survey points were taken;
- The stage-storage relationship is sensitive to the accuracy of the DEM;
- The weir system was simplified for this analysis and approximated as a single weir (with an invert height of 0.67 m AHD and approximate width of 0.4 m). This approximation was required to use the empirical weir equation to calculate flows over the weir; and
- Water levels were only monitored for a short duration and had some anomalies in the time-series which were unexplainable without a long-term dataset.

7. Summary and Recommendations

Field investigations of the One Tree Reach Wetland were undertaken between January and April 2016. Three (3) separate field investigations were completed and involved ground and aerial surveys, soil profiles, surface water quality measurements of open water areas, and the installation of short-term deployable water level and water quality measurement devices to assess the land and water impacts of soil acidification across the site. Field investigations were targeted at identified data gaps from previous studies. The key outcomes of the study are:

- Ground survey data of the wetland was combined with LiDAR of the wider catchment to create a robust Digital Elevation Model (DEM) of the study region;
- A stage-volume relationship was developed from the site topography to assess the hydrologic response of the site to various environmental conditions, including rainfall and tidal inflows;
- An aerial photographic assessment has provided high-resolution aerial photos and video footage, near-infrared data of wetland vegetation, baseline vegetation classifications, and high-resolution photogrammetric digital elevation data of the site;
- Field investigations have confirmed the presence of a submerged concrete culvert in the Northern Channel that restricts tidal flushing of the wetland and reduces fish passage;
- There were minimal variations in the wetland water level data during the monitoring period between March and April 2016. The median level observed was 0.58 m AHD;
- A soil assessment at the One Tree Reach Wetland indicates the presence of AASS at or near (within 400 mm) the ground surface (i.e. ranged from 0.65 to 1.05 m AHD);
- Tidal flows enter the wetland when levels in the Northern Channel exceed 0.67 m AHD versus the previously stated invert level of 0.4 m AHD (WEW, 2013); and
- Small tidal fluctuations and evaporation drive the water balance at the One Tree Reach Wetland.

In summary, the field study and data analysis of the One Tree Reach Wetland indicates that the system, in its existing state, is severely degraded and impacted by ongoing soil acidification. The water balance suggests that the system is a largely stagnant, acid pond discharging to the Hawkesbury River estuary. This study has shown that the wetland ecosystem health would benefit from more efficient tidal flushing and increased connectivity to the wider Hawkesbury River estuary.

7.1 Recommendations

This assessment has found that:

- The highest priority recommendation is to increase tidal exchange within the wetland through modification/removal of the existing submerged concrete culvert at the confluence of the Northern Channel and the Hawkesbury River. The culvert appears to provide no hydrologic purpose and unnecessarily restricts tidal flow into the Northern Channel. Note that a risk analysis would be required before modification/removal of the existing structure.
- It is recommended that the current weir system is redesigned or modified to allow more efficient tidal flushing of the wetland and increased connectivity to the wider Hawkesbury River. It is suggested that the fixed-level weirs are replaced with drop-board weirs (or similar) that are the width of the Northern Channel and maintain water levels above the AASS layer. (It is worth noting that periodic lowering of the weir invert could be effective for short-term management of water quality and weeds across the site.) Alternatively, the

existing weir system could be maintained if the “cut-outs” are extended to the width of the channel to ensure the same top elevation across all elements of the weir.
- It is recommended that any thick vegetation and debris that currently restricts flow through the Northern Channel to the wetland be managed to ensure connectivity.
- Ongoing monitoring of water levels and water quality across the wetland to ensure that the remediation outcomes of the site are achieved.

7.2 Projected Outcomes

The expected outcomes of these recommendations include:

- The Northern Channel will experience increased tidal amplitude (above the creek bed) due to the removal or modification of the submerged culvert structure. If the culvert is removed, it is unlikely to have any continuing amplitude dampening or delayed response to tidal signals;
- Water levels will fluctuate more during a typical tidal cycle than previously in the wetland due to the increased tidal signal in the Northern Channel. If the weir is lowered, there could be substantial water level losses in the wetland during low tide;
- Additional flushing of the wetland will improve water quality outcomes, including acidity, dissolved oxygen and electrical conductivity; and
- The maximum surface area of the ponds will increase due to increased water levels in the wetland to a maximum elevation of approximately 1 m AHD according water level projections. Additional potential inundation areas with water levels increased to 0.8 m AHD and 1 m AHD are shown in Figure 7.1.

