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North Deniliquin Levee Upgrade
Feasibility Report

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1. Introduction

The NSW State Government's Floodplain Management Program and the Flood Prone Land Policy provide partners with local government to manage flood risks and build community resilience. The Flood Prone Land Policy aims to reduce impacts of flooding and flood liability to owners and occupiers of flood prone land. The 2005 Floodplain Development Manual supports the policy and provides framework for Councils to develop and implement floodplain risk management plans.

This Feasibility assessment aims to address part of the final stages of the Flood Prone Land Policy to the North Deniliquin Levee (NDL) upgrade and addresses the recommendations made from the previous WMA Deniliquin Floodplain Risk Management Study.

1.1 Background to the Proposal

Price Merrett Consulting Pty Ltd (PMC) was engaged by the Edward River Council to undertake a feasibility study for the upgrade of the North Deniliquin Levee (NDL) based on the recommendation of the "Deniliquin Floodplain Risk Management Study and Plan, April 2017" by WMA Water. The upgrade is discussed in the WMA report as FM07 and this option has been recommended.

Deniliquin has a long history of flood events with the largest flood being recorded in 1870 which severely devastated the town. This was followed by another two large floods before a makeshift levee was built in 1955, in anticipation of a flood event in the same year. With continual mitigation works and studies performed on the flood nature of the Edward River, the township has remained relatively free of flooding damage since this time. The hydrological record however reflects that for the last 50 years there have been no significant floods which would have tested the impact to the levees' construction and design.

The town's levee system has been constructed into two main levees, one on each side of the Edward River, but the scope of this study will focus on the levee to the north, which has been identified as being overtopped in several locations by a one in one hundred year flood or generally referred to as 1% AEP (Annual Exceedance Probability) or Average Recurrence Interval (ARI) of 100 years.

The NDL is constructed in three sections and covers 5683 metres. The longest part is an earthfill embankment which protects the north side of Deniliquin and is 4698 metres long. The remaining levee includes a 276 metre concrete wall on either side of Davidson Street, a waterfront segment of 102 metre concrete wall and a 607 metre earthfill embankment along the Edward River.

Most of the NDL was originally constructed with less than 0.1m freeboard, due to unacceptable impacts on visual amenity and river access to the community. Therefore the NDL in its current state has limited freeboard which does not provide protection in a 1% AEP event. PMC will assess the various sections of the levee to identify those areas that need raising whilst excluding existing suitable areas. Identifying the best designs in the form of temporary barriers, modification of existing concrete walls and the topping up of the earthen embankment, in order to achieve a uniform level of protection for the Deniliquin Township, will be established.

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1.2 Purpose

Deniliquin has encountered serious flooding on several occasions since its settlement in the mid-19th century. The purpose of this feasibility report is to review and cost options for the levee upgrade and present a final report that includes:

- an assessment of the improvements suggested by the WMA Water Plan (April 2017),
- detailed survey and design and development plans and estimates to facilitate improvements identified,
- survey, design and assessment of locations for a proposed spillway,
- survey and design for improvements to existing North Deniliquin waterfront levee,
- investigation and comparison of existing temporary barrier provisions with other systems, and
- A structural design assessment of any proposed modifications to the existing concrete walls.

The NDL feasibility report will consider options to ensure that the levee can achieve a similar level of protection from flooding through the Edward River floodplain as the South Deniliquin Levee framework.

1.3 Scope

The scope of this feasibility report is to undertake a study of options based upon a preliminary evaluation by WMA Water in its “Edward River at Deniliquin Floodplain Risk Management Plan” (April 2017). The preliminary evaluation has discovered that the North Deniliquin levee, raised on average by 0.4 meters to accomplish a 0.5m freeboard, would ensure the same degree of protection as that in South Deniliquin.

The feasibility report will compare the flood mitigation options against average annual damages to provide an updated benefit/cost analysis. The options will be considered and the recommendations adopted and reviewed by the local Floodplain Risk Management Committee/Council. Communication with all the vital stakeholders in the development of the Feasibility Report will aid council officers to discuss with the local community the development of the thorough feasibility report. A draft report will be created for introduction to the Edward River Council senior staff and be introduced to the Floodplain Risk Management Committee. Once the report is presented and finalised, it will be presented to Council.

1.4 Flood Overview

The flood risk for Deniliquin is characterised by a large slow moving event which is influenced by the flat topography of the area. Flood waters of the Edward River generally have velocities of 1.5 to 2m/s and depths of 8 to 12m in the main channel.

Outside the main channel flow paths are not as defined and velocities around 0.1 to 0.3m/s, and depths are around 1 to 2m in a large event. Generally large flood events spread across the higher, more urbanised areas, and require protection from levees which alleviate the drastic effects of inundation, isolation and possible destruction of residential properties and buildings, flooded roads and risk to life.

Flood heights recorded at the Deniliquin Gauge (Station No: 409003), as taken from the WMA Deniliquin floodplain Risk Management Study and Plan, reflect that increases in flood volumes generally only increase flood heights 0.9m between the 1% AEP and the Probable Maximum Flood (PMF). The result of this is that larger events spread out further across the floodplain rather than just being restricted by the flood channel or levees. WMA report also indicates that the relationship of flood height and flow has changed significantly since the early flood events due to alterations in the catchment. Therefore peak flood flow is a better indicator of the AEP than peak flood height.

FLOOD EVENT	HEIGHT*	FLOW (ML/d)
20% AEP	7.0 m	51,800
10% AEP	8.6 m	86,200
5% AEP	9.4 m	120,200
2% AEP	9.9 m	160,800
1% AEP	**10.1 m (92.5m AHD)**	**190,400**
0.5% AEP	10.2 m	209,500
PMF	11.0 m	561,000
Historic Events		
Oct 1917	9.63 m	189,100
Oct 1993	8.48 m	83,300
Sep 1955	9.02 m	110,900
July 1956	8.99 m	154,100
Nov 1975	9.04 m	119,600
Oct 2016	8.62 m	

*Deniliquin gauge zero = 82.43 AHD

TABLE 1: Flood levels

The nature of flood events at Deniliquin indicates, with relative certainty, that flood peaks do not increase with a significant margin over the 1% AEP with the 0.5% only 100mm higher than the 1%. The determination of adequate levee height and relative freeboard can be measured with an increased level of confidence, when this margin is considered.

1.5 Flood warning time

Table 5 of the WMA report indicates travel times of floods from Hume dam down the Murray River and Edward river systems to Deniliquin is in the order of 10-14 days.

Flood waters in the area are relatively slow to rise, typically 0.3m per day and have a long duration in the order of a couple of weeks. This makes for timely evacuation for residents over a number of days but highlights that Davidson Street remaining open as an evacuation route for North Deniliquin is important. The nature of flooding also is a key factor when the different models for flood mitigation are chosen in the form of temporary barriers, permanent concrete structures and earthen levees.

1.6 Required flood protection

WMA Water, in the Deniliquin Floodplain Risk Management Study and Plan 2017, recommended a 0.5m freeboard for the 1% AEP flood level for the NDL. The background to the assessment of freeboard is discussed in Section 8 of the WMA report. A number of factors were taken into account in determining the proposed freeboard of 0.5m which is detailed in Table 16 of the WMA report.

WMA Freeboard Assessment Results	
Uncertainties in the estimated flood levels	0.15m
Very little post construction settlement of levee is expected as material is a only around 300mm thick and existing bank and bank extension are highly compacted.	
A local surge allowance	0.075m
Wave action of flood waters under windy conditions	0.20m
Climate change and defects in mitigation works also	0.10m
Adopted freeboard	**0.5m**

TABLE 2: Freeboard components

The 1% AEP event is widely used around NSW as the design event for levees as it achieves a balance between the communities expectation of protection against an event that is likely to happen at least once in a lifetime, and not building to an extreme flood event that may not be experienced.

The existing levee system varies in Freeboard and this may be due to revisions in the flood models over time. The existing freeboard is approximately 100mm above the 1% design flood level for a large component of the earth levee section. The concrete wall sections are generally 50-100mm below the 1% AEP design flood level.

The proposed works discussed in WMA report Option FM07, will involve the provision of 500mm freeboard to the 1% design flood event.

The adoption of the 0.5m freeboard would result in North Deniliquin having the same level of protection as South Deniliquin.

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2. Project considerations

2.1 Cultural background

PMC prepared a separate desktop Cultural Heritage Desktop Assessment Report in February 2019 which is summarised below.

The town of Deniliquin is situated in the Deniliquin Local Aboriginal Land Council region which is situated in the Wiradjuri Nation. The region was originally populated by the Wamba Wamba Indigenous people. Their traditional boundaries incorporated the Perrepa Perrepa tribe from the Barham region and joined the lands of the Yorta Yorta nation. The Wamba Wamba Nation straddles the two sides of the Murray River and takes in the sizable townships of Deniliquin, Moulamein and Swan Hill. Additionally being part of the Murray, Wamba Wamba nation further incorporates the significant tributaries of the Edward River and Wakool River (Murray Lower Darling Rivers Indigenous Nations website).

The search on AHIMS, State Heritage Register and State Heritage Inventory, Commonwealth Heritage List and National Heritage List was conducted to identify registered (known) Aboriginal sites or declared Aboriginal places within or adjacent to the existing levee area, as defined by the Office of Environment and Heritage.

The studies have concluded the likelihood of Aboriginal scar trees and mounds potentially being present locally.

Due to the linear nature of the levee, three separate searches were conducted, the east section, the mid-section and the west section. The North Deniliquin levee is based alongside the Edward River with some proportion of it being inside 200m of the water. The general landscape appears to comprise modified trees however, there is additionally the capability that mounds and stone artefacts may be present as the river would have given a focus for camping and occupation for Aboriginal individuals. As a consequence, this landscape characteristic has a great possibility for the existence of Aboriginal sites.

No aboriginal archaeological sites were recorded on these databases within the study area and no other items of Aboriginal heritage significance were identified during the register search.

The NDL alignment has undergone relatively high levels of prior disturbance associated with the construction of the levee, adjacent agriculture and housing developments. Original land clearance and subsequent development have impacted on the entire proposal area. Due to the nature of the proposed works any earth required will be transported from sites not affected by cultural heritage and the next step of the OEH Due Diligence Code of Practice need not be observed.

2.2 Environmental considerations

The flood study of the Edward River at Deniliquin conducted by WMA water, November 2014, has concluded the minimum freeboard review of the levee be raised to 0.5-0.6m designed for the 1% AEP event. This has the effect of works being initiated on the earthfill embankment and the concrete wall which constitute the North Deniliquin Levee.

Aboriginal heritage sites have been documented in the area and past archaeological studies for the region recommend that the most archaeological sensitive regions are generally intact Riverine Red Gum forests along the floodplains of the creeks and rivers along with sand dunes and near water sources.

A Vegetation Assessment has been prepared for the Edward River Shire Council by Dr Steve Hamilton of Hamilton Environmental Services on the vegetation types occurring along the levee alignment. This report is listed in Appendix A.

The identification of these species on and adjacent to the levee has concluded that a number of regrowth indigenous trees less than 10 years of age are present as individuals or patches and will require removal. Clause 50, Division 7 of SEEP (Infrastructure) 2007, development for the purpose of flood mitigation work may be carried out by or on behalf of a public authority without consent on any land. Council are able to undertake works on the levee without consent, and can clear any native vegetation without consent where required to ensure the satisfactory completion of works.

2.3 Policy and Planning considerations

This section considers the statutory planning and legislative framework associated with the levee development.

Legislation

An array of Acts under New South Wales legislation must be considered when development of the levee is undertaken.

The Acts for consideration are:

- Environmental Planning and Assessment Act 1979
- Protection of the Environment Operations Act 1997
- Crown Lands Act 1989
- Land Acquisition Act 1991
- Roads Act 1993
- Local Land Services Act 2013
- National Parks and Wildlife Act 1974
- Heritage Act 1977

The Environmental Planning and Assessment Act 1979 is based on the concept of ecologically sustainable development. Many other Acts relating to the Environment in NSW rely on the EP&A Act to implement their policy. This parent Act of Environmental Planning and Assessment, sets the rules and principals for planning in NSW, and outlines the overreaching framework for planning in NSW.

In relation to flooding, the Act imposes on Council the responsibility to implement the NSW Government's Flood Prone Land Policy through the EP&A Act which makes provision for the Planning Instruments. This legislation introduces the State Environmental Planning Policy (SEPP) and gives the Government scope to make environmental planning instruments, and Local Environmental Planning (LEP).

Environment Planning and Assessment Act 1979	
Part 4 Development assessment and consent	***Part 4 applies to development requiring development consent. However, as the works are permitted without development consent in accordance with Clause 50 of SEPP (Infrastructure) 2007, the provisions of Part 4 of the EP&A Act do not apply, including designated development provisions.***
Part 5 Division 5.1 Environmental impact assessment (except for State significant infrastructure)	***Under Part 5 of the EP&A Act, an EIS would be required if the development was considered to be significant. This development is not considered to be significant due to it being an existing levee. It is not anticipated that the levee upgrade will alter flood impacts and result in significant environment impact. The proposed upgrade works involves clearing of native vegetation on the levee and will not require widening. These works are not considered significant.***

Protection of the Environment Operations Act 1997	
The Department of Environment, Climate Change and Water (DECCW) is responsible for the administration of the Protection of the Environment and Operations Act 1997, which regulates air, noise, land and water pollution.	***At this stage of the levee upgrade project, this act does not apply or is not relevant.***

Crown Lands Act 1989	
The Crown Lands Act 1989 is the legislation for the administration of State lands in NSW. The objects of this Act are to ensure that Crown land is managed for the benefit of the people of New South Wales and in particular to provide for: a) A proper assessment of Crown land, b) The management of Crown land having regard to the principles of Crown land management contained in this Act, c) The proper development and conservation of Crown land having regard to those principles, d) The regulation of the conditions under which Crown land is permitted to be occupied, used, sold, leased, licensed or otherwise dealt with, e) The reservation or dedication of Crown land for public purposes and the management and use of the reserved or dedicated land, and	***The alignment of the existing North Deniliquin Levee is situated across General residential zone, Large Lot residential zone, Primary Production zone, and Crown Lands zone.***

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f) The collection, recording and dissemination of information in relation to Crown land.	
Land Acquisition Act 1991	
(1) This Act applies to the acquisition of land (by agreement or compulsory process) by an authority of the State which is authorised to acquire the land by compulsory process. (2) This Act does not apply to any such acquisition if the land is available for public sale and the land is acquired by agreement.	***At this stage, the act does not apply since the existing levee is not on land to be acquired.***
Roads Act 1993	
The objects of this Act are: (a) to set out the rights of members of the public to pass along public roads, and (b) to set out the rights of persons who own land adjoining a public road to have access to the public road, and (c) to establish the procedures for the opening and closing of a public road, and (d) to provide for the classification of roads, and (e) to provide for the declaration of RMS and other public authorities as roads authorities for both classified and unclassified roads, and (f) to confer certain functions (in particular, the function of carrying out road work) on RMS and on other roads authorities, and (g) to provide for the distribution of the functions conferred by this Act between RMS and other roads authorities, and (h) to regulate the carrying out of various activities on public roads.	Under section 138 of the Roads Act 1993 a person must not "erect a structure or carry out a work in, on or over a public road, or dig up or disturb the surface of a public road" otherwise than with the consent of the appropriate roads authority. ***In the proposed levee upgrade works are likely to impact on public roads to raise the level of the road but not alter alignment. RMS to be consulted.***
Local Land Services Act 2013	
Part 5A Land management (native vegetation)	***At this stage no clearance of native vegetation is required for the upgrade of the levee. If native vegetation removal is required in the upgrade of this levee further investigation of the Act needs to be undertaken.***
National Parks and Wildlife Act 1974	
Part 6 Aboriginal objects and Aboriginal places	***A desktop due diligence study has been undertaken of the existing levee alignment to locate any Aboriginal objects and places. Proposed works will avoid impacting these sites.***
Heritage Act 1977	
	N/A

TABLE 3: Legislation

Statutory Considerations

State Government produces policy for environmental protection under the State Environmental Planning Policy (SEPP) and Environmental Planning Instruments (EPI) as Legislated under the Environmental Planning and Assessment Act 1979.

