School of Civil and Environmental Engineering

Water Research Laboratory

FINAL DRAFT

Tuckean Swamp Hydrologic Options Study

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Executive summary

ES.1 Background

Tuckean Swamp is a 6,000 hectare low-lying floodplain located on the Richmond River, approximately 25 km upstream of Ballina, shown in Figure ES-1. Since the 1880's extensive drainage works have occurred at Tuckean Swamp to allow the rapid discharge of floodwaters from the naturally low-lying floodplain. In 1971, the major drainage works as it exists today was completed with the installation of the Bagotville Barrage. The barrage comprises eight large culverts with one-way floodgate flaps to enable drainage from the Tuckean floodplain, whilst excluding downstream tidal waters and backwater flooding from the Richmond River. These floodgates also act to promote the lowering of groundwater levels across the connected upstream floodplain. The artificial drainage system, including the Bagotville Barrage, have facilitated agricultural development of this land, which is mostly used for grazing and sugar cane. Approximately 550 ha of the lowest lying area on the floodplain is owned and managed by National Parks and Wildlife Services (NPWS), referred to as the Tuckean Nature Reserve (TNR), indicated on Figure ES-1.

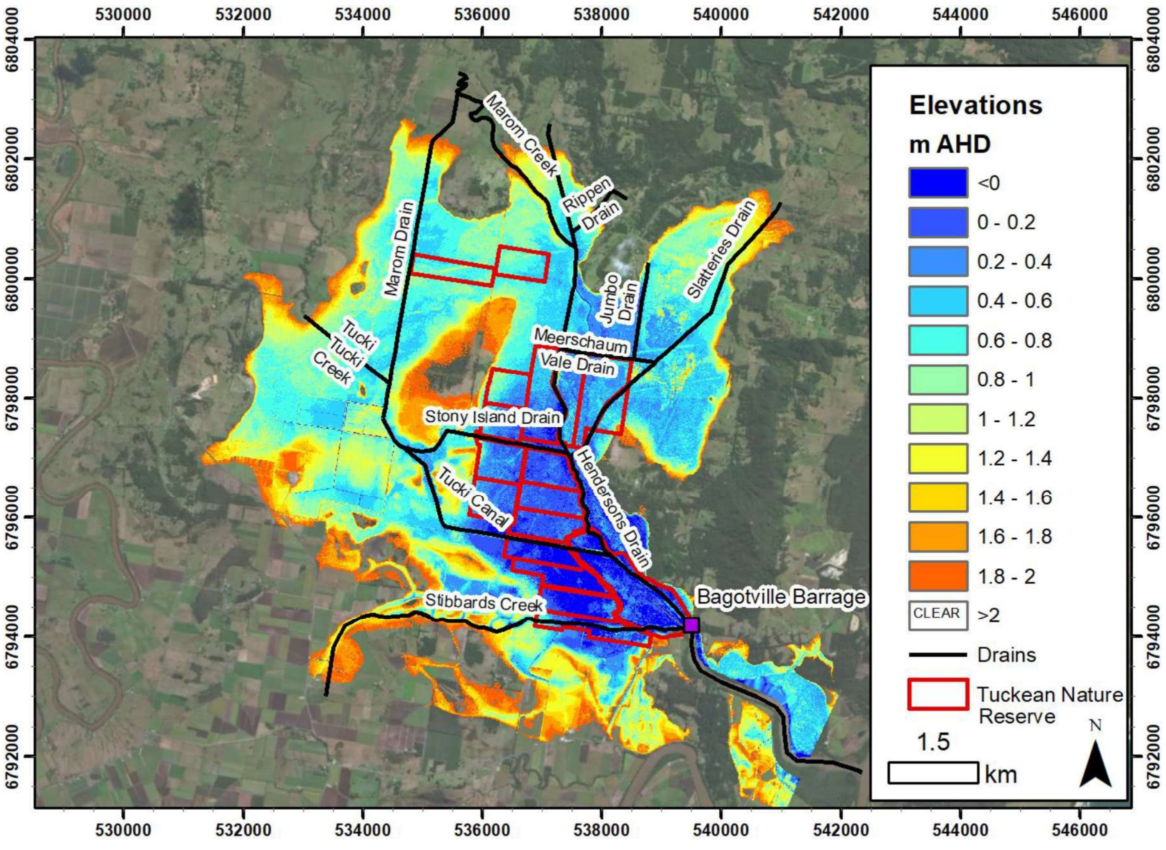


Figure ES-1: The Tuckean floodplain

The extensive man-made drainage network has also had unintended environmental impacts, including the production of acidic discharge from the drainage of acid sulfate soils (ASS), as well as 'blackwater' (low-oxygen water) runoff into the broader estuary. The Tuckean floodplain has been identified as one of the worst acid sulfate soil affected areas in NSW. While some limited tidal flushing was introduced into the system in 2002 to improve surface water quality (through three (3) sluice gates in the barrage), few other strategies have been implemented that have resulted in long-term improvements in floodplain water quality. Subsequently, poor water quality from the Tuckean region continues to be an ongoing issue.

This study identifies the areas of the Tuckean floodplain that are having the greatest impact on water quality in the region, using extensive field data and a conceptual understanding of the site. Using this information, six (6) alternative drainage management options have been developed to address and mitigate some of the issues associated with ASS. The aim of this study is to investigate the feasibility and quantify the impact of each of these alternatives, not only in terms of water quality, but also the potential impact on floodplain inundation, drainage and saltwater intrusion.

An aim of this study is to improve the overall understanding of the hydrology of Tuckean Swamp and floodplain through extensive field data collection and numerical modelling. With a better understanding of how the site currently functions, different management options can be investigated targeted at decreasing acidic discharges from the site and improving overall water quality. While the environmental benefits are important, it is vital that any hydrologic impacts to the wider floodplain and adjacent landholders are equally considered.

The options investigated in this study were developed with input from the Tuckean Steering Committee, consisting of representation from OzFish, Rous County Council, Ballina Shire Council, Lismore City Council, Richmond Valley Council, National Parks and Wildlife Services, Department of Planning, Industry and Environment (formerly OEH), Local Land Services, Jali LALC, Department of Primary Industry – Fisheries and the Nature Conservancy. Funding has been provided by the Saltwater Recreational Fishing Trust Flagship Fish Habitat Action Plan. While not all possible drainage management options have been considered in detail, the drainage options investigated in this study are small-to-medium scale remediation strategies that aim to improve surface water quality by reducing acid drainage from the Tuckean floodplain, whilst quantifying potential hydrological impacts to adjacent landholders.

ES.2 Field data collection

Extensive field data collection campaigns were undertaken between March 2018 and February 2019. The data collection was targeted to filling information gaps identified in the existing literature. Data collected primarily related to:

- Water levels at strategic locations throughout the drainage network;
- Floodplain topography;
- Drain cross-sections (bathymetry);
- Size and elevation of major drainage structures; and
- Water quality.

Existing soil profile data was also examined to identify areas with high ASS occurrence throughout the floodplain. As a substantial amount of information on soil types and acidity already existed, minimal additional soils data was required to be collected during this study.

ES.3 Priority ASS areas

To guide the development of the management strategies, it is necessary to divide the floodplain into management sub-areas and to prioritise which areas should be targeted to improve overall floodplain water quality. This prioritisation specifically targets water quality and is not intended to be the only source of information used when considering the on-going management of the floodplain.