7.3 Associated Risks of Projected Outcomes

The associated risks of the projected outcomes may include:

- Inundation of neighbouring properties - this risk could be avoided by separating the Council managed portion of the wetland from the adjacent private land through the installation of a flow control structure (such as a weir);
- Impact to wetland infrastructure - the recommendations provided in this study aim to create a more natural wetland system, however, it is expected that increased tidal flushing would have minimal impact on existing wetland infrastructure; and
- Potential vegetation die-back – as the wetland transitions to a more natural system, it is possible that vegetation lines will be altered. However, it is expected that increased tidal flushing would benefit existing EEC’s, including Coastal Saltmarsh.

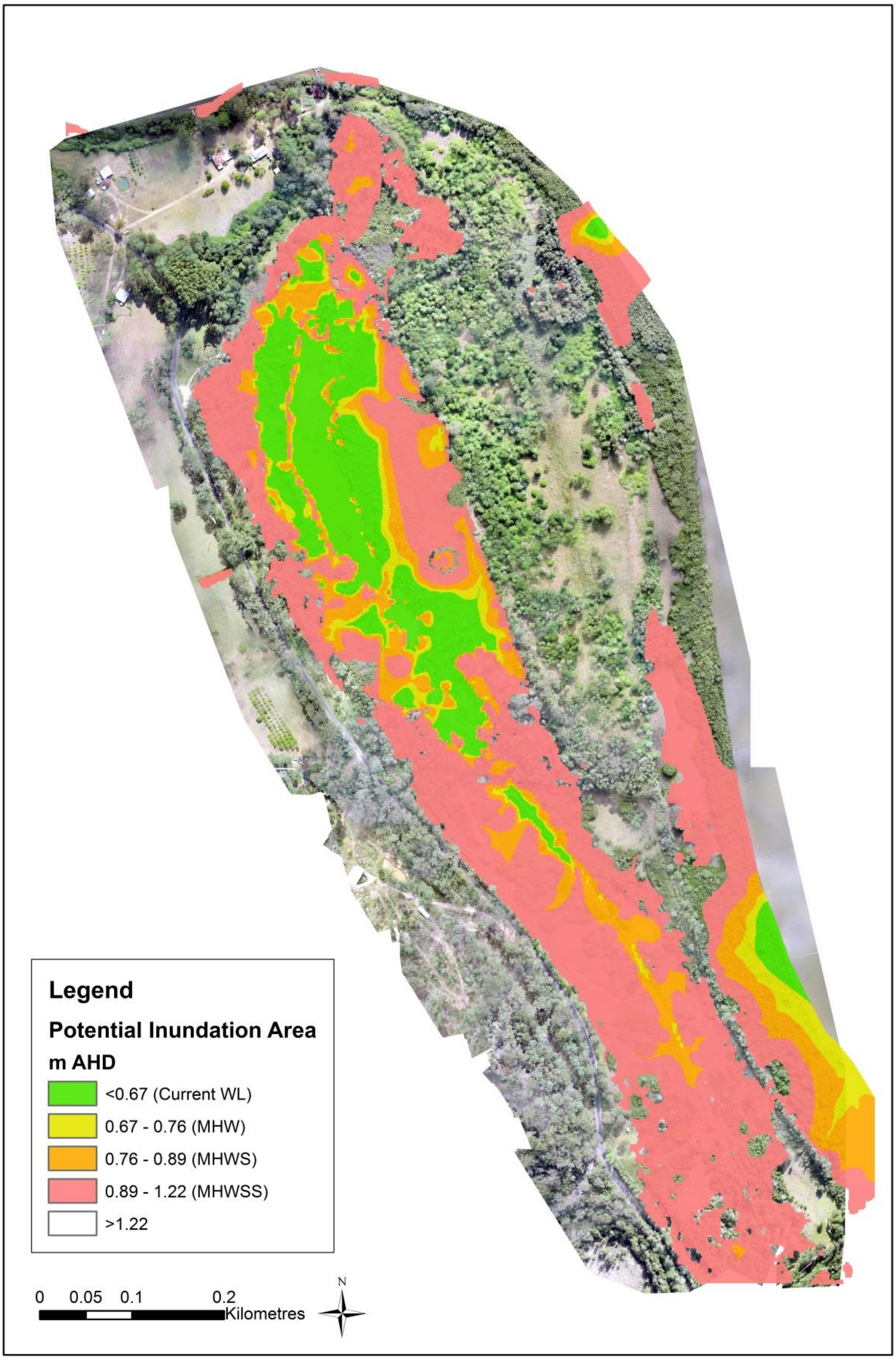

Figure 7.1: Potential Areas of Additional Inundation (Tidal Planes at Wisemans Ferry)

8. References

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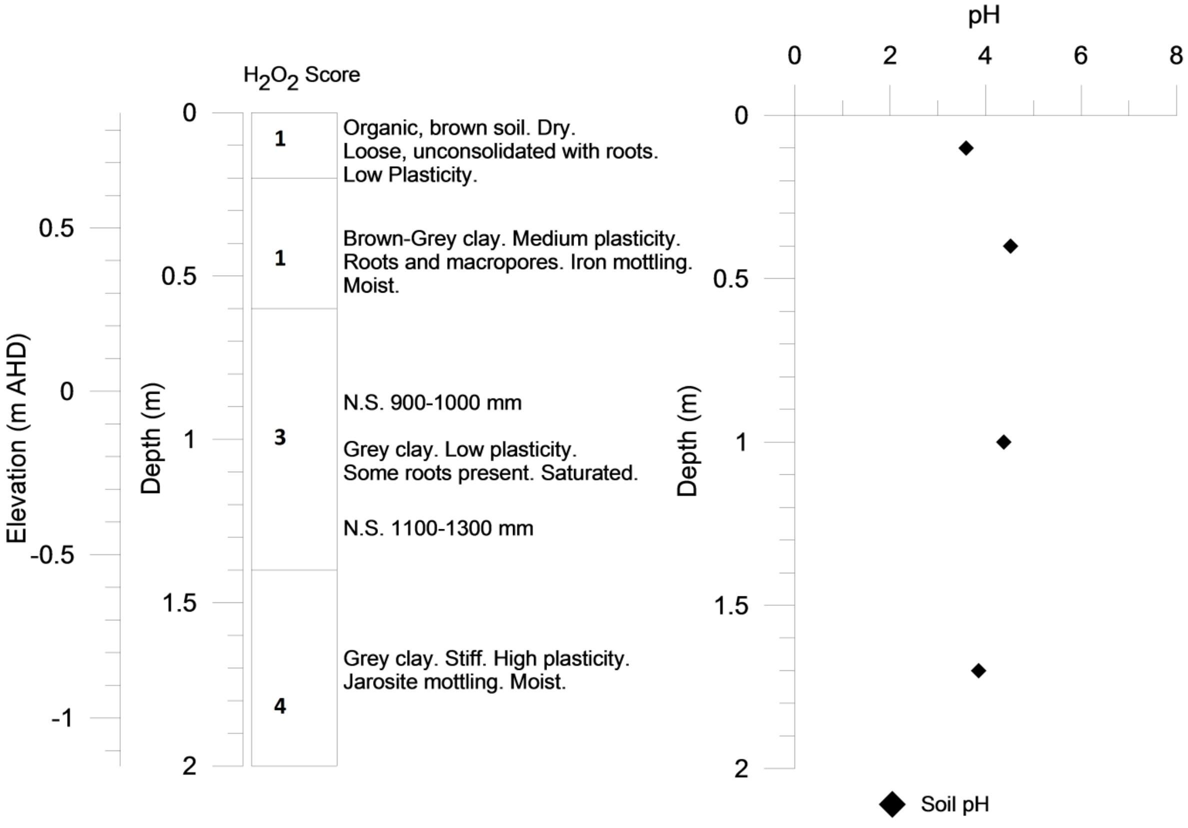
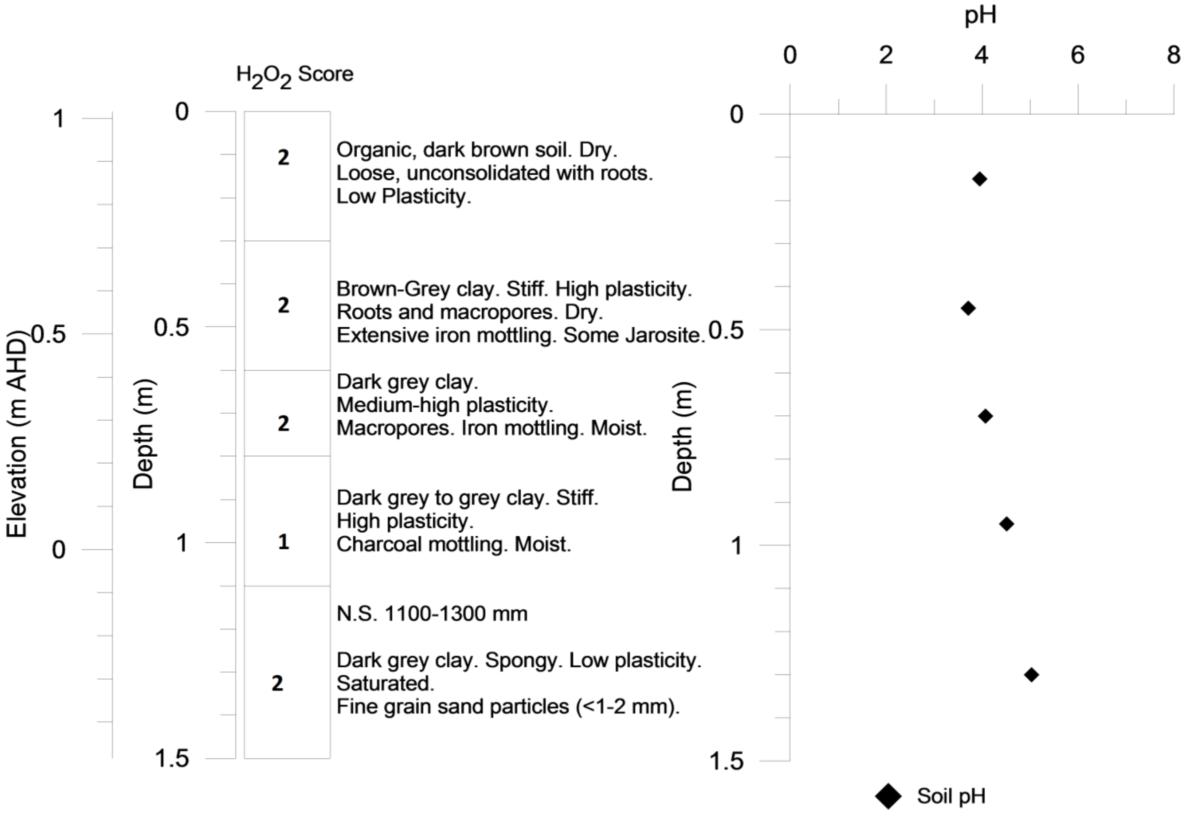
Appendix A – Soil Profile Data