The State Environmental Planning Policy (SEPP) 2007 is to assist in the effective delivery of public infrastructure throughout the State and deal with matters of State or Regional environmental planning. SEPP aims to identify types of development that are of minimal environmental impact that may be carried out without the need for development consent. This includes clearly defining the environmental assessment and approval process for public infrastructure and services facilities. The effect of a SEPP is that it can override a Local Environment Plan (LEP), and can prohibit certain types of development or can allow development in a certain zone.

The Murray Regional Environmental Plan No.2- Riverine Land (REP) promotes consistency between NSW and Victorian planning in relation to its river and floodplain. Considerations, as listed below, will need to be referenced in any local flood related policy to ensure these controls are implemented. Any works which alter the natural or existing condition or topography of land (such as construction or alteration of levee, channels and mounds) and which are likely to affect the hydrology of the River Murray System require council consent.

The EPI applicable to NDL is the Deniliquin Local Environment Plan (LEP) 2013. The LEP for Deniliquin (Edward River Council) 2013, is a legal document prepared by Council and approved by the State Government to regulate land use and development.

LEP's guide the planning decisions for the Local Shire and considers the zoning areas which the levee bank runs through and natural sensitivity classifications for land, biodiversity and water.

State Environment Planning Policy (Infrastructure) 2007 **SEPP**	
Division 7 Flood mitigation work	Development permitted without consent (1) Development for the purpose of flood mitigation work may be carried out by or on behalf of a public authority without consent on any land. (2) A reference in this clause to development for the purpose of flood mitigation work includes a reference to development for any of the following purposes if the development is in connection with flood mitigation work: (a) construction works, (b) routine maintenance works, (c) environmental management works. ***Under this clause the upgrade of the Deniliquin North levee is permitted without consent.***
Borrow Pit options The objective of State	***According to Clause 50, Division 7 of the Infrastructure SEPP, development for the purpose of <u>flood mitigation work</u> may be carried out by or on behalf of a public authority without***

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Environmental Planning Policy (Infrastructure) 2007, is to assist in the effective delivery of public infrastructure throughout the State by achieving a number of aims. This includes clearly defining the environmental assessment and approval process for public infrastructure and services facilities.	***consent on any land. This includes development for any of the following purposes if the development is in connection with flood mitigation work:*** ***(a) construction works,*** ***(b) routine maintenance works, and*** ***(c) environmental management works.***
According to Clause 5 of SEPP (Infrastructure) 2007	If development for a particular purpose that may be carried out without consent includes construction works, the following works or activities are (subject to and without limiting that provision) taken to be construction works if they are carried out for that purpose: (a) accessways, (b) temporary construction yards, (c) temporary lay-down areas for materials or equipment, (d) temporary structures, (e) conduct investigations, (f) clearing of vegetation (including any necessary cutting, lopping, ringbarking or removal of trees) and associated rectification and landscaping, (g) demolition, (h) relocation or removal of infrastructure, and (i) extraction of extractive materials at the construction site solely for the purpose of the construction. ***As such, the proposed extraction of material (borrow activities or extraction of materials at the construction site) for the levee upgrades works are permitted without consent as part of the works.***
Local Environmental Plan 2013 Edward River Council (Deniliquin) LEP	
Part 2 – Permitted or prohibited Development Land Use Under this LEP the existing levee bank alignment traverses a number of land use zones.	
Primary Production (RU1)	***Flood mitigation works – permitted with consent***
General Residential (R1)	***Flood mitigation works – permitted with consent***
Large Lot Residential (R5)	***Flood mitigation works – permitted with consent***
Enterprise Corridor (B6)	***Flood mitigation works – permitted with consent***
Part 6 – Additional Local Provisions	

Part of the existing levee bank alignment is within the mapped area of terrestrial biodiversity and the Riparian land and water courses area	
6.3 Terrestrial Biodiversity	The objective of this clause is to maintain terrestrial biodiversity by: (a) protecting native fauna and flora, and (b) protecting the ecological processes necessary for their continued existence, and (c) encouraging the conservation and recovery of native fauna and flora and their habitats. Before determining a development application for development on land to which this clause applies, the consent authority must consider: (a) whether the development is likely to have: (i) any adverse impact on the condition, ecological value and significance of the fauna and flora on the land, and (ii) any adverse impact on the importance of the vegetation on the land to the habitat and survival of native fauna, and (iii) any potential to fragment, disturb or diminish the biodiversity structure, function and composition of the land, and (iv) any adverse impact on the habitat elements providing connectivity on the land, and (b) any appropriate measures proposed to avoid, minimize or mitigate the impacts of the development. ***The upgrade of the Deniliquin North levee over the current footprint minimises the impact to terrestrial biodiversity. A construction management plan will ensure that any areas of high conservation significance are protected during works.***
Murray Regional Environment Plan No:2 –Riverine Land	Consult with DWR, MDBC and councils Floodplain management committee must consider the following aspects for approval: a) Access(to the waterway) b) Bank Disturbance c) Flooding d) Land Degradation e) Landscape f) River related uses g) Water Quality
Flood Planning Levels Policy	Edward River Council Town Planning 5.9 Suitability of freeboard

TABLE 4: Statutory Considerations

Summary of planning considerations

Determination of the appropriate assessment and approval pathway requires consideration of local government and state planning instruments.

The ISEPP provides clear definition of environmental assessment and approval process for public infrastructure and service facilities.

Under Division 7 Flood mitigation works, Clause 50 of the ISEPP states that development for the purpose flood mitigation work may be carried out by or on behalf of a public authority without consent on any land. This work would be carried on behalf of council; therefore levee upgrade work may proceed on the existing alignment without the need to obtain development consent.

2.4 Land use

The majority of the area is classed as *Primary Production,* with large sections of *General Industrial* and *Large Lot Residential* also outside the town centre. On the North side of the river, the Davidson Street area remains classed as *1(a) General Rural* and *2(urban*), while north of Brick Kiln Creek there is an area of *General Residential* centred along the Cobb Highway. Adjacent to the urban areas, there are large areas of *National Parks and Nature Reserves, Private Recreation and Public Recreation.*

Flood risk in the area relates to the inundation of property, roads and infrastructure, and evacuation restraints in different areas. Inundation in frequent floods (e.g. 10% AEP) is relatively minor but in larger events (5% and 2%AEP), widespread flooding of Northern Deniliquin results in evacuation and the floodplain can have a width of several kilometres.

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2.5 Zoning and planning overlays

The arrangement of the existing NDL is positioned across three land zonings being:
• General residential (R1)
• Large Lot residential (R5)
• Primary Production (RU1)

According to the Draft Deniliquin Rural Residential Land Use Strategy completed by GHD in April 2019, land within the floodway is the most constrained, however flood liable land presents a general restriction to development. An area along the Riverina Highway and Quarry Street has been proposed to be rezoned to RU1 Primary Production. Reasons sighted for this proposal include unsuitable location, low market appeal and future approval associated costs relating to biodiversity location.

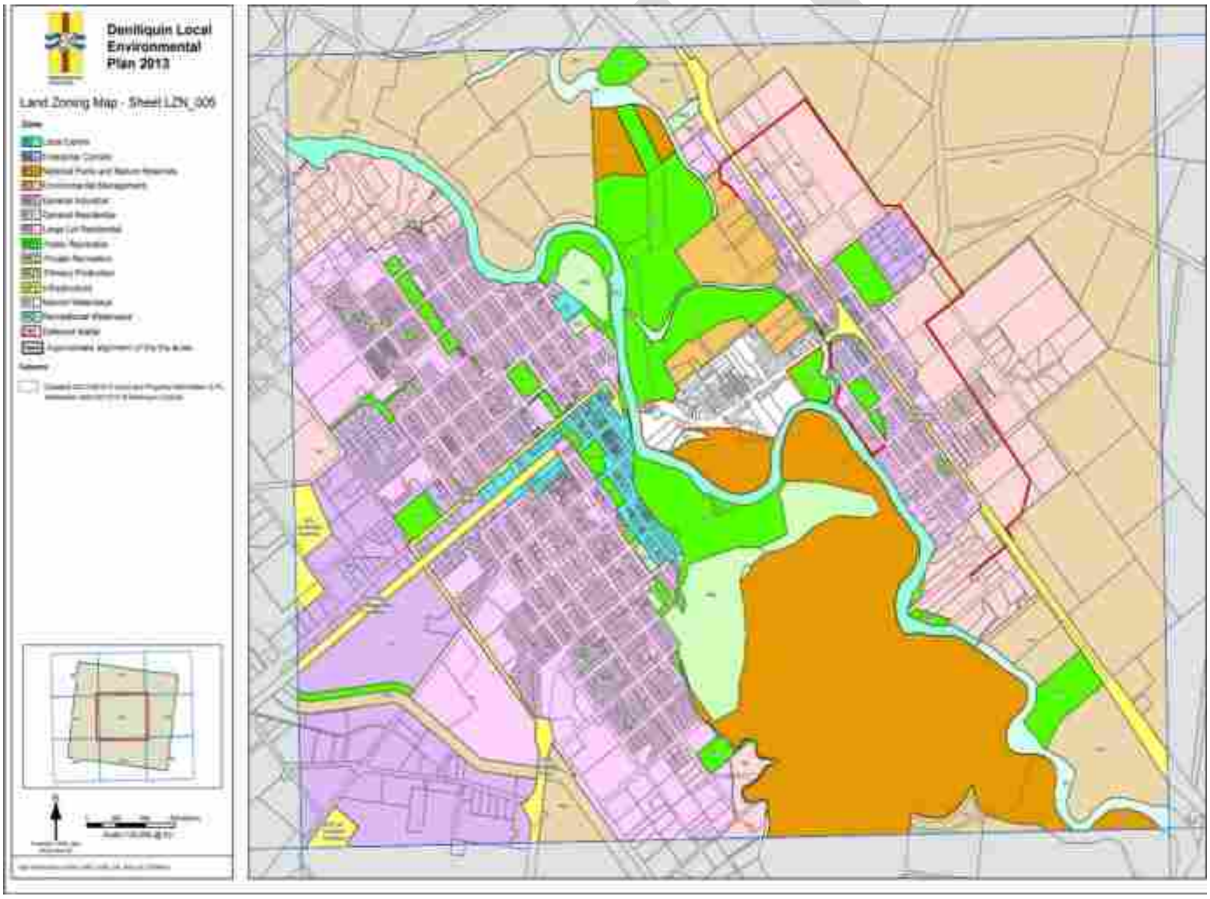

Figure 1: Land zoning map with alignment of levee.
Levee shown as a thick red line

2.6 Biodiversity & riparian landscape

The Deniliquin Township lays on the north and south sides of the Edwards River, typically urbanized and cleared land, made up of the Deniliquin State Forest, natural wetlands and riparian zones. The prevalence of mature red gums is significant along the entire river, along with intermittent sections of natural vegetation upstream and downstream of the town.

The area is home to a large range of native avian, marsupial, and aquatic species, some being endangered. The biodiversity of the area is contributed to by the landscape features of the flood plain consisting of the main river channel, flood runners and oxbow lakes. All of which become inundated during a significant flood event along with the extended flood plain.

The NDL upgrade falls within the Terrestrial biodiversity local provision. The objective of this clause is to maintain terrestrial biodiversity by:

(a) protecting native fauna and flora, and
(b) protecting the ecological processes necessary for their continued existence, and
(c) encouraging the conservation and recovery of native fauna and flora and their habitats.

Due to the already existing levee, the upgrade will not affect the terrestrial biodiversity clause.

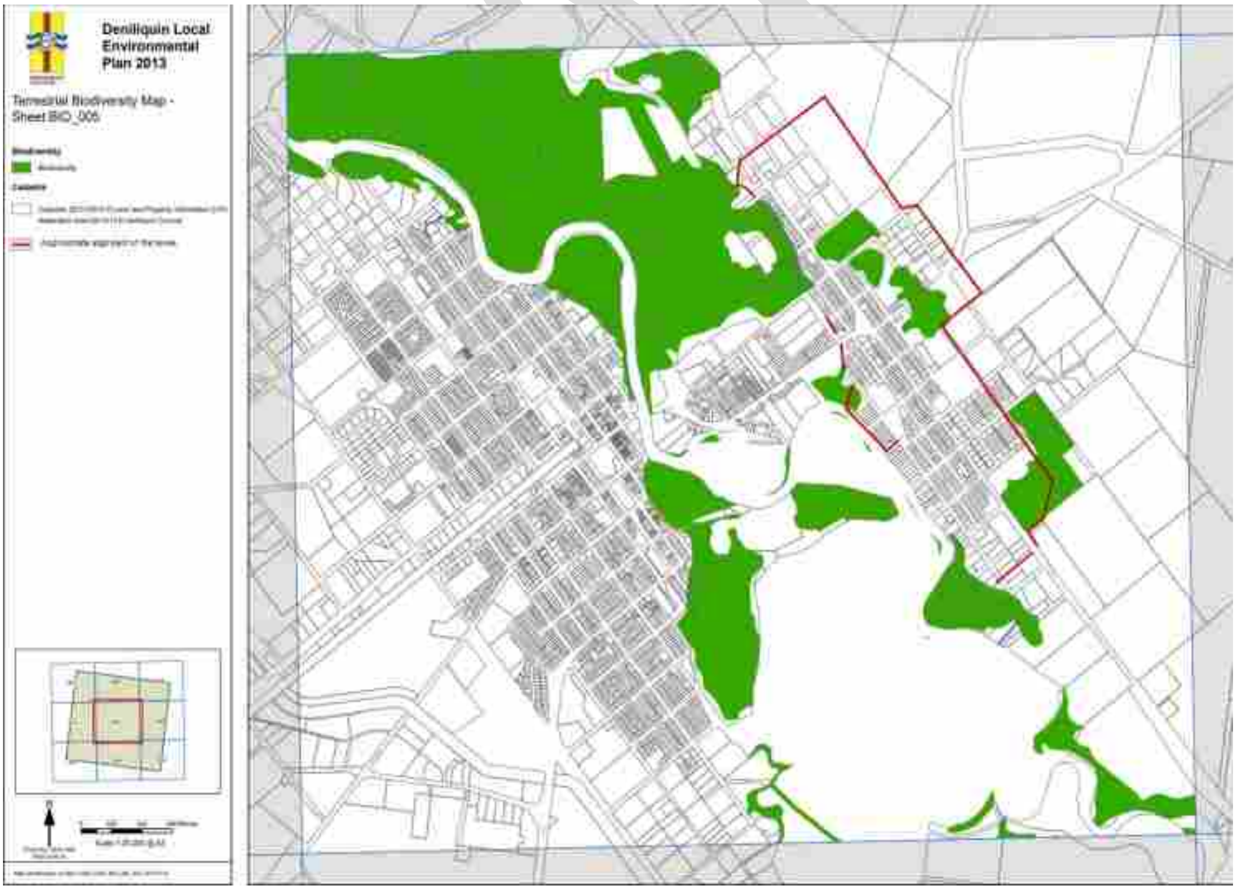

Figure 2: Terrestrial biodiversity local provision map.
Alignment of levee shown as a thick red line

The existing concrete wall affects the riparian land and watercourses. The objective of this clause is to protect and maintain the following:

(a) water quality within watercourses,
(b) the stability of the bed and banks of watercourses,
(c) aquatic and riparian habitats,
(d) ecological processes within watercourses and riparian areas.