The Tuckean floodplain was divided into 10 major floodplain sub-sections representing major drainage areas. Based on the conceptual understanding of the floodplain drainage, topography and acid generation on the site, the sub-areas were ranked in order of priority for addressing ASS issues. The management sub-areas and prioritisation are shown in Figure ES-2. The highest priority areas around Meerschaum Vale and Slatteries Drains, and in the lower Tuckean Nature Reserve are broadly consistent with the priority areas identified by previous studies.

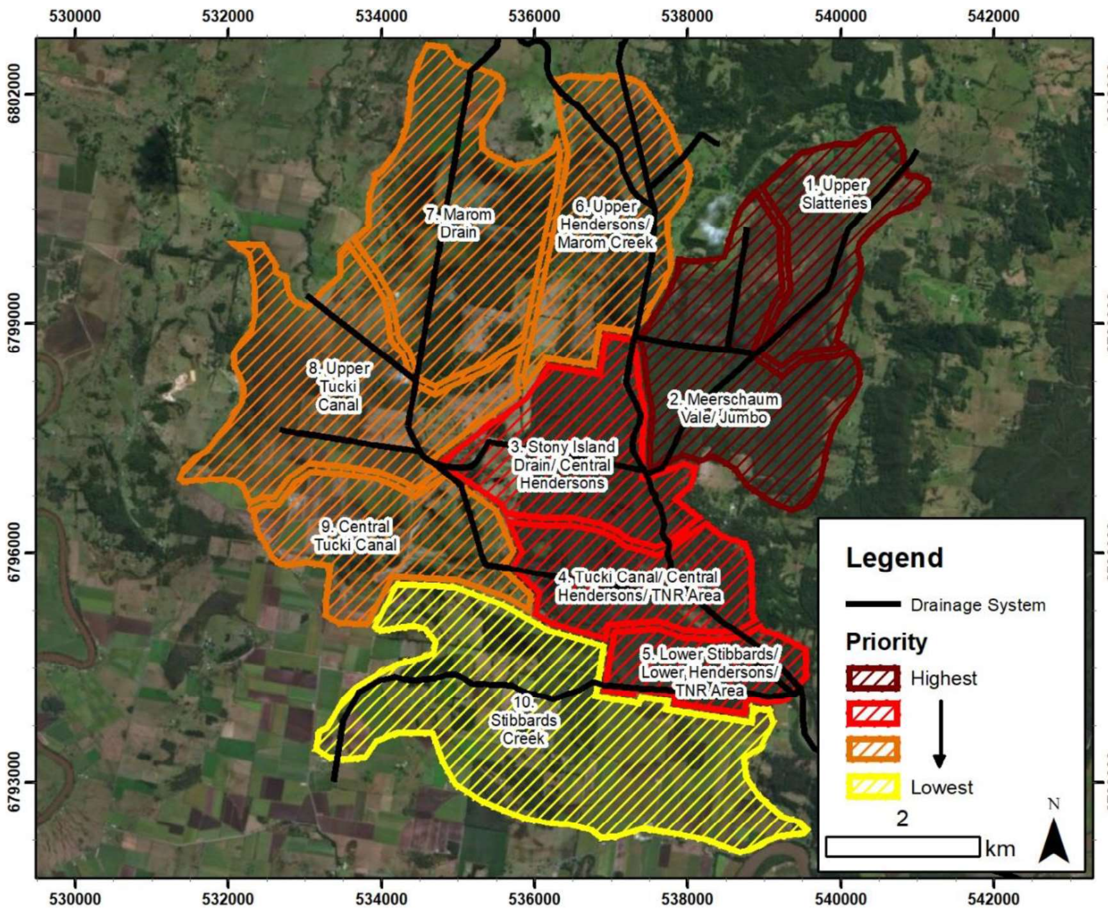


Figure ES-2: ASS prioritisation of the Tuckean floodplain

ES.4 Modelling summary

Based on the field data collected and other existing information, a detailed, dynamically linked 1-D/2-D hydrodynamic numerical model of the Tuckean Swamp floodplain was developed using the MIKE suite of models. The model was constructed to represent the floodplain as it exists today and collected data was input into the model and used to verify the model's ability to replicate the present (often referred to as the "Base Case") day to day conditions. Once the existing Base Case was verified, modifications were made within the model and used to test "what if" scenarios of different drainage management options (referred to as "modelling scenarios"). Using a numerical model allows for any number of management options to be tested to understand what impacts they might have during different hydrological conditions.

Based on the prioritisation of the floodplain, six (6) drainage management scenarios were chosen through discussion with the Tuckean Steering Committee. The management scenarios can be broadly divided into two (2) categories, summarised in Table ES-1. The freshwater management options target the highest priority areas around Meerschaum Vale and Slatteries Drains, while the saltwater management options focus on the high priority areas centred around the Tuckean Nature Reserve.

Table ES-1: Summary of model scenarios

Category	Model Description
Current	**Base Case –** the model was run to replicate existing floodplain hydrodynamics
Freshwater management options *Focus on the north-eastern (Slatteries) corner of the floodplain*	**Scenario 1 –** Reshaping of major drains in the north-eastern corner of the floodplain (Slatteries, Meerschaum Vale and Jumbo Drains) **Scenario 2 –** Weir implementation at the downstream end of Meerschaum Vale Drain **Scenario 5 –** Reshaping of drains (as per Scenario 1), but encouraging small catchment flows onto the floodplain
Saltwater management options *Focus on the Bagotville Barrage management, targeting the Tuckean Nature Reserve*	**Scenario 3 –** Alternative management of barrage sluice gates during dry periods **Scenario 4 –** Hinging open the Bagotville Barrage **Scenario 6 –** Hinging open the Bagotville Barrage, and installing structure upstream of the Tuckean Nature Reserve on all the major drains

The model results for each scenario were interrogated to understand not only the potential environmental benefits, but also the impact on surrounding landholders relating to:

- Floodplain inundation;
- Drainage times; and
- Saltwater intrusion.

ES.4.1 Scenario 1 – Reshaping Slatteries, Meerschaum Vale and Jumbo Drains

Description:

Scenario 1 investigates the impacts of reshaping, or 'swaling', major drains in the north-east section of the floodplain (see Figure ES-3). Raising drain invert levels while maintaining the effective drain cross-sectional area aims to reduce groundwater discharge while maintaining the drainage capacity of the existing system. Ideally, the invert would be raised above the ASS layer to effectively prevent advective acid transport. However, the ASS layer in this area is near the surface, so inverts of the drain have been raised within the model to a level that will reduce acid transport while still allowing sufficient gradient within the channels to maintain drainage. An example of a swaled drain cross section is shown in Figure ES-4.