This section provides a summary of the soil profile data collected during the field investigations.

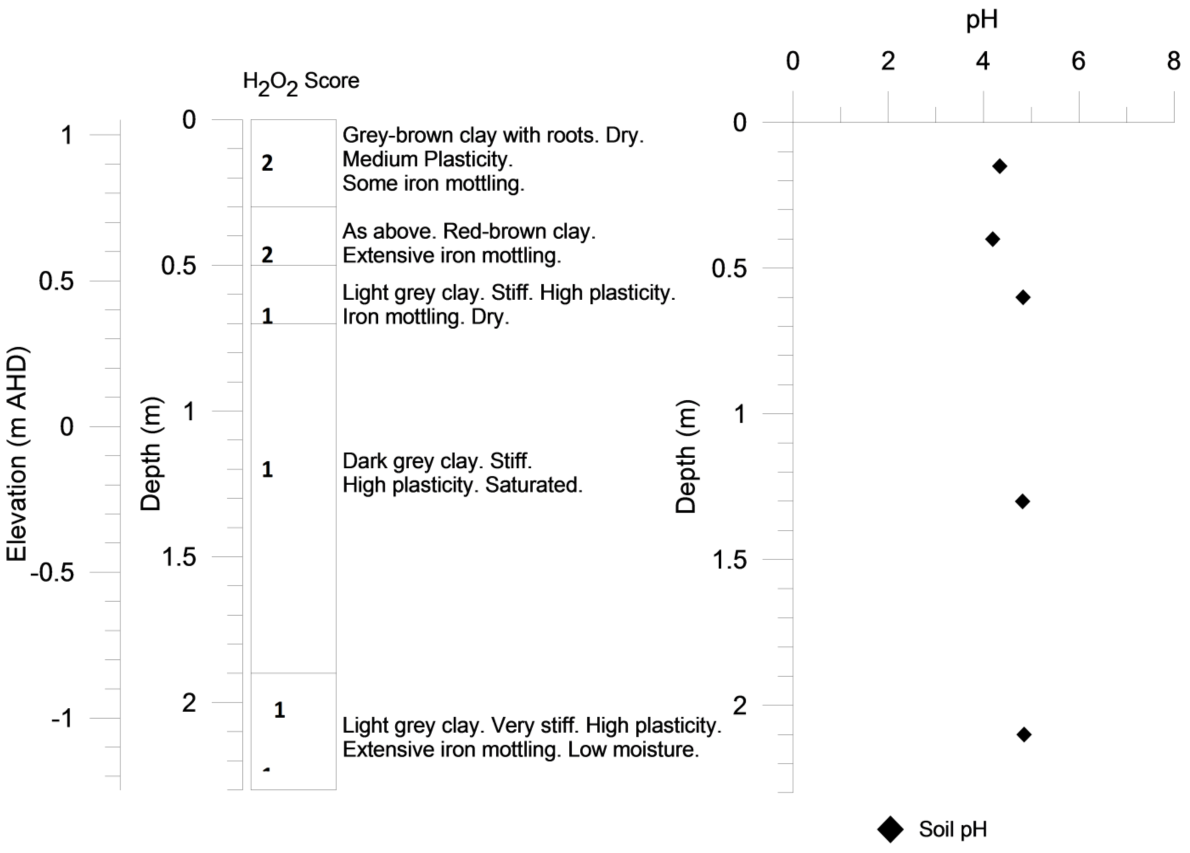
Location	P1
Date	07/03/2016
Easting (m)	317828.786
Northing (m)	6298981.143
Elevation (m AHD)	0.853



Location	P2
Date	07/03/2016
Easting (m)	317826.359
Northing (m)	6299026.626
Elevation (m AHD)	1.016