However, the upgrade of the NDL would not impact on the riparian and watercourses because the proposed upgrade will only involve works on the existing concrete wall.

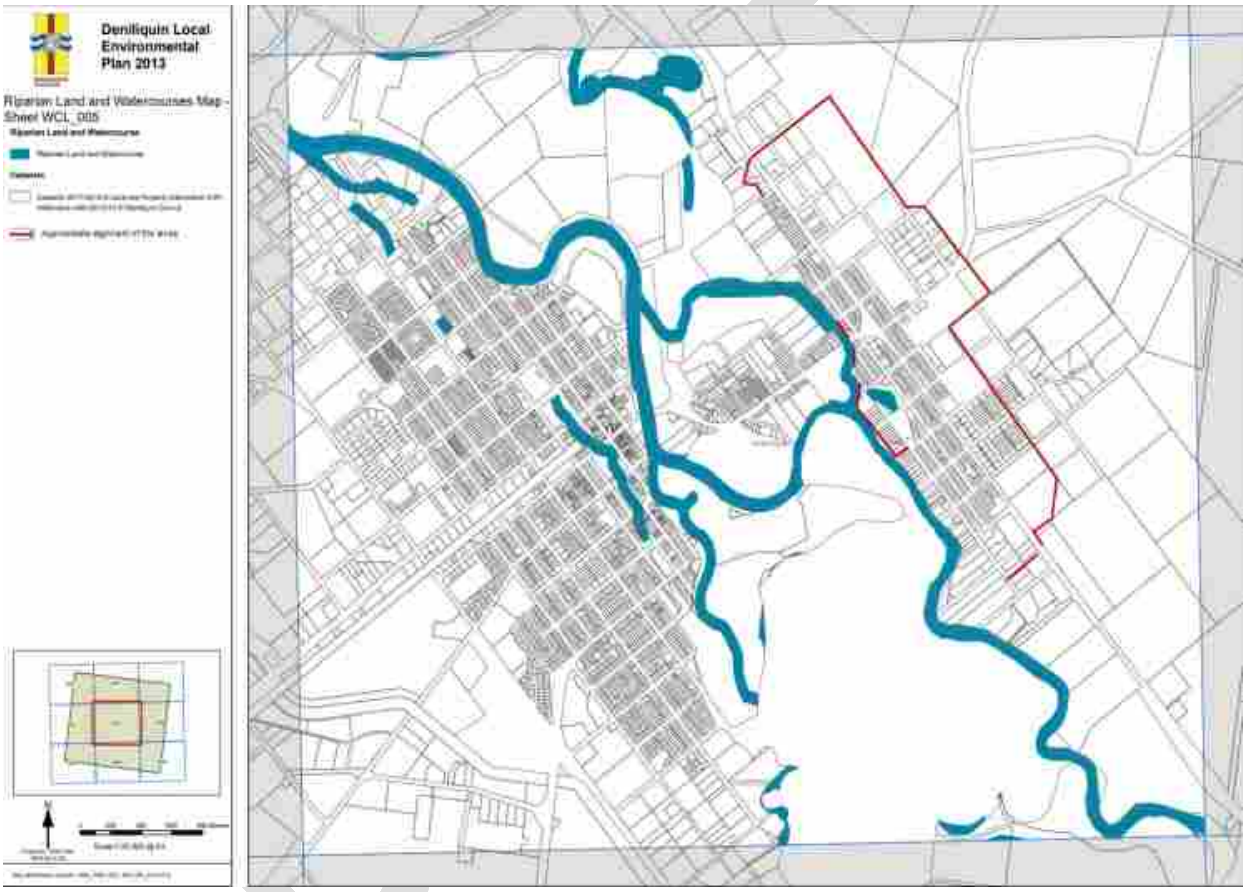

Figure 3: Riparian land and watercourses local provision map.
Alignment of levee shown as a thick red line

2.7 Borrow area options

The new material used in the bulk levee fill should have sufficient clay content to provide permeability for the duration of the flood event. The earthfill material to be used for the levee should consist of fine grained inorganic cohesive soils, free of rocks, organic material and other deleterious material. The clay content of the soil should be sufficient to ensure that when the appropriate amount of water is added, the soil can be molded by hand.

Soil properties and performance in levee construction varies considerably depending on the local environment. It is important that local knowledge in soil behavior be considered when assessing soil suitability. The construction method and design configuration can allow soils which do not meet the guidelines to be used effectively in construction. Ongoing maintenance can also improve the use of materials outside the ideal range.

As a general guide the bulk levee earthfill should ideally have the following parameters:

- Plasticity Index (PI) above 10%
- Grading with at least 25% finer than 0.075 mm and at least 75% finer than 4.75 mm.
- The maximum particle size should be less than 75 mm.
- Linear shrinkage of material within 300mm of the surface to be less than 10% or within the main levee fill of less than 15%

Location of borrow pits should be chosen with care. Their locality can impact on the levee by possibly undermining the stability of the levee during flood events if excavated on the water side, or if on the land side existing permeable layers can be exposed.

Additionally the cost of transport to the levee site should be factored in, as sourcing material from considerable distances can add $10-15/m^3.

Stockpiles of loose material should also be kept to a minimum and sites planned with forethought to reduce the working footprint for the project.

2.8 Visual impact & noise

VISUAL IMPACT

Due to the previous floods experienced in Deniliquin, the proposed levee upgrade will involve raising the NDL to the same level as the South Deniliquin levee to manage the flood risk. The Deniliquin Floodplain Risk Management Study and Plan by WMA Water (April 2017) has proposed an option to elevate the NDL to the 1%AEP and a freeboard of 0.5m, which would result in improving the flood protection. Community concerns need to be addressed with the choice of the proposed Option FM07, and the various consequences of the chosen 0.5m freeboard should be discussed with residents to ameliorate opposition and assist with the restrictive easement issues along the river sections. The recommendations in Option FM07 highlight the use of Temporary flood barriers to ensure continued visual amenity and access to the waterfront.

NOISE

The earthworks, ground disturbances and construction traffic/equipment associated with the project would have a short term elevated noise levels.

The works are expected to generate an elevated volume of traffic during the construction, which would contribute to traffic noise. Construction machinery while in use on site would also generate noise. Predicted construction equipment is likely to include scrappers, bulldozers, rollers and construction vehicles such as trucks.

This would be mitigated by having the works undertaken during daylight hours with no evening or night work and hence no disruption to local residents at this time.

DUST

Dust produced project works will be managed under Edward River Council policy as determined by EPA Guidelines. Sufficient dust suppressant measures will be undertaken to keep any emissions to a minimum.

2.9 Levee design

A typical cross section of an earthen levee is shown in Figure 4. The Guideline describes a 3 to 4m crest width with a 3:1 batter on the water side and a 2:1 batter on the dry side with an impermeable clay core. This is constructed on a well compacted, impermeable foundation. The integrity of an earthen levee is largely maintained by protecting the levee from drying out or cracking. The moisture content of the compacted bank is essentially sealed in by crest capping layer. The width of this layer depends upon the requirement for vehicle access, and in these situations crushed rock or asphalt may be used. Local topsoil and grasses will also provide erosion resistant cover for the batters.

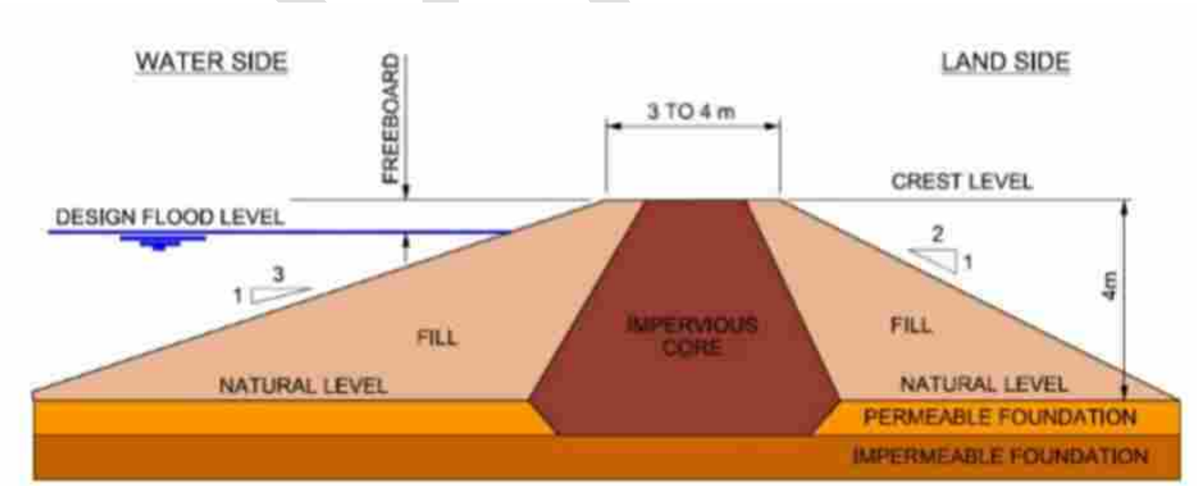

Figure 4- Typical NSW earth embankment levee cross section (from the Levee Owners Guideline)

Geotechnical investigation of the current levee will determine the suitability of the soil types of the in situ structure. Any new works conducted on the levee will be in performed in accordance with recommended specifications relating to soil types and construction techniques.

Deniliquin Levee Bank Owner's Manual produced for Edward River Council contains a management schedule which can be adopted to cover a strategy for the maintenance of any new works performed on the NDL.

The requirement for inspections immediately before a flood event as well as during and after should be conducted on all associated components of the levee system. Annual inspections should be undertaken as part of regular maintenance along with five yearly audits.

Inspections should coverall associated components including drains, floodways and waterways, to ensure there are no problems in these areas, eg;

- Rabbit burrows;
- Trees;
- Scour of banks;
- Build-up of debris;
- Weed growth;
- Vegetation cover.

Record keeping in a designated log book should incorporate any works performed as well as noted areas of concern.

The Owner's Manual also gives details on the maintenance of the different concrete sections of the levee as well as methods for repair. Recommendations are also referred to during a flood event for constant inspections and a major audit to be undertaken once a flood event has receded in order to review the integrity of the various sections of the levee.

2.9.1 Levee Alignment Assessment

WMA Water in their report designated that the current levee alignment is acceptable and best suited for the flood protection required from the 1% AEP with a 0.5m freeboard. WMA Flood modelling indicates the degree of afflux or change in current flood levels in the 1% AEP event is minimal if the levee is raised in its current position.

There are two main sections of levee as discussed previously, being the River section and the eastern earthen levee section.

The existing western River levees are a mixture of earth and retaining walls. The alignment is currently considered to be as close as practical to the existing residences therefore moving a permanent levee further away from the river would be highly contentious. Moving towards the River is also impractical due to the steep level change. Any changes to the permanent levee alignment would impact on residences along the river and be very costly.

The alignment of the eastern levee is not restricted from levels or infrastructure to the same degree to the same degree as the River levee. Other factors are present which make alternative alignments impractical for this section such as:

a) Restrictions in flood plain storage from moving further east
b) Moving east would likely raise flood levels along the river section and eastern sections.
c) Moving off the existing levee alignment would be significantly higher cost in constructing a new levee compared to simply topping up the existing levee.
d) Moving the eastern levee further towards town will impact on R5 zoned land

Therefore upgrading the existing levee on its current alignment is considered the least impact and cost for construction.