Model Outcomes:

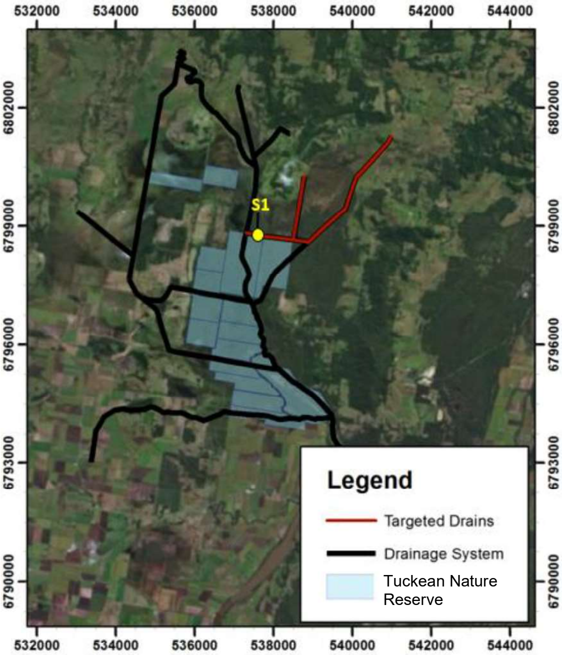
The results of the model indicated the following:

- Water levels increase by 20 – 30 cm within the drainage network during dry periods.
- Drainage is prolonged after rainfall events (Figure ES-4).
- Reduced diffusive and advective acid transport from the highest acid contributing area on the floodplain around Meerschaum Vale and Slatteries Drains.
- As the ASS layer is at or near the surface in this area, drains will still intersect ASS layers and some acid discharge will continue.
- Minimal changes to mean and maximum floodplain inundation over the five (5) month modelling period.

Implementation considerations:

In addition to the model results, the following implementation considerations have been identified:

- Swale drains require a larger footprint than the narrower, deeper drains that they replace, which would require agreement from landholders.
- Fill material may be required.
- ASS management plan would be required.



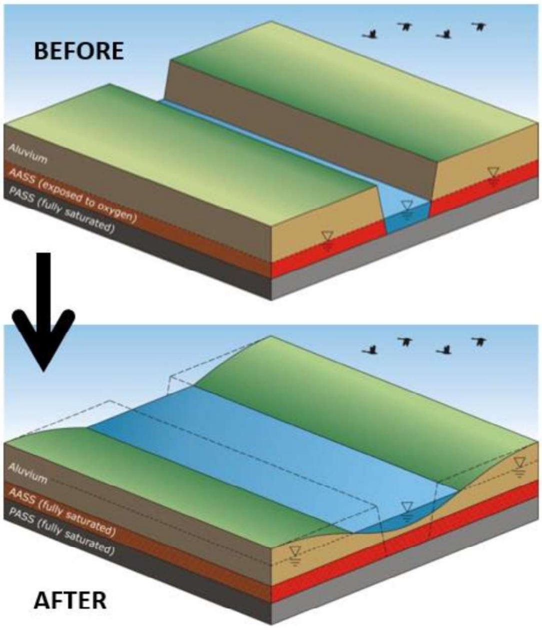


Figure ES-3: Left – Drains targeted for drain reshaping, Right – example of new profile sitting above the ASS layer after the drain reshaping (Water level extraction point S1 highlighted)

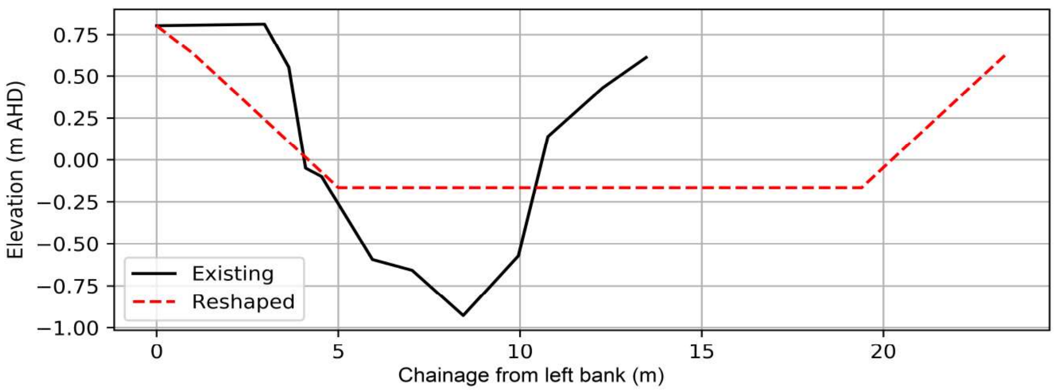


Figure ES-4: Example of reshaped drain cross section

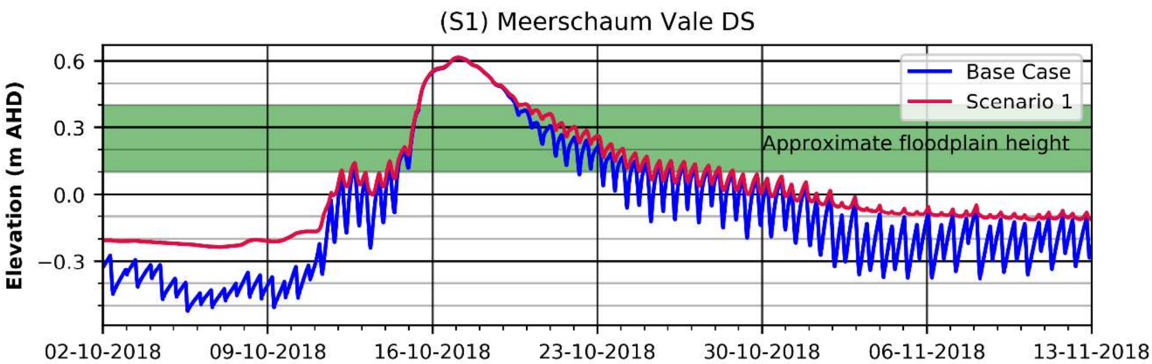


Figure ES-5: Water level changes in Meerschaum Vale Drain (location shown in Figure ES-3)

ES.4.2 Scenario 2 – Weir at Meerschaum Vale Drain

Description:

Scenario 2 investigates the impacts of the installation of a weir structure at the end of Meerschaum Vale Drain, as shown in Figure ES-6, with an invert level of 0 m AHD. Weirs promote higher surface water and groundwater elevations to reduce groundwater drawdown by minimising the hydraulic gradient between groundwater and drainage channels, resulting in reduced acid discharge. An invert of 0 m AHD was chosen to minimise impacts to surrounding landholders, while significantly increasing the water level control within Meerschaum Vale Drain, as shown in Figure ES-7.

Model outcomes:

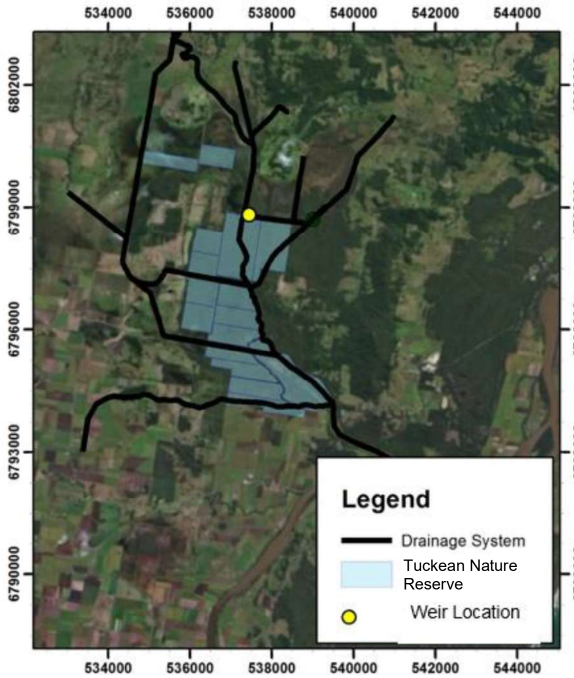
The results of the model indicated the following:

- Increased water levels during dry periods and significantly prolonged drainage after rainfall events (Figure ES-8).
- Reduced advective acid transport from the highest acid contributing area on the floodplain.
- Diffusive acid transport will remain similar.
- ASS exist above 0 m AHD on the floodplain. This option will reduce acid transport, but not eliminate it.
- Minimal changes to mean and maximum floodplain inundation over the five (5) month modelling period.