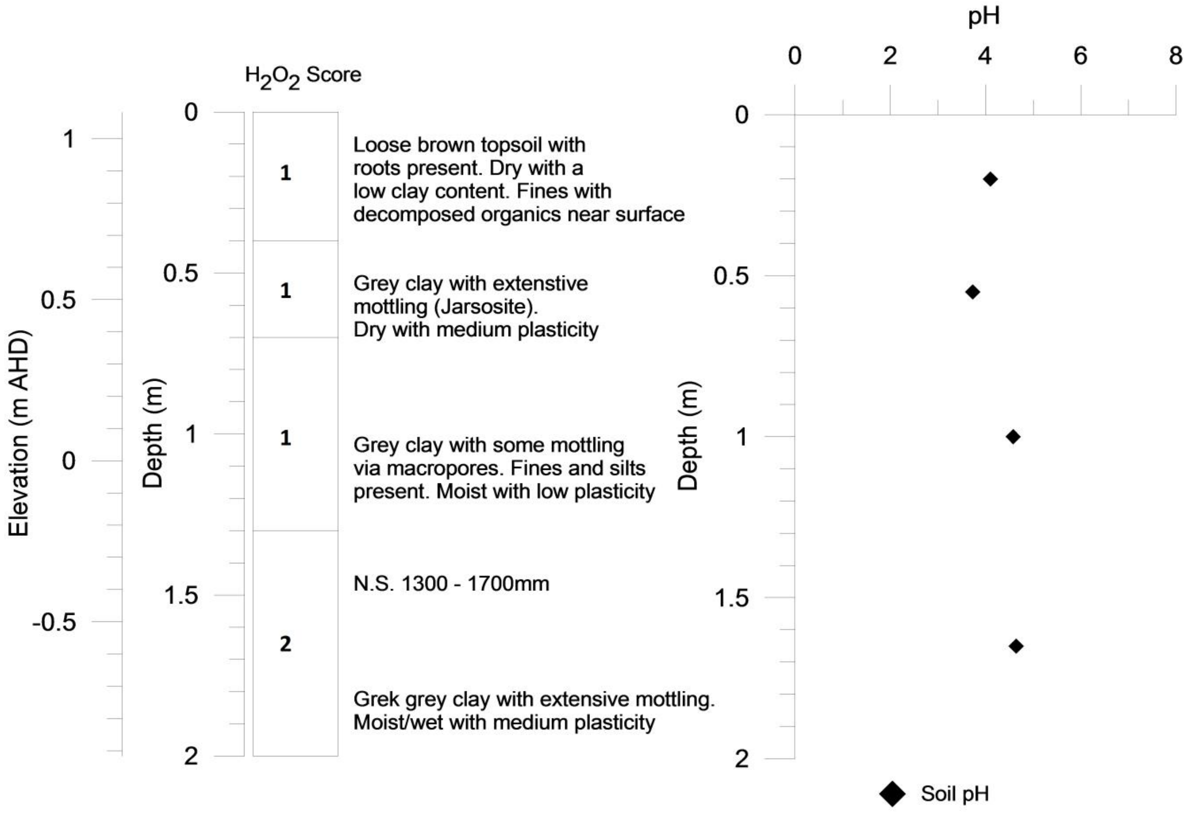


Location	P3
Date	07/03/2016
Easting (m)	317961.237
Northing (m)	6298637.05
Elevation (m AHD)	1.053