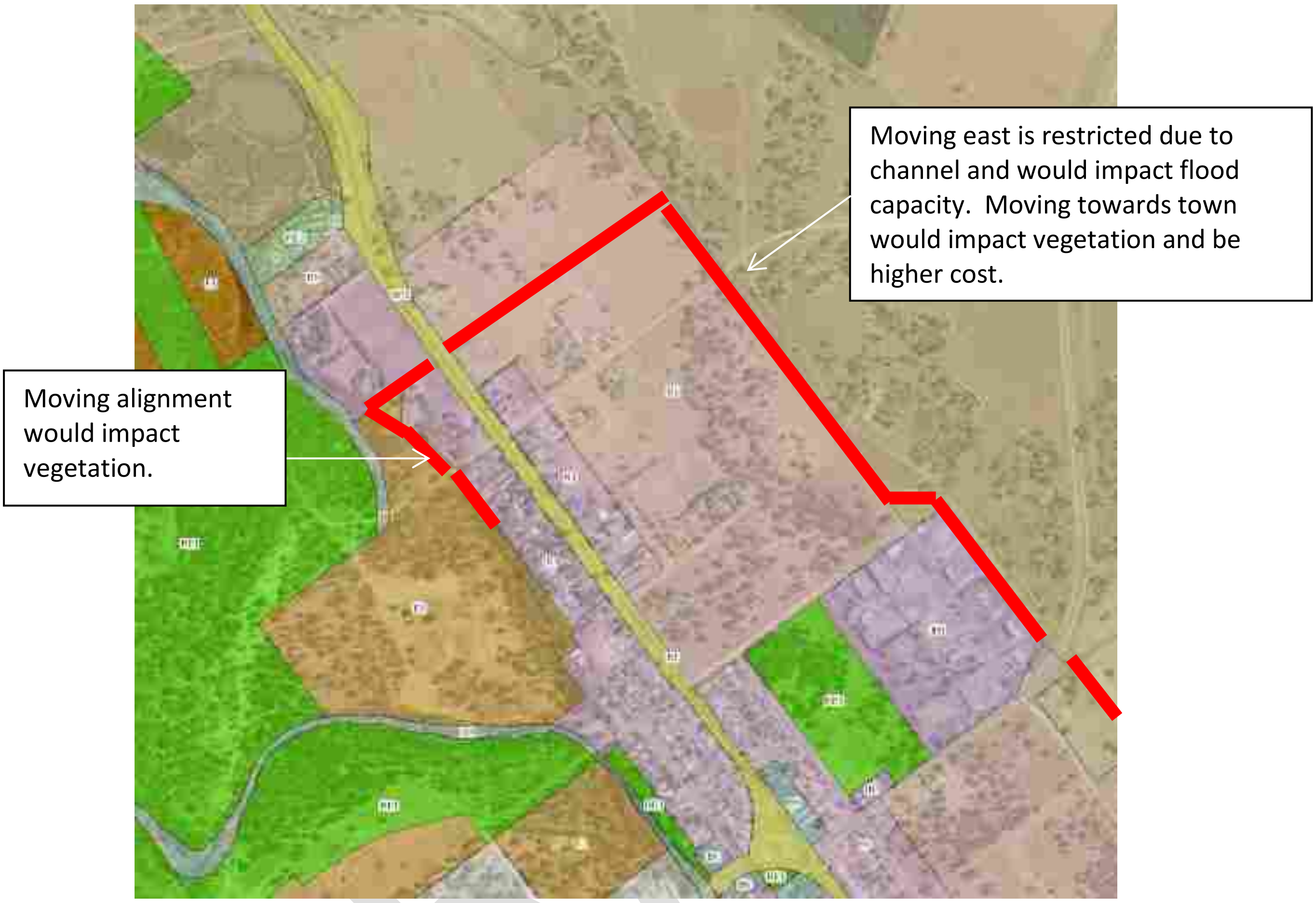

Figure 5: North eastern Levee section with zone overlay.

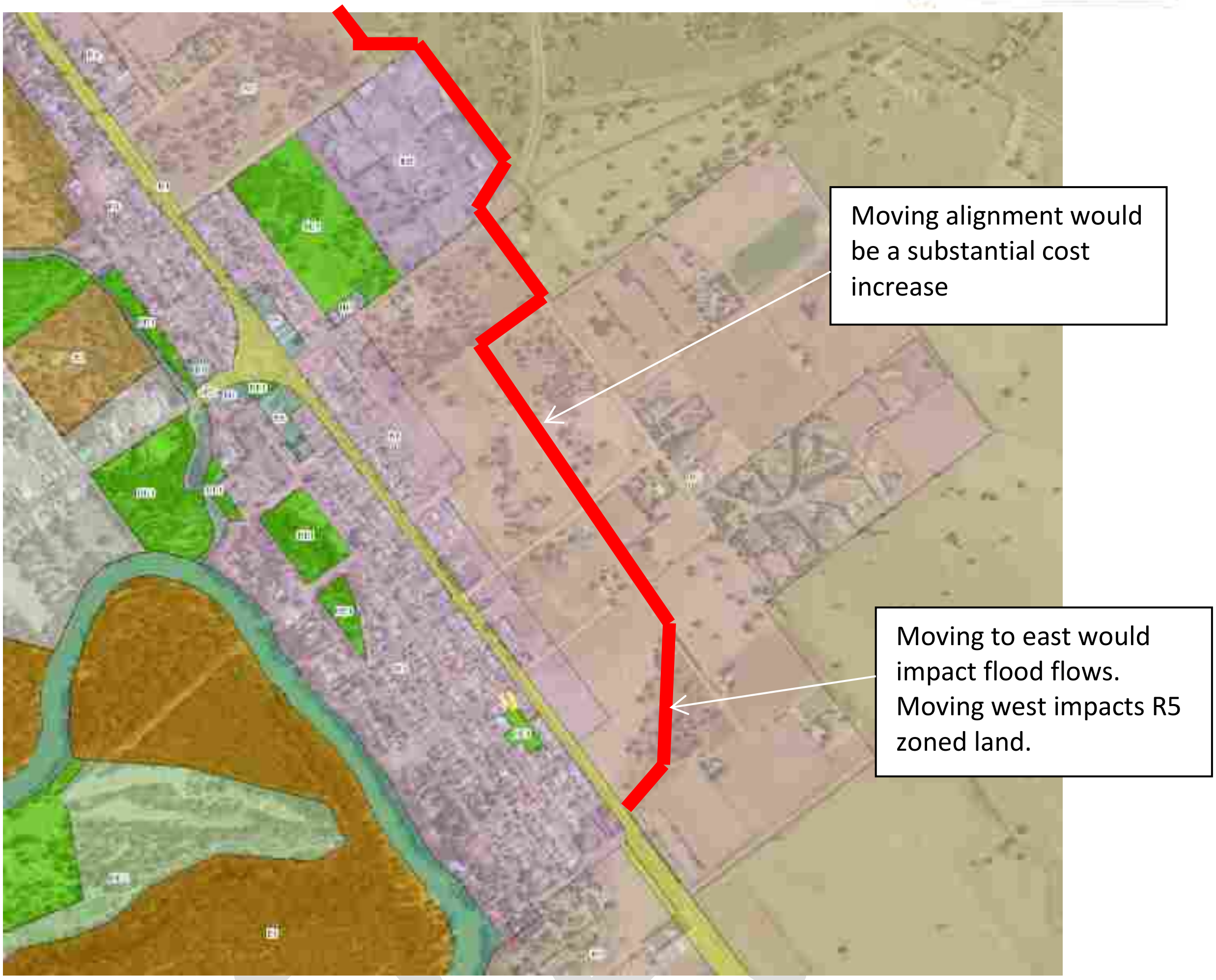

Figure 6: South eastern Levee section with zone overlay.

3. Proposed Works

The NDL system comprises two main types of structural flood protection including an earthen levee on the eastern side and a mix of concrete retaining walls and earth banks on the west or along the Edwards River.

The proposed levee reconstruction is detailed on preliminary design plans prepared by PMC. The typical arrangement of the levee will be a 3.0m gravelled crest with minimum 3:1 dry side batters and 3:1 river side batters. The batter slopes may vary slightly where there are existing trees located near the base of the existing levee to minimise the number of trees removed. There is 0.5m freeboard provided from the estimated 1% flood event to provide for wave action, inaccuracies in modelling and possible bank subsidence. Geotechnical investigation will identify any areas that require more significant structural works and highlight areas where structural integrity is adequate.

East Levee – Design Sections

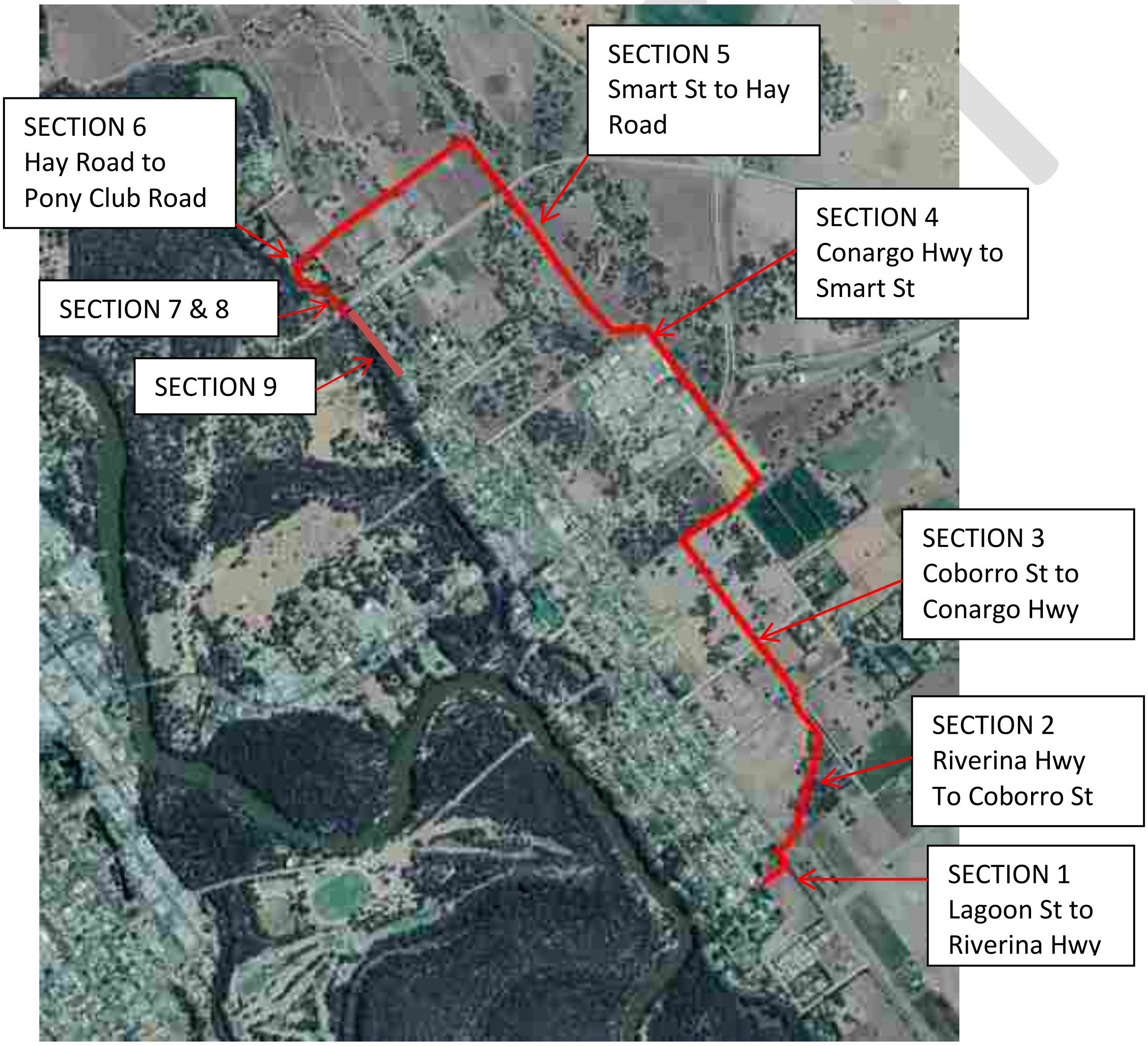

Figure 7: Eastern Levee Sections

Section 1 – Lagoon Street to Riverina Highway

The existing earth levee bank is approximately 1m high, 3.5m crest width and 5:1 batters. The levee needs to be raised around 500mm to achieve design freeboard. Raising the existing bank is the most economical and practical option to achieve the required level of protection.

Figure 8: Section 1 Lagoon Street to Riverina Highway

Figure 9: Section 1 midway looking towards highway

General Works components Section 1	**Quantity**	**Estimate**
Stripping topsoil on existing bank	240 lin. m	$ 2,000
Tine, moisture condition and compact existing bank	240 lin. m	$ 2,000
Supply and install suitable fill material in layers	630 cub.m	$ 15,750
Reinstate topsoil	240 lin. m	$ 2,000
Supply and place gravel over crest	72 cub.m	$ 10,800
Total Works Section 1 -		**$ 32,550**

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Riverina Highway crossing

Due to the available warning time of an approaching flood event, a temporary structure is deemed suitable for this location. The preferred option is to maintain the existing profile through the road reserve and place a temporary bank or structure across the highway reserve prior to a flood event.

The centreline of the highway is approximately 300mm below the 1% flood event. Table drains are approximately 900mm below the 1% level therefore would require filling around 1.6m. The total fill required for the crossing is approximately 310m3 which with suitable construction equipment and good material this is not considered a problem.

A stockpile already exists nearby therefore no additional costs are considered necessary.

Figure 10: Riverina Highway Crossing

Section 2 –Riverina Highway to Coborro Street

The existing earth embankment is approximately 1.2m high with a crest width of 3.3m and batters of 4:1. The bank is approximately at the 1% flood level and would need to be raised 500mm to achieve freeboard. Raising the existing bank is the most economical and practical option to achieve the required level of protection.

This section will have construction constraints due to existing native vegetation adjacent to the toe of the existing bank. Traffic management requirements would increase if vehicles need to gain access via the Riverina Highway. It is likely that this can be mitigated through the main construction access off Coborro Street during works.

Some vegetation regrowth will need to be removed prior to commencing levee works.

Figure 11: Riverina Highway to Coborro Street

General Works components Section 2	Quantity	Estimate
Clearing vegetation, traffic management and fencing		$ 10,000
Stripping topsoil on existing bank	560 lin. m	$ 5,000
Tine, moisture condition and compact existing bank	560 lin. m	$ 5,000
Supply and install suitable fill material in layers	1,365 cub.m	$ 34,125

Reinstate topsoil	560 lin. m	$ 5,000
Supply and place gravel over crest	225 cub.m	$ 33,750
Total Works Section 2 -		**$ 92,875**

Figure 12: Looking North CH 480 Section 2

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Section 3 – Coborro St to Conargo Highway

The section of bank between Coborro Street and the Conargo Highway is made up of raised roads and banks. The levee is 1.5m high at the south and increases to 2m near Conargo Road. The crest width is around 3.5m and is generally 1m above the 1% flood level. The batters are 3:1 both wet and dry sides. Therefore no works are proposed.