Implementation considerations

In addition to the model results, the following implementation considerations have been identified:

- Weirs often result in stagnation of water behind the structure, leading to a potential build-up of weeds that need to be managed.
- A higher weir would further reduce acid transport but would have greater implications for local floodplain inundation and drainage times.



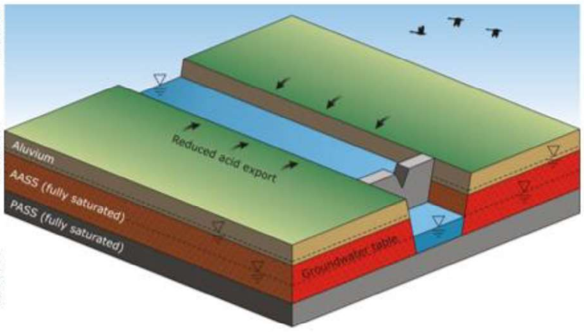


Figure ES-6: Left – Location of weir structure, Right - Reduced acid export as a result of a weir structure holding up water levels

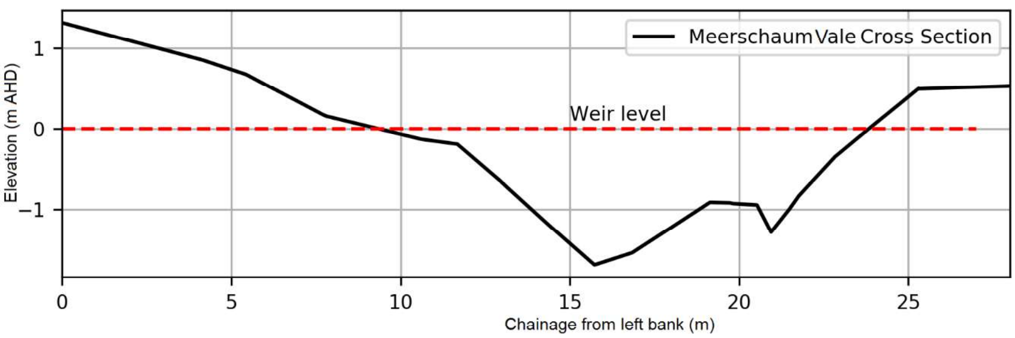


Figure ES-7: Weir level, compared to Meerschaum Vale Drain cross section

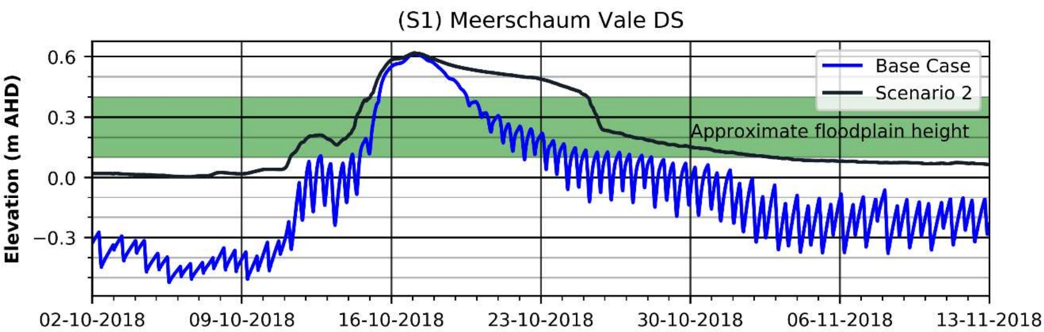


Figure ES-8: Water level changes at key locations (location shown in Figure ES-3, immediately upstream of weir)

ES.4.3 Scenario 3 – Existing sluice gate management

Description:

Three (3) 1 m x 1 m sluice gates were previously installed in 2003 on the three (3) northern Bagotville Barrage gates. Flows through the sluice gates allow controlled tidal inflows into Hendersons Drain, which increases salinity within the lower Tuckean Nature Reserve and promotes better flushing. The sluice gates are shut prior to catchment rainfall to maintain flood capacity.

The model was run for three (3) alternative sluice gate configurations (during dry periods only):

- **Scenario 3a:** One sluice gate open 150 mm;
- **Scenario 3b:** One sluice gate open 500 mm; and
- **Scenario 3c:** Two sluice gates open 500 mm.

Model Outcomes:

The results of the model indicated the following:

- Floodplain inundation under all three (3) configurations is largely contained within the Tuckean Nature Reserve boundary, except for a small area east of Hendersons Drain, shown in Figure ES-9.
- If the sluice gates are shut 24 hours before the onset of rainfall, there is no change to drain storage capacity.
- Salinity remains low (<5% of Tuckean Broadwater) at the confluence of Hendersons and Meerschaum Vale Drain under all three scenarios, shown in Figure ES10.
- Natural buffering capacity in saltwater acts to neutralise acid within surface waters.
- Acid discharge during dry conditions from within the Tuckean Nature Reserve area will reduce, however acid will continue to be discharged from the remainder of the floodplain.

Implementation Considerations:

In addition to the model results, the following implementation considerations have been identified:

- Salinity will be higher in Stibbards Creek with potential impacts to adjacent floodplain areas through high hydraulic conductivity sand layers in this area (and other areas) may have to be managed. This may require the installation of additional monitoring equipment and additional soil investigations.
- Significant changes to salinity within the Tuckean Nature Reserve will change the ecology of the system, and an environmental assessment may be required.