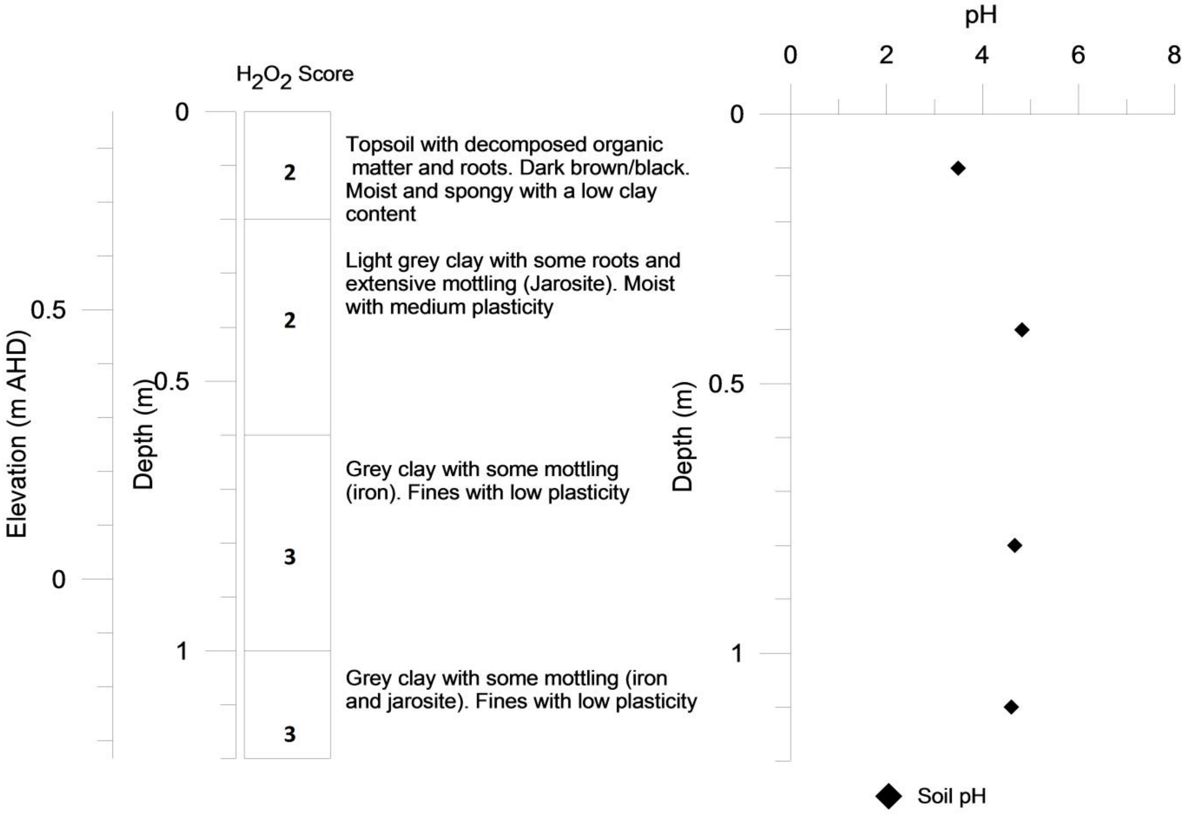


NO IMAGE

Location	P4
Date	27/04/2016
Easting (m)	317797.116
Northing (m)	6298971.849
Elevation (m AHD)	1.083



Location	P5
Date	27/04/2016
Easting (m)	317851.819
Northing (m)	6299001.118
Elevation (m AHD)	0.868



Appendix B – Background on UAV Aerial Survey Data

The use of UAVs as a mapping and measurement tool has grown significantly in recent years and has been pioneered by WRL engineers to provide high quality survey data sets in numerous locations across NSW. While traditional land-based (e.g. RTK-GPS) or airborne (e.g. LiDAR) methods of collecting topographic data over large areas can be labour-intensive and/or costly, UAV surveying provides cost-effective, rapid airborne sampling of an area at high-accuracy and very high spatial resolution.

The surveys were undertaken utilising a Sensefly eBee RTK UAV (Figure B.1) equipped with a Canon Ixus RGB camera with key features summarised in Table B.1. This platform is a fully autonomous survey-grade mapping UAV which carries on-board its own RTK-GNSS receiver. During flights, the eBee RTK maintains radio connection to a ground-based GNSS base station, providing in-flight processing of RTK corrections via the CORSnet-NSW network of permanent satellite base stations. This results in high precision navigation and individual image geo-tagging.

Table B.1: Specifications of the UAV system

Feature	Description
Type	Fixed wing UAV
Wingspan, Weight	96 cm, 700 g
Endurance	Up to 40 minute flight time
Cruise Speed	40-90 km/hr
Wind Resistance	Gusts up to 45 km/hr
Coverage per Flight	Up to 2km2
Onboard Sensors	RGB/NIR camera RTK receiver inertial measurement unit pitot probe optical ground sensor

Figure B.1: UAV

Post processing was completed using Postflight Terra 3D commercial software to produce a geo-rectified orthomosaic image and 3D digital elevation model. This software uses advanced photogrammetry techniques to produce elevation data through the automatic detection of common features between many overlapping images to produce a dense point cloud dataset. The data output differs from that acquired using laser returns (i.e. LIDAR) in that a UAV-derived point cloud may represent the upper surface of dense vegetation or building roof rather than a ground return. The algorithm relies on the assumption that ground features remain stationary while the survey platform is in motion. For this reason, the algorithm generally has limitations mapping moving objects such as water surfaces.

The data products produced include a densified point cloud as well as an ortho-rectified mosaic of each survey area. The point cloud data has RGB pixel colours assigned to it which provides a powerful visualisation tool. Typical ground resolutions of the imagery produced by the UAV in this study vary from 2 to 3 cm/pixel and an average density of 50 points per m^3.

Appendix C – Empirical Weir Equation

For a rectangular weir as given in Figure 3.12, the well-known discharge formula can be written as:

$$q = \frac{2}{3} c_d b (2g)^{\frac{1}{2}} h^{\frac{2}{3}}$$

where: q = flow (m^3/s)
h = head over weir (m)
b = width of weir (m)
c_d = discharge coefficient

The following assumptions were made on the current weir conditions:

- The representative control height of the weir was taken as 0.67 m AHD;
- The weir system is represented by a single weir with a width of 0.4 m; and
- A discharge coefficient of 0.62 was assumed (Osman Akan, 2006).