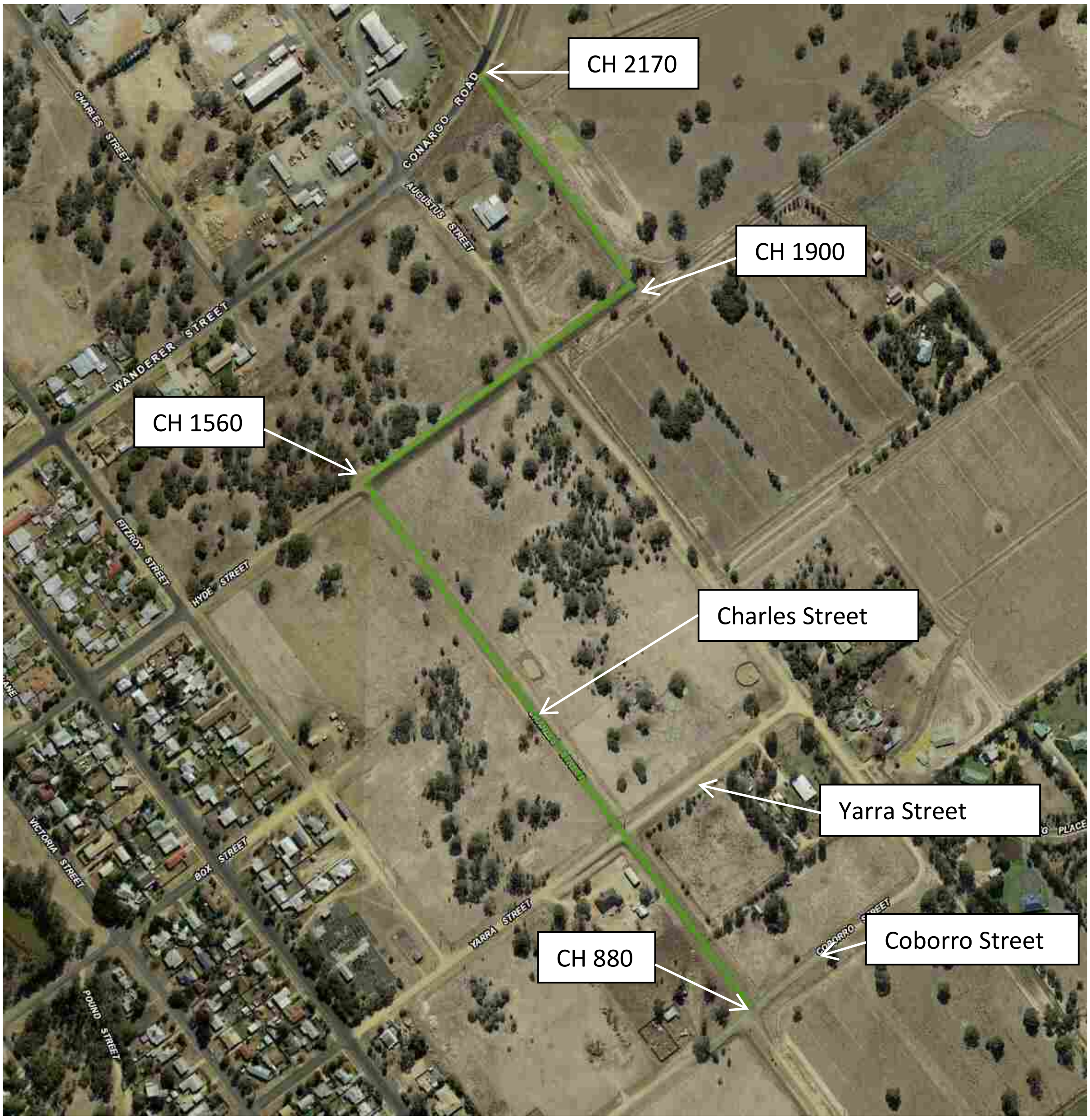

Figure 13: Coborro Street to Conargo Highway

Conargo Highway crossing

Similar to the Riverina Highway crossing, ample warning time is available to prepare for an approaching flood event. Therefore a temporary structure is deemed suitable for this location. The preferred option is to maintain the existing profile through the road reserve and place a temporary bank or structure across the highway reserve prior to a flood event.

Due to the cross fall on the road and large level differences to the sidecut adjacent to the road, temporary structures such as gates are not considered appropriate. Earth fill is considered the most suitable due to the grade changes and height to provide temporary protection.

The crossing point is located on a bend with superelevation so there is one-way crossfall on the road falling towards the north. Figure 12 of the WMA report shows a 0.5m flood level difference across the Highway. The table drain on the south will require 1.65m of fill to meet the 1% flood level so approximately 2.2m to provide 500mm freeboard.

Topsoil would need to be stripped during the temporary filling of the sidecut. The total fill required for the crossing is approximately 380m3 which with suitable construction equipment and good material this is not considered a problem.

A stockpile already exists nearby therefore no additional costs are considered necessary.

Figure 14: Conargo Highway Crossing

Section 4- Conargo Highway to Smart Street

The existing bank from the Conargo Road up to Smart Street runs parallel with Flanagan's Channel. It is around 4m in width and 1m high with batters generally 4:1 on the dry side and 5:1 on the wet side. To achieve 500mm freeboard the bank needs to be raised by approximately 150mm. Raising the bank is considered relatively straight forward due to the large amount of area available particularly on the east side. A minor amount of vegetation regrowth will need to be removed.

At Smart Street, the existing road centreline is 92.30 which is 500mm above the 1% flood level.

No works are proposed for the intersection of the levee and Smart Street.

Figure 15: Conargo Highway to Smart Street

General Works components Section 4	Quantity	Estimate
Clearing vegetation, traffic management and fencing		$ 3,000
Stripping topsoil/gravel on existing bank	1140 lin. m	$ 9,100

Tine, moisture condition and compact existing bank	1140 lin. m	$ 9,100
Supply and install suitable fill material in layers	668 cub.m	$ 16,700
Reinstate topsoil on batters	1140 lin. m	$ 9,000
Supply and place gravel over crest	342 cub.m	$ 51,300
Total Works Section 4 -		**$ 98,200**

Figure 16: Looking South-East along Flanagans Channel Levee from Smart Street

Figure 17: Looking West at Smart Street crossing.

Section 5 – Smart Street to Cobb Highway

The existing bank from Smart Street to the Cobb Highway is 1m high and requires raising by approximately 200mm to achieve freeboard. The existing bank in the section of August Street has a crest width of 3m and the section in April Street the crest narrows slightly to 2.6m. Batters are generally 4:1 on the dry side and 5:1 on the wet side. There is a proposed spillway which has been recommended from the WMA report discussed in FM07.

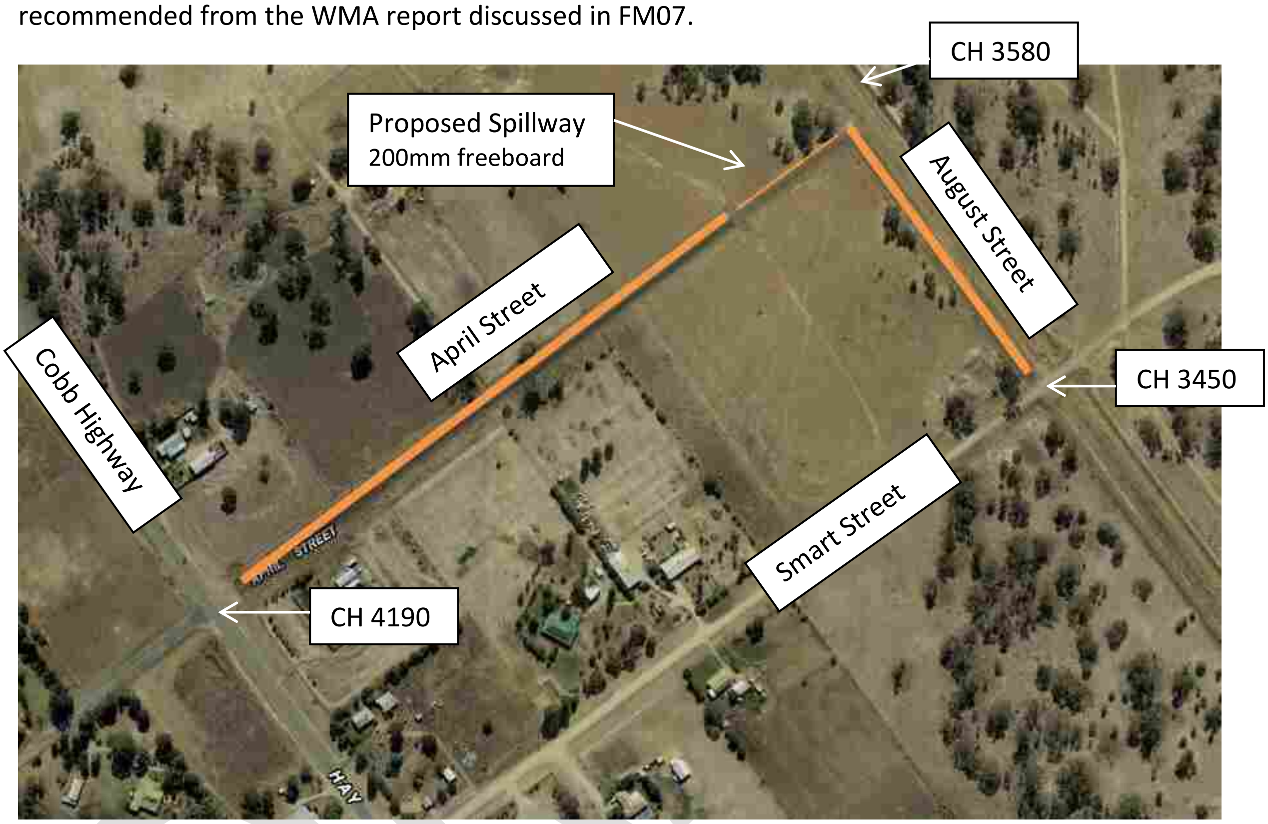

Figure 18: Smart Street to Cobb Highway

Spillway

The spillway is proposed to have 200mm freeboard from the 1% flood therefore the existing bank in this location would need to be lowered 100mm. Grading 200mm off and simply placing the compacted 100mm crushed rock layer would be sufficient to bring up to design level.

Downstream batters of a spillway should be a flat as practical to prevent erosion. Stripped topsoil can be placed on the downstream or property side to flatten the batter.

General Works components - section 5	Quantity	Estimate
Clearing vegetation, traffic management and fencing		$ 4,000

Stripping topsoil on existing bank	820 lin. m	$ 7,000
Tine, moisture condition and compact existing bank	820 lin. m	$ 8,000
Supply and install suitable fill material in layers	600 cub.m	$ 15,000
Reinstate topsoil	820 lin. m	$ 7,000
Supply and place gravel over crest	246 cub.m	$ 45,000
Total Works Section 5		**$ 86,000**

Figure 19: Levee north of Smart Street to be raised 200mm

Figure 20: Levee north of Cobb Highway to be raised 200mm

Cobb Highway to April Street

The centreline of the Cobb Highway at the junction of the levee is 92.16 which is 120mm above the 1% flood level. Temporary earth barrier would be placed across Cobb Highway. A stockpile exists to the south west of the intersection. The edge of seal is currently around 100mm below the 1% AEP level. From the Cobb Highway, April Street is a gravel road which is currently around 8m in width.

Figure 21: Looking west along April Street towards Cobb Highway

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Section 6 – April St

From the Cobb Highway, April Street is a gravel road which is currently around 8m in width. It requires raising approximately 350mm to achieve the design freeboard. The option considered most practical is to raise the road approximately 300mm with a central crown and matching the edges. The width of the gravel road would be maintained with 4% cross fall.

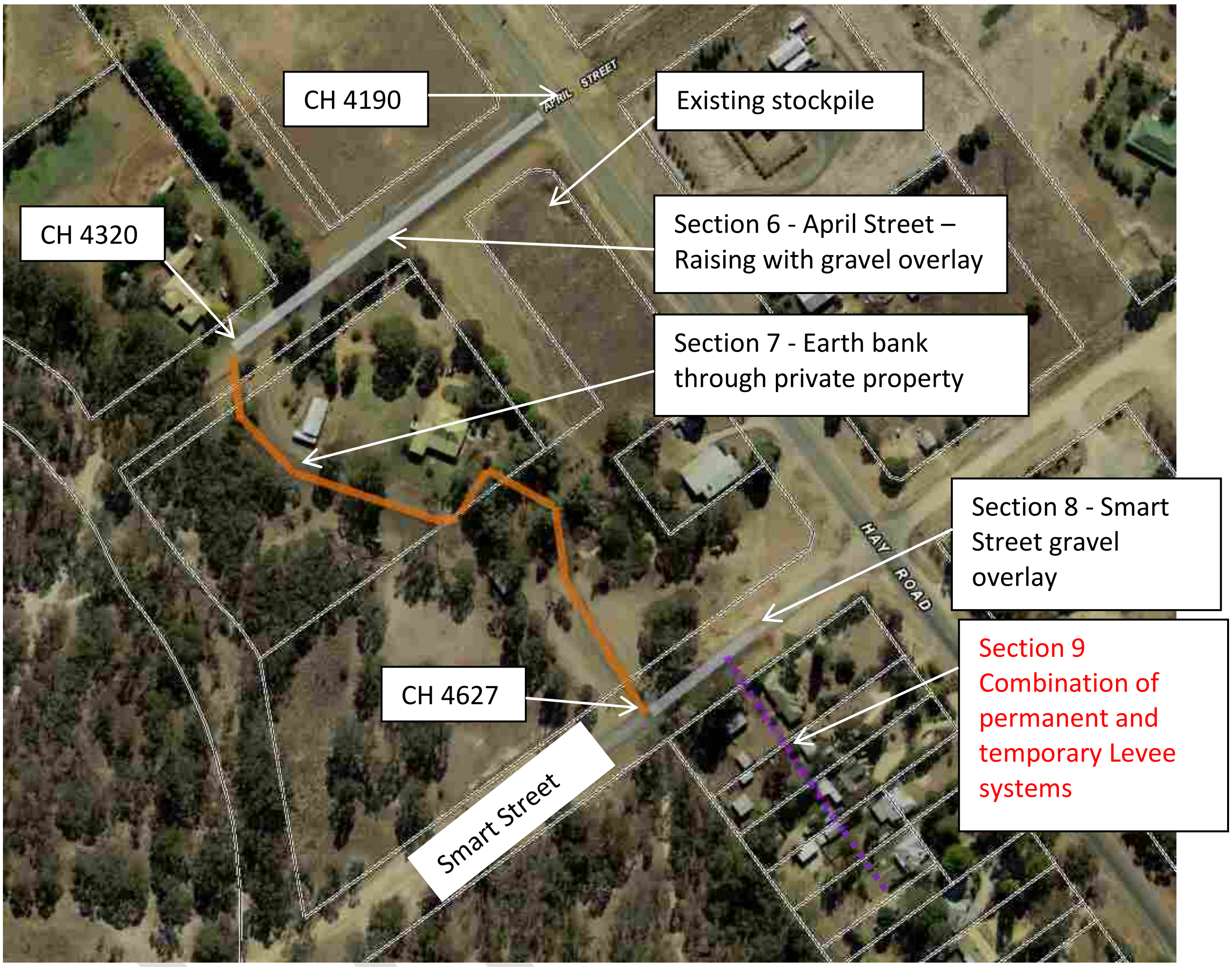

Figure 22: Section 6- April Street upgrade and Section 7 through private property

General Works components - Section 6	Quantity	Estimate
Traffic management		$ 3,000
Tine, moisture condition and compact existing road	144 lin. m 8m wide	$ 8,000
Supply and install 20mm DGB CR material in layers	350 cub.m	$ 52,500
Reinstate shoulders and verge both sides	144 lin. m	$ 5,000
Total Works Section 6		**$ 68,500**

Section 7 April Street to Smart Street through private property

From April Street the levee meanders within private property towards Smart Street. The section from April Street to high ground (CH 4460) the existing crest width is around 3.2m, wet side batters are 4:1 with dry or property side at 6:1. From high ground at CH4560 to Smart Street the crest is 3.5m and the batters are 4:1 both sides. The batters within Smart Street Road are 3:1 and should be flattened as much as practical for road safety aspects.