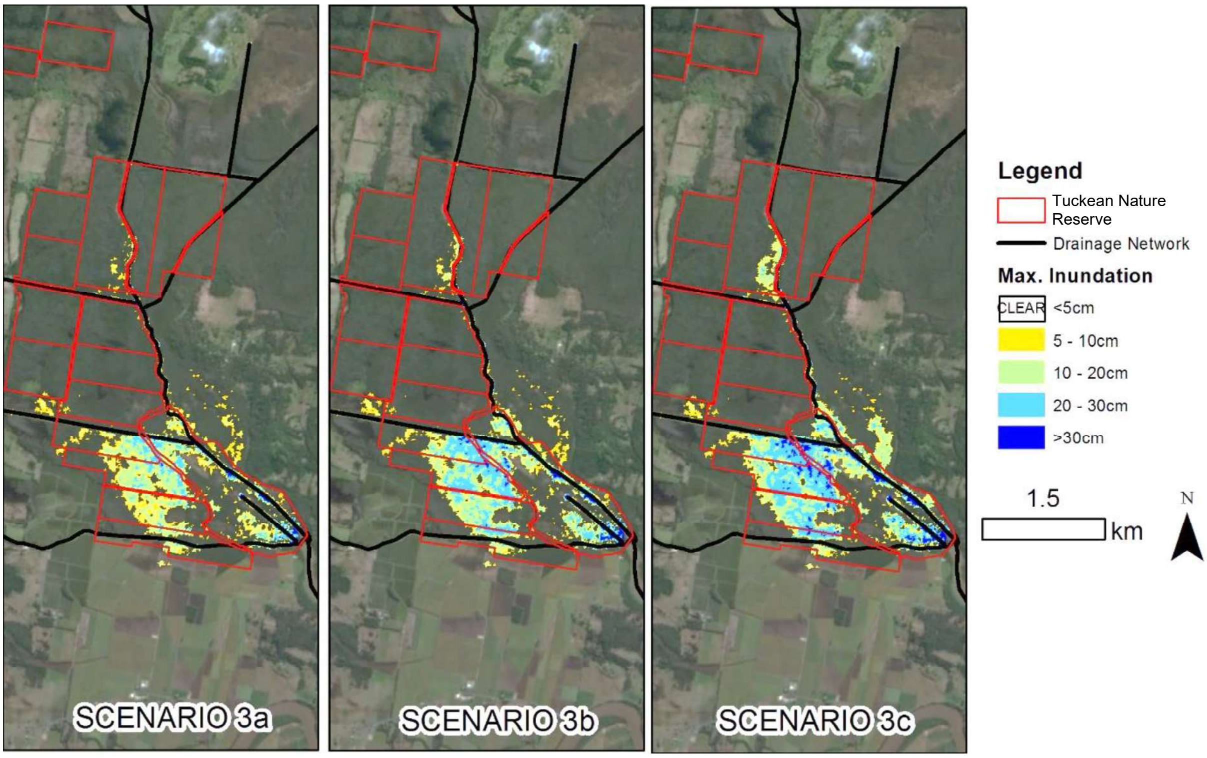


Figure ES-9: Maximum floodplain inundation in Scenario 3a, 3b and 3c

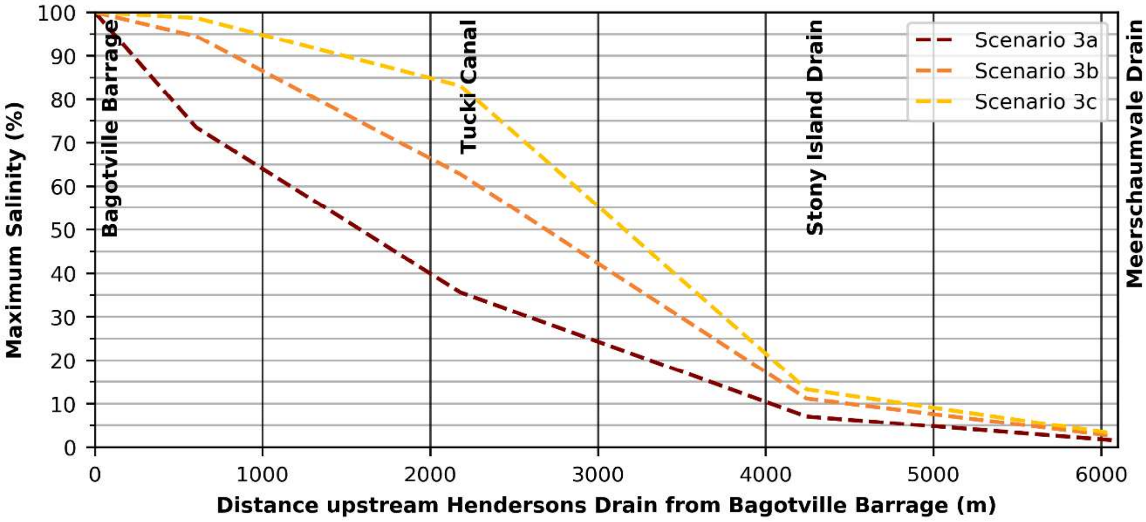


Figure ES-10: Maximum salinity (as a percentage of salinity in the Tuckean Broadwater) up Hendersons Drain

ES.4.4 Scenario 4 – Hinging open the barrage gates

Description:

There are eight 3 m x 3.5 m one-way flood gates on the Bagotville Barrage that allow flows to discharge into the Richmond River, but prevent tidal flows into the swamp. This option aims to quantify the impacts of hinging open the gates on the floodplain. By hinging open the gates, but leaving the structure intact, this option allows for the broadscale reintroduction of tidal flows into the swamp in desirable periods, while still allowing for the opportunity to close the gates to prevent backwater flooding from the Richmond River. Improved tidal connectivity increases flushing and increases the natural acid buffering capacity of the system.

Model Outcomes:

The results of the model indicated the following:

- A large portion of the floodplain becomes inundated during day to day tidal cycles, including almost all the Tuckean Nature Reserve and privately-owned areas south of Stibbards Creek, along Tucki Canal and east of Hendersons Drain.
- During extended dry periods, salinity in Hendersons Drain at the confluence of Meerschaum Vale Drain can reach as high as 20% of the salinity in the Tuckean Broadwater, and up to 10% in Jumbo Drain (shown in Figure ES-11).
- Average water levels increase throughout the floodplain (illustrated in Figure ES-12).
- Advective acid transport would be reduced due to higher average water levels.
- High salinity in the drains will improve the natural acid neutralisation capacity.
- Peak water levels during small to medium catchment events increase, and drainage times increase significantly.

Implementation Considerations:

In addition to the model results, the following implementation considerations have been identified:

- Groundwater connectivity to private land would require additional consideration and monitoring.
- Large changes in the ecosystems would likely occur on the impacted areas of the floodplain which would require further environmental assessment.
- The increased floodplain and drain salinity would require substantial changes in land management practises in some privately-owned properties. This may involve some land acquisition or landholder compensation.

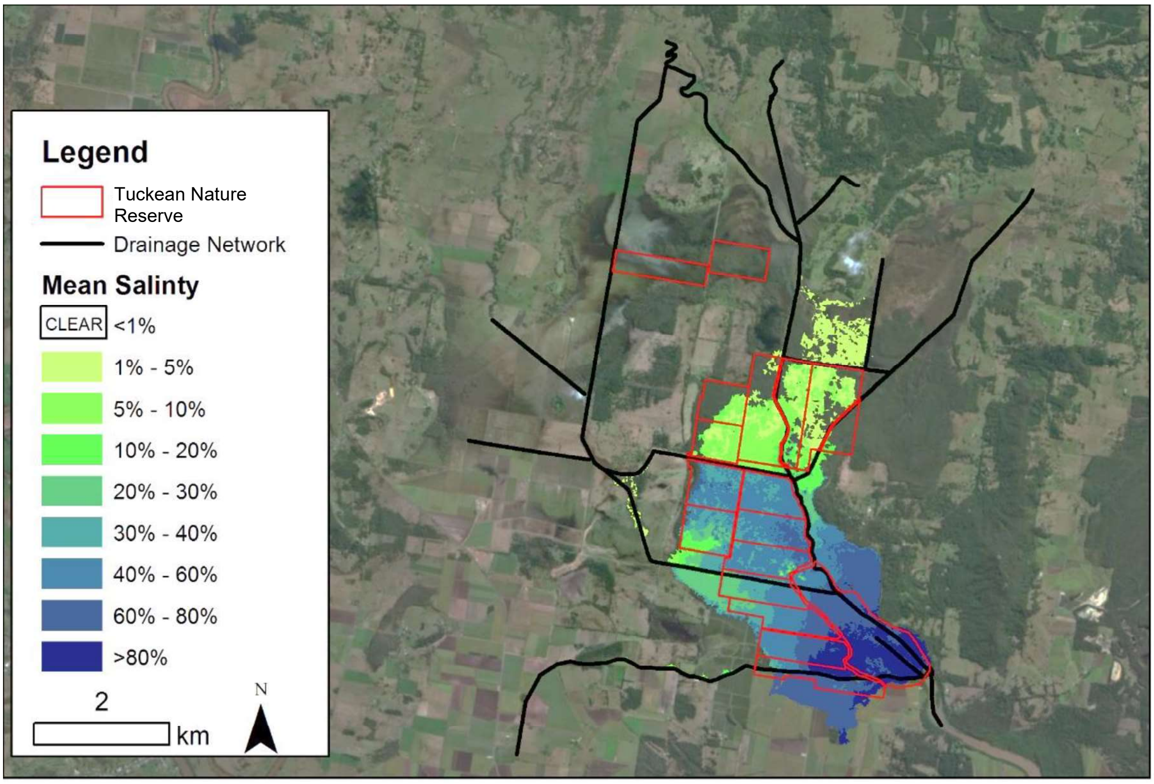


Figure ES-11: Mean salinity (as a percentage of salinity in the Tuckean Broadwater) for Scenario 4

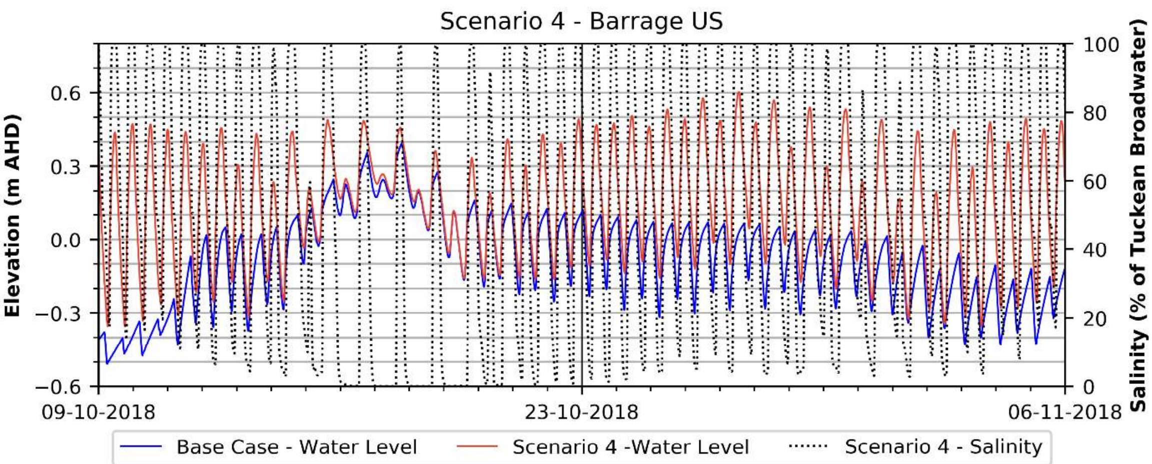


Figure ES-12: Water levels and salinity upstream of the Bagotville Barrage in Scenario 4

ES.4.5 Scenario 5 – Reflooding near Slatteries Drain

Description:

Scenario 5 uses the modified drainage network that was developed for Scenario 1. However, small to medium catchment flows from the Slatteries catchment are diverted onto the floodplain to increase runoff residence time on the low-lying land immediately west of Slatteries Drain. This aims to promote acid containment via elevated groundwater levels and increase the coverage of water tolerant vegetation. Figure ES-13 shows the modifications to the model (beyond those described in Scenario 1) for this scenario, including an additional drain, a weir (invert +0.7 m AHD) and lowered floodplain bathymetry. The aim of this is to redirect low flows onto the floodplain, while still maintaining flood conveyance through Slatteries Drain.

Model Outcomes:

The results of the model indicated the following:

- A 25 ha area would be inundated most of the time, with typical water depths of 0.1 to 0.2 m. This area would only dry during extended droughts. Otherwise changes to mean (shown in Figure ES-14) and maximum floodplain inundation do not change significantly.
- Drainage times after rainfall increase upstream of the new weir structure but remain largely unchanged from Scenario 1 otherwise.
- Advective acid transport would reduce, particularly from the 25 ha of area that is actively re-flooded, and due to the swaling of the drains.
- The incremental improvements (compared to Scenario 1) are largely limited to the 25 ha of reflooded land.

Implementation Considerations (additional to Scenario 1):

In addition to the model results, the following implementation considerations have been identified:

- This drainage option would require the discontinuing to current land management practices on the affected property. This may require land acquisition or landholder compensation.
- ASS management plan would be required.
- Potential ecological changes should be considered.
- Active re-flooding elsewhere on the floodplain (such as off Meerschaum Vale Drain) could be considered depending on the land available.
- Higher groundwater levels in surrounding area.

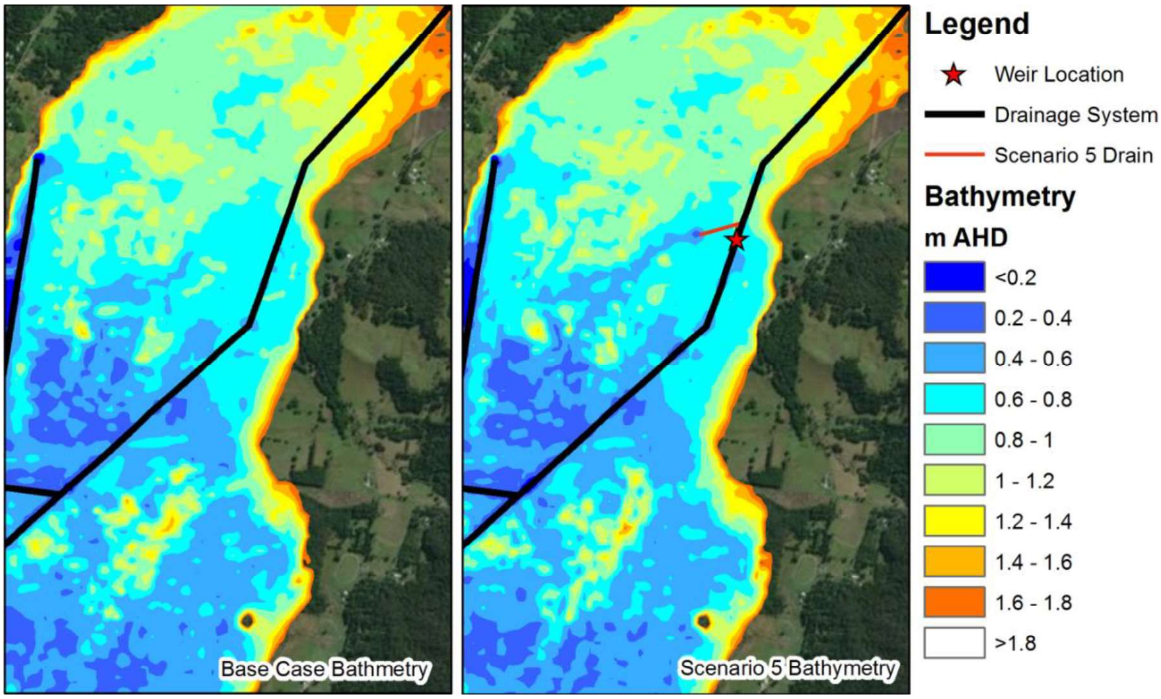


Figure ES-13: Modifications for Scenario 5 (Left – original bathymetry, Right – Scenario 5 bathymetry, with new channel in floodplain)