To achieve freeboard, the levee needs to be raised around 600mm. Location to be discussed with landholder but expect this would generally follow the existing alignment. The land falls away heading towards the river so the levee crest should not be moved any further west from its current position.

Proposed upgrades with earth bank are considered most economical. The batters on the property side will need to be maintained at a sufficient grade for landholder aesthetics and maintenance.

The toe of the bank at CH 4420 may need to be steepened slightly to account for an existing shed.

Figure 23: Entry to private property from April Street.

Figure 24: Levee through No: 156-168 April Street onto Smart Street.

General Works components - Section 7	**Quantity**	**Estimate**
Stripping topsoil and gravel on existing bank	300 lin. m	$ 6,000
Tine, moisture condition and compact existing bank	300 lin. m	$ 3,000
Supply and install suitable fill material in layers	750 cub.m	$ 18,750
Reinstate topsoil	820 lin. m	$ 5,000
Reinstate stockpiled gravel over crest and top up	90 cub.m	$ 10,000
Total Works Section 7		**$ 42,750**

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Section 8 – Smart Street

Where the levee meets Smart Street at CH 4640 (Figure 24), the centreline of the road is 92.20. Refer to Sheet 18 of PMC drawings for details of levels. The 1% flood level is 92.10 so the current road centreline has 100mm freeboard. Smart Street falls away heading west at a grade of 2% so raising the road will need to consider reduction in sight lines for vehicles. Heading east from the levee intersection the road levels raise slightly to 92.4 before falling back towards the highway. At the north side of Smart Street and north of the existing levee, the toe or drain bed is approximately 1.9m below the edge of road. This steep drop off currently at 2.5(H):1(V) would make raising the north side of Smart Street problematic as it nears the levee. The south side of Smart Street is much flatter with a level difference of 600mm at the levee or 8(H):1(V) batter.

The option for Smart Street is to consider raising the southern end of the street to 92.5 which would give a new batter of 5(H):1(V), providing a one way cross fall to the north. From a road safety perspective this batter is still acceptable. Whilst this is only a freeboard of around 250mm the deployment of temporary barriers if necessary would be very easy to achieve additional height of 250mm. This could be either gravel or earth.

General Works components - Section 8	**Quantity**	**Estimate**
Traffic management and setout		$ 5,000
Tine, moisture condition, shaping and boxing existing road	60 lin. m 7m wide	$ 8,000
Supply and install 20mm DGB CR material in layers to achieve one way cross fall, raising south edge of gravel by approximately 300mm. Consider grading existing limestone across to provide an even layer of CR across full width.	32 cub.m	$ 10,000
Reinstate shoulders and verge on south sides	144 lin. m	$ 5,000
Total Works Section 8		**$ 28,000**

Alternative options could involve a retaining type structure on the side south side of Smart Street however a raised barrier close to the road would be a potential road safety issue.

Leaving the road at current levels is another option which would require provision of temporary barriers of approximately 400-500mm high along Smart Street.

Considering raising the road as much as practical to minimise the height of freeboard to achieve from a temporary barrier is going to minimise need for resources during a large flood event.

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Section 9 – No. 438 to 428 Hay Road.

Refer to PMC drawings sheet 19 for details of existing levels. The design levee height including freeboard is reached (92.7m) at the southern boundary of No. 426 Hay Street. The houses between 426 and Smart Street have following floor levels:

- 438 – 92.60
- 436 – 92.22
- 434 – 92.19
- 432 – 92.10
- 430 – 92.33
- 428 - 93.13
- 426 – 93.24

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Ground levels vary along the proposed levee alignment with a low dip through 436 to 430 of approximately 91.6. To achieve the 500mm freeboard a barrier of 1.2m is required. To achieve the full height with a temporary barrier would be costly and more susceptible to failure. Earth barriers of this height would be hindered due to fencing and other infrastructure. It is recommended that portion of the alignment be raised close as practical to the design level including freeboard. This section will be subject to further consultation.

Figure 25: Section 9 - Temporary Levee through properties No. 438 to 428 Hay rd.

Alternatively if a resolution on the levee position cannot be agreed, a temporary barrier around Smart Street and Cobb Highway could be a backup solution. The western edge of bitumen on Cobb Hwy is approximately 300mm below 1% flood level.

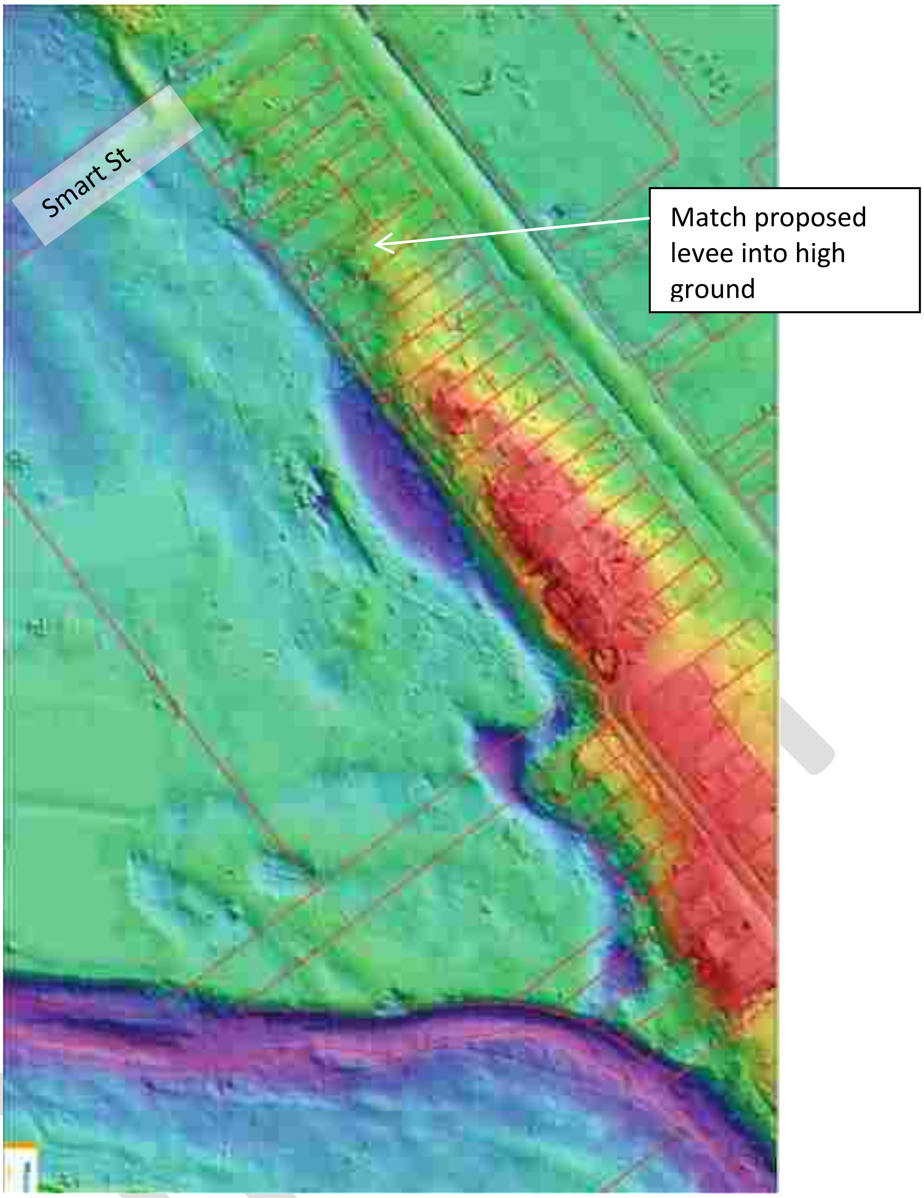

Figure 26: Section 9 – LiDAR showing ridge.

General Works components - Section 9	**Quantity**	**Estimate**
Needs further consultation with owners. following meeting in January levee option will be finalised.		60,000

River Section

The river section flood protection system currently comprises a mixture of banks, high ground and concrete retaining walls.

No. 350 Victoria Street to Davidson Street

Chainage 0 starts approximately 7m North West of the retaining wall behind the motel. To provide 500mm freeboard, the section from the retaining wall running along the boundary of 350 Victoria Street will require temporary protection. The ground level near the end of the retaining wall is around 92.6 which is 100mm above the 1% flood level. Ground levels across No. 340 are around 92.8 which is 300mm freeboard. A breach from the 1% flood at No. 340 is very unlikely as wave action impacts would be negligible.

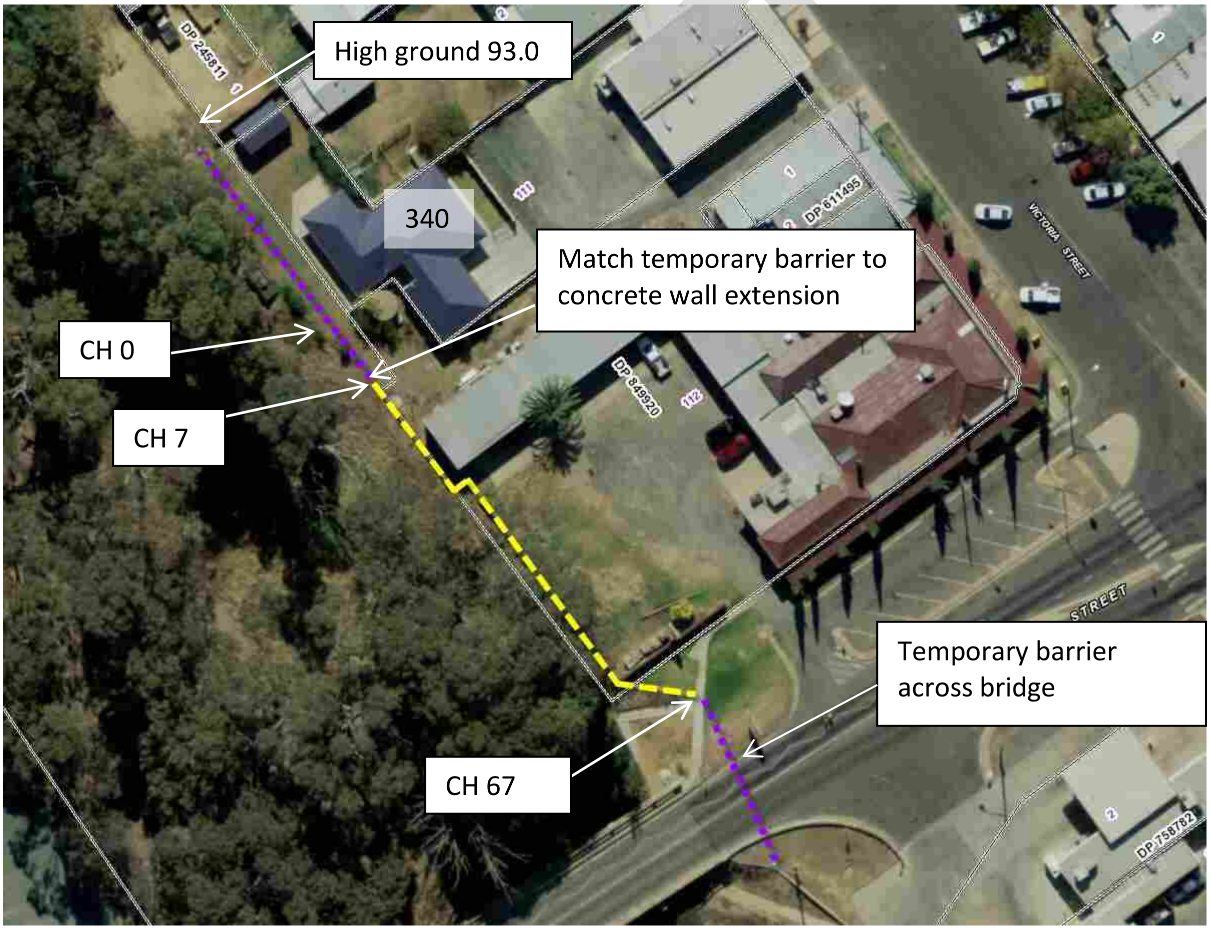

Figure 27: No. 350 Victoria Street to Davidson Street

CH 7 across Motel to Davidson St CH 67 (60m)

The existing concrete wall is approximately 100mm below the 1% flood level. A temporary system to attach onto the existing concrete wall is proposed however a permanent system could be an option if the motel is upgrading the boundary fence. Further discussion with the motel is required.

Davidson Street

The road centreline at the temporary crossing is 150mm above the 1% flood level. Noting that the 0.5% flood event is only 100mm above the 1% level there is relatively low risk of this area being breached. Anticipated wave action is not going to erode the hard surfaces and with relatively slow rising floods the ability to action works at this location is not considered difficult. Therefore to provide desired freeboard, temporary barriers providing 350mm protection are considered adequate. Temporary barriers would be suitable due to the low flood protection height. Temporary Barrier installation, type and storage are discussed in Section 5 of this report. The guardrail on the south side will be a problem with ridged barriers therefore sandbags would be considered more adaptable to this location. The top (or back) of kerb at the crossing point is 92.7 which is 200mm above the 1% flood level and 100mm above the 0.5% flood level. In the event of wave action, due to the flat grades and hard surfaces, the risk of any issues arising is extremely low.

Road modifications or more elaborate barrier systems for protection are not considered necessary in this area due to the road surface already above the 0.5% flood event.

General Works components - North Davidson St	Quantity	Estimate
CH -23 to 7 Temporary barrier rear of No.340 (NOAQ type)	30 lin.m	$ 12,000
CH 7 to 71 Temporary concrete barrier attachment	64 lin. m	$ 34,000
CH 71 – 90 Davidson Street - Temporary barrier (NOAQ across road and sandbags from guardrail)	18 lin.m	$ 8,000
Total		**$ 54,000**

CH 90 (South east side of Davidson St) to CH 147 Conroy St (57m)

The existing concrete wall is approximately 100mm below the 1% design flood level. Temporary system to attach onto the existing concrete wall is proposed to provide freeboard of 500mm.

Figure 28: South East side of Davidson Street to Conroy Street

Figure 29: Realistic impression of sleeper retaining wall on existing wall.

Temporary system such as NOAQ wall or similar would be connected to the end of the wall attachment. This type of system is discussed in Section 7 at length, however it comprises moulded heavy grade plastic sections being joined together in order to act as a barrier.

If there is a high chance of the sleeper retaining walls being subject to water for a prolonged amount of time, it is recommended an impervious barrier be placed on the wet or river side to prevent leakage. The amount of leakage expected through wave action is negligible and would be collected within the town drainage system. Pumps are likely to be deployed in a high river event for the town drainage system which can also account for any seepage issues. Each wall section is 200 high therefore a design 1% flood event would be around half way up the bottom sleeper row. Note that the 0.5% (1:200 AEP) is only another 100mm higher than the 1% event which would be at the top of the bottom row of sleepers.