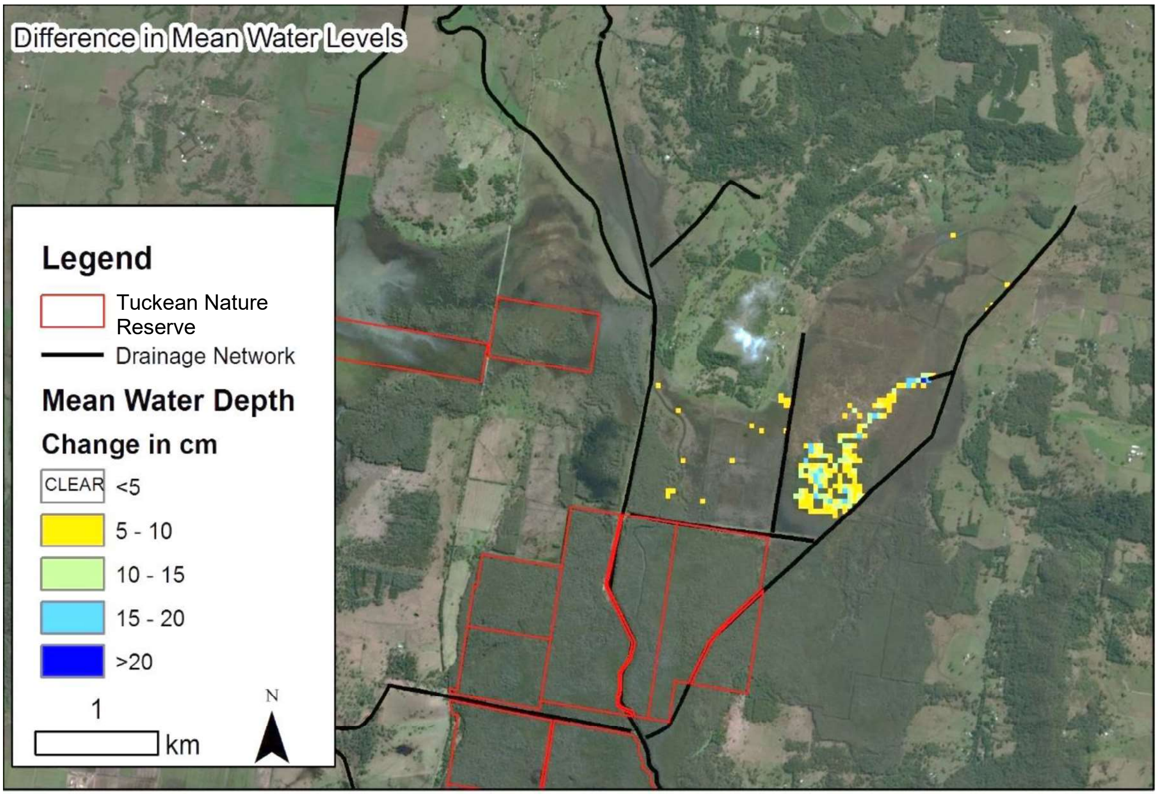


Figure ES-14: Change in mean water levels (compared to Base Case) in Scenario 5

ES.4.6 Scenario 6 – Hinging open the barrage gate and installing upstream floodgate structures

Description:

Scenario 4 considered a scenario where the barrage gates are hinged open, but there are no upstream flood mitigation structures in place to reduce the impact to areas upstream of the Tuckean Nature Reserve. Scenario 6 assesses the impact of installing four (4) new one-way floodgate structures at the edge of the Tuckean Nature Reserve on Stibbards Creek, Tucki Canal, Stony Island Drain and Hendersons Drain (locations shown in Figure ES-15). The aim of this scenario is to improve tidal flushing within the Tuckean Nature Reserve without impacting adjacent landholders

Model Outcomes:

The results of the model indicated the following:

- A large portion of the floodplain becomes inundated during day to day tidal cycles, including almost all the Tuckean Nature Reserve and privately-owned areas south of Stibbards Creek, along Tucki Canal and east of Hendersons Drain, shown in Figure ES-16.
- Floodplain flows continue to allow saltwater intrusion beyond the Tucki and Hendersons gates. Substantial drain levee improvements and bunding would be required to minimise saltwater intrusion.
- Levee improvements would be required along Stibbards Creek (downstream of the new floodgate) to prevent tidal overtopping. Levee improvements are shown in Figure ES-17.
- Saltwater does not flow upstream of the Stibbards Creek gates.

Implementation Considerations:

In addition to the model results, the following implementation considerations have been identified:

- Substantial earthworks would be required in addition to the floodgates structures to improve the drain levee to the south of Meerschaum Vale Drain and south of Stibbards Creek and to create a bund to contain saltwater within the boundaries of the Tuckean Nature Reserve near Tucki Canal.
- Salinity will be high in Stibbards Creek, downstream of the new floodgate structure. Saltwater transport through high hydraulic conductivity sands in this area (and other areas) may have to be managed.
- Large changes in the ecosystems would likely occur on the impacted areas of the floodplain which would require further environmental assessment.

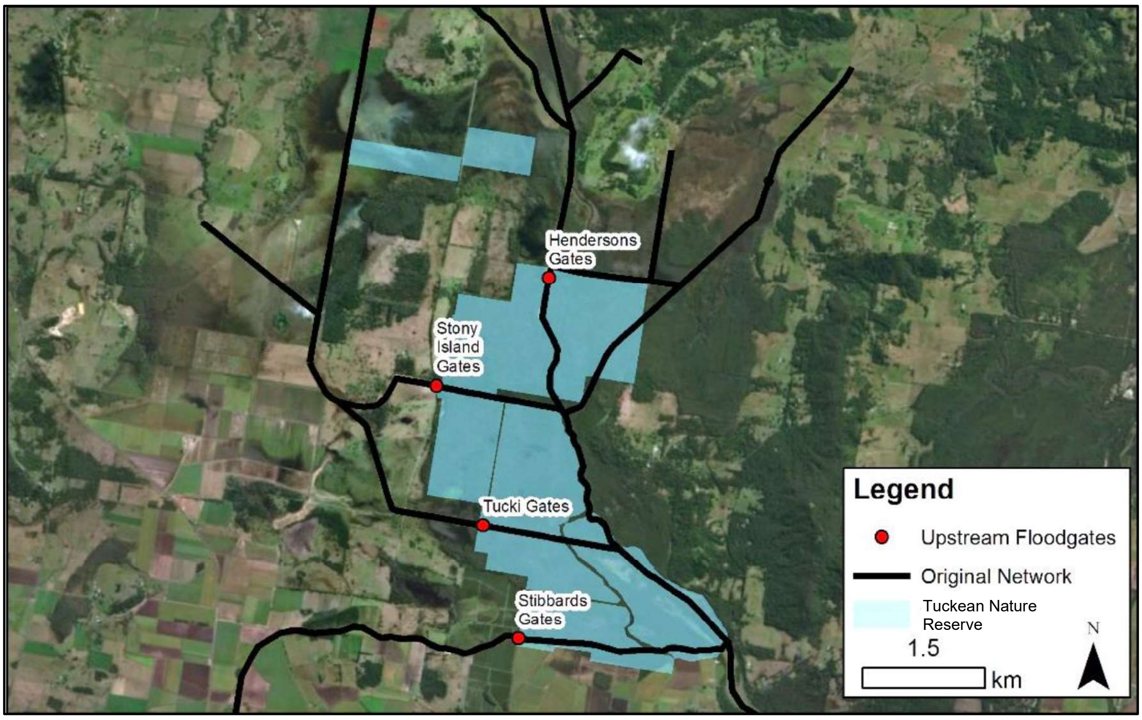


Figure ES-15: Location of new floodgates for Scenario 6

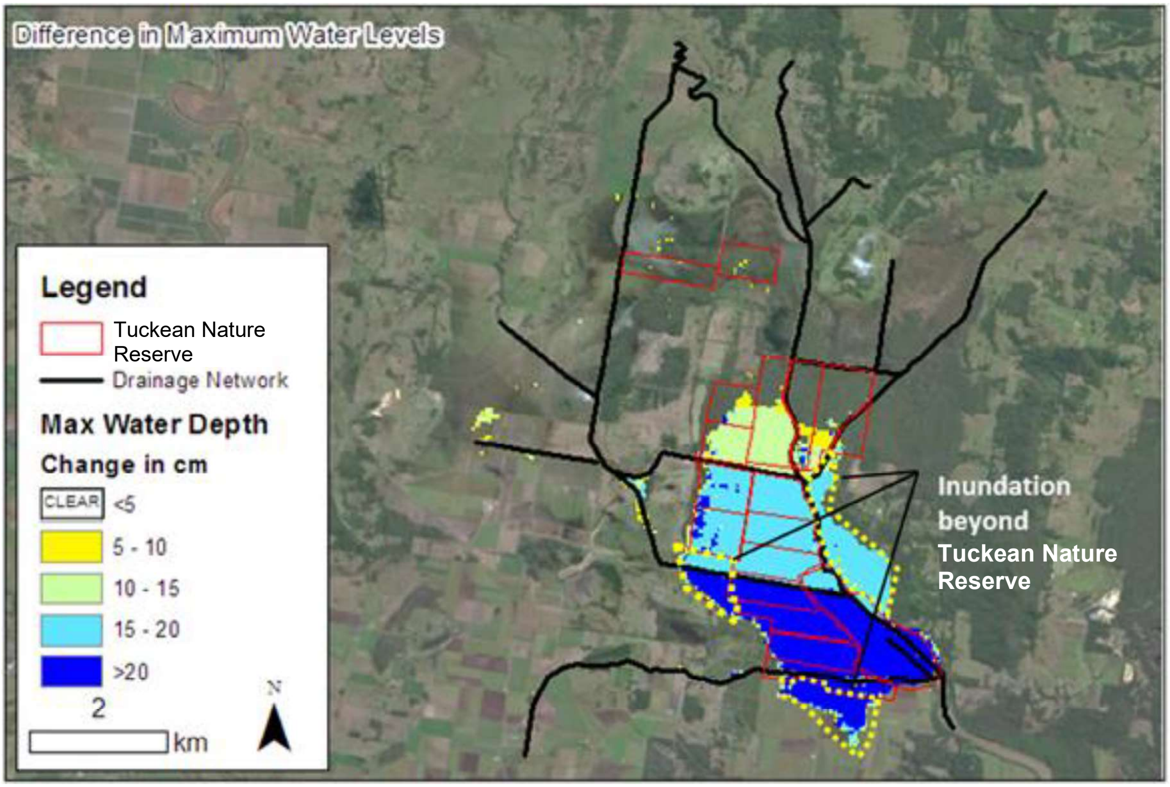


Figure ES-16: Change in maximum inundation for scenario 6, including areas beyond Tuckean Nature Reserve (TNR) area

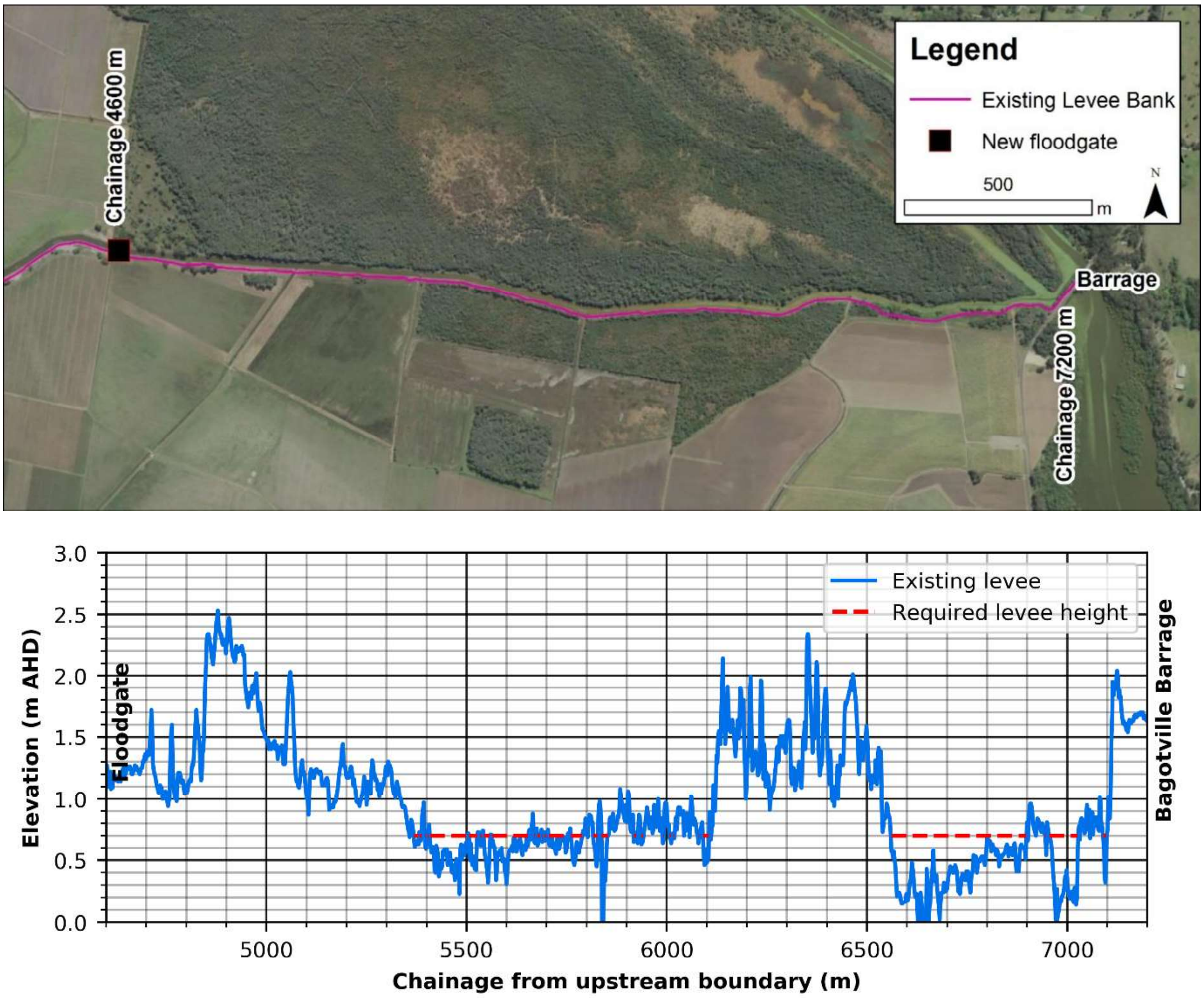


Figure ES-17: Example of levee improvements required along Stibbards Drain