There are a number of ways to limit seepage through the walls if it is of concern. Rubber seals can be placed between the existing concrete wall and the temporary concrete sleeper barriers. Seals can also be placed in the gaps between the UC section and concrete sleepers. Alternatively a rubber sheet can be placed over the wall prior to the placement of the UC fitting. The rubber sheet will provide a seal between the existing concrete wall and the UC attachment. The sheet can then be folded back up against the temporary barrier to provide a water tight seal.

CH 147 to No. 205 behind No. 328 Davidson Street (58m)

The existing bank or high ground from the end of the concrete wall starts off close to the 1% design flood level at 92.50. Nearing the property driveway to No. 328, the ground rises and just south east of the driveway the high ground reaches 93.0 which provides 500mm freeboard.

A permanent concrete wall could be considered along the existing bank from the end of the existing concrete wall to the property No:328 fence. This is around 33m and it is estimated to cost $1000/m.

A concrete wall on the private property would not be favourable therefore the last 30m would preferably be a temporary barrier system.

Temporary barrier systems such as NOAQ box wall ($400/m) or just sandbags are sufficient for flood depths of 0-0.5m.

General Works components - South Davidson St	**Quantity**	**Estimate**
Temporary concrete barrier attachment CH 90-147	57 lin. m	$ 24,000
Temporary barrier CH 147 to CH 205 (NOAQ type)	58 lin.m	$ 23,200
Total		**$ 57,200**

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CH 410 - Hyde Street near Water Tower to CH 547 (137m)

The existing bank between CH 410 and CH 547 has a 3.6m crest at 92.45. This is about 200mm below the 1% flood level. To achive 500mm freeboard the bank would need to be raised or flood protection measure to provide 700mm additional height. The batters of the existing bank are around 4(H):1(V) on the wet side and slighly flatter on the dry side. The height of the bank is around 2.3m.

Property No. 308 River Street is to the east of the bank and zoned R1 or General Residential. There would be a good probability that this site would be developed in the future. Depending on the scale and detail of the development it should be taken into consideration that changes are likely to occur therefore a levee system should be mindful of this.

Figure 30: Hyde Street to Water Tower

Raising the bank with earth fill is not practical due to the height and impact the bank would have on existing vegetation. Large temporary concrete blocks are another option that could be deployed however due to the space constraints and resources to place the blocks they are not recommended. Therefore due to the limited area to work within, a retaining wall system is proposed.

Characteristics of the design flood to consider at this location include:

- Very low hydraulic head pressure against the wall with the toe of the wall close to the 1% level.
- Potential ground movement due to being on a clay embankment.
- Low floodwater velocity
- Wave action at this location is going to be less compared to other sections of the levee due to the narrow nature of Kiln Creek and presence of trees.
- Amenity needs to be considered.
- Water levels at the peak are likely to only last 2-3 days above gauge of 10.07m. 10.10m is design 1% level.
- Considerations for future development in this area.

Option 1 – Concrete Sleeper and gravel top up.

A concrete sleeper retaining wall system has a number of benefits suited to this particular situation.

- Sleeper retaining walls have ability to hold back water forces as demonstrated at other township locations such as Creswick in Victoria. Risks of seepage issues are very low due to the design water level being at the toe of the wall for a relatively short period of time (1-2days). If flood levels were predicted to be greater than the 1% the increase in height is only marginal. Seepage can be reduced though lapping GCL (geo-synthetic clay liner), rubber sheet or plastic sheeting over the wall and down the base.
- Wave or surge action will not impact the stability of the wall.
- Sleeper retaining wall system copes with potential ground movement due to being on a clay embankment. The gaps between walls and UC can be reduced with rubber seals installed as the walls are installed for flood mitigation.
- Ease of installation of walls for flood mitigation and can be installed in layers as deemed necessary.
- Would allow views as the UC channel posts are at 1.8m spacing.
- Future modifications or changes to the wall position would not be a major cost compared with a permanent wall.

Gravel fill can be placed up to the height of the 1% flood level which would help with any potential seepage. The impact of seepage through wave action or increase in flood level is considered low due to the very low hydraulic pressure and if required a rubber seal could be placed between concrete walls. The concrete sleeper retaining system will cope with future ground movement which is likely on a 2.3m bank constructed with clay. The panels of the levee system could be inserted later therefore having the UC posts ready for installation. A stainless wire could be run through the top of the posts to provide a barrier fence. Whilst not intending to be a building code compliant barrier fence it would serve a purpose. With the panels removed the impact on the visual amenity of the area is minimised. The cost of the concrete sleeper retaining walls are around $450/m for this height.

Figure 31: Looking South CH500 along Hyde St bank

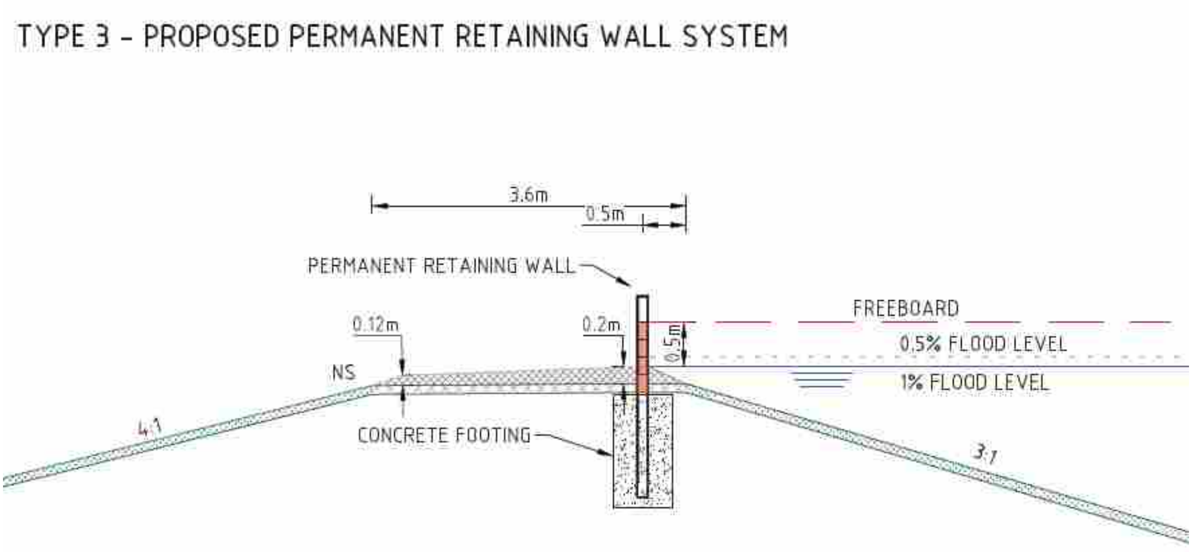


Figure 32: Retaining wall proposal along Hyde Street bank

General Works components - Option 1	Quantity	Estimate
200mm thick DGB gravel (PI 10-15) 137 lin.m	100 cub.m	$ 15,000
Concrete sleeper retaining wall – 1m above existing	137 lin. m	$ 61,600
Total		**$ 76,600**

Option 2 – Solid Concrete Retaining Wall.

The solid concrete retaining wall will be around $1000/m which is double the cost of the sleeper retaining system. The solid retaining walls would have better water retaining ability however as the design flood level is at the base of the proposed wall, this characteristic is not critical.

The solid wall would limit views from any future development on 308 River Street. If modifications were required to the wall with the future development the costs to alter a solid concrete wall will be far greater than a concrete sleeper retaining structure.

Option 3 – **Gravel 200mm and temporary barriers**

A third option could be raising the gravel track surface around 200mm with suitable crushed rock and then deploying temporary barriers in a flood event. The NOAQ barrier system is around $400/m and could be used on the gravel surface with some ground preparation to reduce any potential seepage under the wall.

The cost of this option would be approximately $ 70,000.

With a large drop off behind the bank the temporary barrier system is considered a higher risk. An impact from a floating log could cause a problem for this system if not well monitored. Whilst the provision of barriers is providing the required freeboard to the 1% AEP and likelihood of any impact is low, it is a consideration.

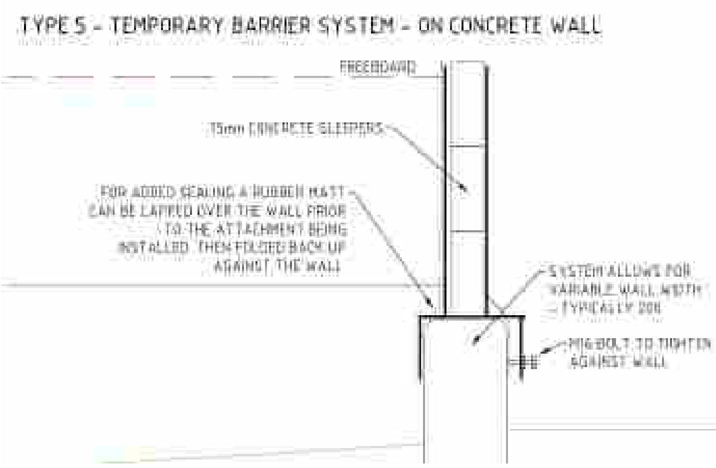
Option 1 is recommended as a compromise between cost, reliability and amenity.

CH 547 to CH 658 (111m)

The existing concrete wall is approximately 150mm below the 1% flood levels. In this section the retaining wall height to the property side is up to 1.6m above surface levels.

Figure 33: No. 308 River Street – existing concrete wall

This section of wall contains a Council pump station which is located on the concrete wall. It is understood this structure would be made redundant in the near future.



To provide freeboard a temporary attachment system is proposed similar to the South Deniliquin Levee. A manufactured frame will slot over the concrete wall and have tightening mechanism to clamp to the wall. Then concrete sleepers can be inserted to provide a solid barrier. As sections of the concrete wall vary in width, having a universal fitting device is critical. This can save time during installation. By not drilling into the concrete, potential impacts to the structural integrity of the wall are minimised.

Figure 34: Photo looking at CH 570 where concrete wall is highest above surface level.

Due to the height of the wall approximately 1.5m above existing ground level near the pump shed, it is recommended that fill be placed on the dry side of the existing retaining wall to assist in the deployment of temporary barriers. The width should be a minimum 3m to provide sufficient access for a service vehicle.

General Works components	Quantity	Estimate
Temporary concrete barrier attachment CH 547-658	111 lin. m	$ 44,400

CH 658 to CH 793 (135m) Box Street

This existing bank crosses properties No. 304 to 290 at close to the 1% flood height. To match the 1% level height, filling of approximately 200mm would be required from 298 to 290 for a length of 80m. Temporary barrier system such as NOAQ box wall ($400/m) or similar would be required to provide the additional 500mm freeboard. Locating the high ground is difficult to determine on visual inspection as it travels through landscaped yards. It is recommended that at boundary fences a connection post or system that is permanently fixed would give an understanding of the required height to achieve 500 freeboard. This would also help define the alignment and provide ability to fix barriers onto.

Figure 35: Box Street looking north – 298 on right

General Works components - CH 658 to 793	Quantity	Estimate
Filling 200mm between No.290 -304	65 m3	$ 6,000
CH 658 – 793 Temporary NOAQ	135 lin. m	$ 54,000
Galvanised or concrete posts fixed at fence boundaries depicting the 1% flood level + 500mm.	3	$ 1,500

Box Street CH 793 to CH 888 (95m)

The concrete wall section crosses properties No:288 to 280. A temporary barrier system attached on top of concrete wall is proposed. To achieve 500mm freeboard the wall would need to be higher by approximately 600mm.

Figure 36: No. 288 to 280 Box Street

General Works components	Quantity	Estimate
Temporary concrete barrier attachment CH 793 - 888	95 lin. m	$ 38,000

CH 888 to CH 936 (48m)

The levee consists of a bank crossing properties No. 278A and 276 and is 150 below the 1% flood level in some sections. Depending on the type of temporary barrier system chosen there may be some minor filling and levelling of the surface to ensure the barrier system reaches 500mm above the flood level. NOAQ box wall ($400/m) claims to provide protection up to 0.5m.

Fixed flood mitigation barriers are not considered appropriate due to the level of access and aesthetics.

Figure 37: No. 278A to 266 River Street

CH 946 to CH 1030 (84m)

This section of existing concrete retaining wall crosses properties No. 272 to 266 River Street. Temporary barrier system on top of concrete wall is considered most economical effective. To achieve 500mm freeboard the wall would need to be higher by approximately 600mm.

Figure 38: Image of wall at 272 River Street

General Works components - CH 888 to 1030	Quantity	Estimate
Temporary barrier rear of 278A and 276 (NOAQ type)	48 lin.m	$ 20,000
Temporary concrete barrier attachment CH 946 to 1030	84 lin. m	$ 33,500
Total		**$ 55,500**

CH 1030 to CH 1120 (90m)

This is the southern section of the levee system and comprises high ground crossing properties No. 262 and 254. Ground levels vary along the alignment due to changes in landscaping. Typically ground levels are at or just above the 1% flood level. To provide additional 500mm flood protection height it is again recommended that temporary barrier systems be deployed. Alternative options are limited due to impacts to aesthetics.

Figure 39: No. 262 to 254 River Street

General Works components No. 262 to 254 River Street	Quantity	Estimate
Fill and landscaping low sections.	20m	$ 8,000
Temporary NOAQ walls or similar CH 1030-1120	90 lin. m	$ 36,000
Galvanised or concrete posts fixed at fence boundaries depicting the 1% flood level + 500mm.	3	$ 1,500

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3.1 Summary of Section Costs

Eastern Levee

SECTION	ESTIMATE
1- 240m Lagoon St to Riverina Hwy	$ 32,550
2- 560m Riverina Hwy to Coborro St.	$ 92,875
3- Coborro St. to Conargo Hwy	0
4- 1140m Conargo Hwy to Smart St.	$ 98,200
5- 820m Smart St. to Cobb Hwy	$ 86,000
6- 144m April St.	$ 68,500
7-300m April St to Smart St.	$ 42,750
8- 60m Smart St.	$ 28,000
9- No. 438 to 428 Hay Rd.	$ 60,000
TOTAL	**$ 508,875**

River Levee System

SECTION	ESTIMATE
1- 60m Motel to Davidson St	$ 54,000
2- 57m Davidson to Conroy St	$ 24,000
3- 58m No. 328 Davidson St	$ 23,200
4- 137m Hyde St to Water Tower	$ 76,600
5- 111m River St	$ 44,400
6- 132m Box St	$ 55,500
7- 95m No. 288 to 280 Box St	$ 38,000
8- 47m No. 278A to 266 River St	$ 20,000
9- 84m No. 272 River St	$ 33,600
10- 90m No. 262 to 254 River St	$ 45,500
TOTAL	**$ 414,800**
OVERALL TOTAL *(with 15% contingency added)*	**$ 1,062,226**

TABLE 4: Section costs

A 15% contingency reserve was added in the calculations in order to allow for risks and uncertainties and is established for the project based on acceptable risk, the degree of uncertainty, and the desired level of confidence for meeting the project budget. Section 4 of this report goes onto examine the economic aspects of the FM07 project.

4. Cost Estimates and Recommendations

Levee options identified under the "Edward River at Deniliquin Floodplain Risk Management Study and Plan" (April 2017) proposed a number of potential scenarios for flood mitigation works around Deniliquin. The option FM07 was assessed by WMA Water and evaluated against the other options. The allocation of a significantly high score identified it as a high priority.

The other recommended measures for North Deniliquin are:

FM07	Levee upgrade to 1% AEP + 0.5m Freeboard
PM01	Revision of FPL/FPA
PM02	Amendments to Planning Policies
PM03	Changes to s149(2) and (5) Certificates
RM01	Flood Emergency Response Management
RM02	Improvement of Flood Warning System
RM03	Evacuation
RM04	Community Flood Awareness

The proposed works would comprise a number of permanent and temporary barriers to provide additional protection to the North Deniliquin area. The options recommended consider a number of factors such as warning time, aesthetics, costs, as well as environmental and social considerations.

A classification of the benefits of flood management intervention is represented below and reference taken from" Assessment of the economic and social benefits of a South Rockhampton Flood Levee". Rolfe et al (2014)[1].

Direct Impacts	Indirect Impacts	Generated Impacts
• Reduced disaster management costs • Reduced residential and flood damage • Reduced maintenance and repair costs • Reduced Public Health and safety risks • Improved social well-being and improved community resilience	• Reduced insurance premiums • Reduced business interruptions and losses • Avoided additional infrastructure • Improving reputation	• Improved property values • Provide urban renewal opportunities • Provide recreation opportunities

TABLE 5: Classification of Benefits by Type

Option FM07 produced by WMA Water has been chosen to provide the most conservative economic outcome for the upgrade project. It has taken into account direct and indirect damages associated with significant flood events. The upgraded levee will offer an enhanced level of protection for the people, property and infrastructure of Deniliquin against 1% AEP with a 0.5m freeboard. This level would raise the North Deniliquin Levee to have the same level of protection as that in South Deniliquin.

4.1 Economic Assessment

A useful tool for comparing different project options against each other is cost benefit analysis (CBA) which factors in a number of aspects in the quantification of flood damages as part of the floodplain risk management process.

Flood damages are defined as either tangible or intangible:

- Intangible damages are often associated with the health and welfare of the citizens. The direct intangible losses in this damage class can include irreversible losses, like loss of human life and cultural heritage. Indirect intangible damages mostly involve an interruption in the citizen's everyday lives, and can span from health issues to annoyances like power and water supply interruptions, to difficulties in getting to work. The impact of these damages is very difficult to quantify but it does not diminish the importance of their impact.
- Tangible damages are more easily quantified and include loss caused from direct contact with flood water, such as damage to buildings and their contents. These can be more clearly specified in monetary terms.

The allocation of actual costs to tangible damages then allows for the generation of a benefit/cost ratio (BCR) which can then be used to judge the relative merits of competing projects.

4.1.1 Cost Benefit Analysis (CBA)

The basic principle of cost benefit analysis indicates whether a project results in an increase of economic welfare, i.e. whether the benefits generated by the project exceeds the costs of it.

According to the Guidelines put out by the NSW Government on cost benefit analysis, this analytical technique clarifies the scope of assessment and will be referenced in this report. The factors calculated as part of the analysis include:

- Benefit Cost ratios (BCR) were calculated by WMA Water in their report and represent the ratio of the present value of total benefits to the present value of total costs.
- Net Present Value (NPV) is the difference between the present value of benefits and the present value of costs. It is an important factor in analysing whether a project adds value.
- In order to compare costs and benefits it is necessary to evaluate the factors over time. This is done by discounting the value of the future costs and benefits to determine their present value.
- A lifespan must also be allocated to the CBA as assets with a long life become more difficult to forecast costs and benefits.

The difference in NPV of base case damages, less the NPV of the damages once the flood levee project has been implemented, is then evaluated over the economic life of the structure, assumed to be 20 years. This is in accordance with NSW Treasury Guidelines, with allowance for a 7% discount rate for option FM07, to the capital costs of the works. The discount rate is specific to the entity that generates the funds, and is related to the rate of return that investment expects.

Ongoing maintenance costs were not considered in the analysis by WMA as they were deemed to be similar in expenditure as currently budgeted by Council, and not eligible for funding. Conversely to this, in PMC's calculations a value for maintenance cost was included in calculations as it was determined to be a relevant factor when values were examined over time.

WMA's Study also undertook the economic assessment across the entire township of Deniliquin, including data as a whole, rather than assessing the individual options against their specific target area it is focusing on. PMC however have considered costings specific to the NDL and Option FM07 and have isolated them in this case in order to give a true reflection of the economic benefit to Deniliquin.

4.1.2 OPTION FM07- 1% AEP + 0.5m Freeboard Upgrade

WMA Water proposed a number of options for mitigation works around Deniliquin. Option FM07 consists of raising the levee to achieve a level of protection at the 1% AEP with an allowance of 0.5m freeboard. To achieve this, the section upstream of Davidson Street would be raised around 0.6m, as would the section near Brick Kiln Creek Bridge. The section near Smart Street would be between 0.3 – 0.7m higher, while the remainder would need an increase of around 0.1m or less. This option also proposes the use of temporary barriers to maintain visual amenity along the waterfront to ameliorate community concern.

PMC have undertaken assessment of the costs of works and the analysis found that the recommended Option FM07 has a strong benefit-cost ratio. Typically, a ratio greater than 1 is preferred in order to justify funding. According to WMA Deniliquin Floodplain Risk Management Study and Plan, and PMC, the following figures have been obtained and are shown in Table 6.

PMC have recalculated the BCR, as shown in the bottom of the table, in terms of the actual cost of works determined for each section of the levee, specific to the works carried out at that location. Figures used were extrapolated from the WMA report and the total of $50,000 was adopted of the average damage per flood affected property for the 1% AEP, in order to determine the BCR.

WMA Economic Assessment taken from Deniliquin Floodplain Risk Management Study and Plan	
Net Present Value of Damages for residential and commercial combined for Deniliquin township (20 year economic life)	$35,300,295
Net Present Value of Damages After Implementation FM07 (20 years)	$32,940,700
Reduction in area AAD (after option FM07 implementation)	$2,359,595
Average damages per flood affected Property	$50,000
Estimated Cost of Works by WMA	$1,855,100
Estimated Benefit Cost Ratio	**1.3**

TABLE 6: Original Economic Assessment from WMA Study

PMC has designed the best options for the different sections of the existing levee and calculated the cost of each section using the latest price estimates. Based on this, the cost of works is significantly less than the estimate proposed by WMA water in their study. This reduction in the cost of works is reflected in the increased benefit cost ratio.

Updated Levee Costings for Deniliquin Township	
Total Cost of works ex GST With 15% contingency *7% discount rate*	$ 1,002,394
Updated Benefit Cost Ratio	**2.3**

TABLE 7: Updated Benefit Cost Ratio using new estimate

WMA Study and Plan for the North Deniliquin Levee included the whole of Deniliquin when it evaluated the benefit/cost ratio and extrapolated figures across the whole levee system, including the North and South of Deniliquin. This report prepared by PMC identifies a cost/benefit ratio specifically for the NDL and relates to premises that are protected in this area.

Assumptions made in evaluating the benefits of the works:

- Average annual damages are considered to be zero in this analysis as all houses are presumed to be protected as the levee does not fail in a 1% AEP.

- The methodology also contains the assumption that events over and above the 1% AEP are not incorporated into the calculations as the exceedance of the levee is total, and a significant number of extra dwellings are incorporated into the flood area.

The Table below gives the benefit cost ratio as calculated by PMC with the updated costings specifically for the North Deniliquin Levee.

Cost Benefit Analysis for North Deniliquin Levee - Option FM07	
Years (economic life)	20
Discount rate	7%
Average damages per flood affected property	$ 80,000
Reduction in Average Annual Damage	$ 272,610
Annual Maintenance costs	$ 1,000
Total Capital cost of works over 20 years	$ 1,002,394
Total Benefits (7%) over 20 years	$ 2,888,034
Benefit Cost Ratio	**2.9**

TABLE 8: Benefit Cost Ratio over 20 years for NDL for 1% AEP

The mitigation option FM07, of raising the North Deniliquin Levee, reflects a realistic and achievable model and the implementation of this option with increased public awareness will generate the most viably effective outcome.

4.1.3 Sensitivity Analysis

The assessment of the net present value of the project is performed under different scenarios and varies the critical assumptions related to the project. This sensitivity testing assesses the possible outcomes of a CBA under alternative scenarios. The assumptions related to FM07 include:

- No failure of the levee under the 1% AEP;
- Accuracy in flood modelling data;
- This scenario assumes hundreds of properties would be inundated in a 1% AEP event, whereas with the upgrade, the number of properties effected in the NDL are reduced to zero, resulting in a significant reduction in damages.

The assumptions lead to the variability in the scenarios and can be summarised below.

Discount rate of 7% is the recommended value. Sensitivity testing for the benefit cost ratios, at 3% and 10% discount rate, at 20 years design life, is shown below.

Sensitivity Test	NPV Benefits	NPV Costs	Benefit Cost Ratio
3% Discount rate	$ 4.06m	$ 1.04m	3.9
7% Discount rate	$ 2.90m	$ 1.00m	2.9
10% Discount rate	$ 2.32m	$ 0.94m	2.4
Capital cost + 20% *7% Discount Rate*	$ 2.88m	$ 1.20m	2.4
Capital cost – 20% *7% Discount Rate*	$ 2.88m	$ 0.84m	3.5

TABLE 9: Sensitivity Analysis for direct benefits

4.1.4 Direct Benefit to Physical Assets

Disaster mitigation works aim to reduce the underlying risk to the community, to a socially acceptable level. In determining a beneficial economic return on investment an examination of the major direct and indirect tangible costs resulting from flooding such as:

- The benefit to physical assets by avoided damages;

- Avoided productivity losses from disruption to services and businesses;
- Better insurance cover for residents;
- Improved property values, is taken into account.

Data taken from the WMA Study and Plan (Figure 16) shows a diagrammatic representation of the number of commercial and residential buildings affected above floor level. It represents the range of flood events from those not flooded right up to the 10%, 5%, 2%, 1%, 0.5% and PMF flood event, extending across Deniliquin and its outskirts, before any mitigation works are carried out.

Figure 40: Design Event for which Property is First Flooded above Floor Level

The distribution of flood affected homes behind the NDL shows the homes that are flooded above floor level in the 1% Annual Exceedance Probability, as indicated in *Figure 36* above and represented by the yellow dots. The specific study area behind the NDL shows that 192 premises are affected by the 1% AEP above floor level. Option FM07 of raising the levee in its various sections to prevent flooding with 0.5m freeboard will protect all these dwellings.

4.1.5 Reduced Business Interruptions and Losses

Interruptions to business operations are a major cost of flood events. Losses can occur through the impact on property and stock, loss of staff wages, inability to trade, and impact on the supply chain.

The probability that businesses will experience a one in one hundred year flood event in a 70 year period is 50%, as calculated by WMA in the Deniliquin Floodplain Risk Management Study and Plan, which potentially leads to the consideration that vulnerable commercial and industrial developments associate Flood Planning Levels (FPL) with the 1% AEP. As a risk management factor of the social aspects and the tangible effects associated with a flood event, it is plausible to limit the exposure of people to floods.

4.1.6 Reduced Insurance Premiums

Flood modelling carried out by WMA Water identified that once the upgrade is implemented, North Deniliquin will not be subject to flood related development controls and the area behind the levee will be excluded from the Flood Planning Area (FPA). This will have beneficial impacts on flood insurance for residential and commercial properties.

Upgrading the NDL is estimated to protect 192 dwellings from flooding above floor level which may reduce the cost of flood insurance premiums. An expected reduction in annual costs is dependent on the size of the premium reduction and the number of households that take out flood insurance.

4.1.7 Improved Property Values

Median home prices in Deniliquin are estimated at $197,500, with a compound growth rate of 1.6%, according to RealEstate.com.au. Whilst improved consumer confidence will take some time to be generated in home buyers, property values can be considered to rise as the area behind the NDL is shown to be protected from future flood events.

Flood mitigation investments are major forward-looking commitments. Crucially, these investments can involve relatively modest upfront expenditures with incremental additions and enhancements into the future. Cost effectiveness in this case is also enhanced when a larger number of people and properties are protected. Similarly, potential payoffs of mitigation are also increased when measures are taken to limit damage from exposure to extreme flood events that are a recurrent feature of the environment, thus producing more constant economic returns.

4.1.8 Reduced Disaster Management Costs

Local government services have estimated the annual average damages for residential and commercial/industrial property to be $3.04M in the Study area. By minimising the impact of flooding across North Deniliquin, local government, State level services and volunteer services whose investment into adverse and risky impacts will be minimised.

4.1.9 Summary of CBA

The results of the CBA contain analysis of the direct benefits the project delivers but not the indirect benefits. The CBA highlights the economic merit and will contribute to effectively reducing the town's ongoing exposure to flood risk.

5. Technical Assessment

The NDL comprises a number of different levee types due to the location and local environment factors. When considering raising the existing levee system to bring it up to a standard similar to the south levee, a number of factors are considered such as:

- Freeboard
- Flood water characteristics (velocity and rate of rise)
- Community expectations
- Maintenance
- Environmental and heritage
- Cost of construction
- Height difference between flood events

5.1 Earth Levee Upgrade

The raising of the earth embankment section is relatively straight forward as the increase ranges from 100-500mm. The existing levee alignment is considered the most economical and practical to achieve the increase in protection.

5.2 Road Crossings

Out of the 8 road crossings there are five along the levee alignment which would require attention in a large flood event.

Levee Chainage	Road	1% Flood	CL level	Drain level	Volume of fill m3)	Comments
CH 270	Riverina Hwy	92.7	92.31	91.68	450	1% level crosses road by 400mm. Should be first crossing to fill. Road would be blocked by floodwaters to south anyway.
CH 1100	Yarra St	92.40	93.56			Sufficient height
CH 1790	August St	92.40	93.44			Sufficient height
CH 2170	Conargo Rd	92.40 sth 91.90 nth	92.38	90.8	370	Hydraulic drop across road
CH 3350	Smart St NE	91.80	92.30			Sufficient height
CH 4190	Cobb Hwy	91.80 wst 92.04 est	92.16	91.3	190	Majority of works in filling drain. Approx. 900mm to 1% level.
CH 4627	Smart St SW	92.20	92.2			Minor improvements 300mm re-sheet of road will achieve close to 400mm FB.
CH 80	Davidson St	92.50	92.67	92.4		Temporary barriers to provide freeboard only as current levels close to 1%

5.3 Temporary Barriers

Temporary barriers are considered a compromise for flood protection typically due to existing constraints which do not allow for a permanent structure. The use of temporary barriers along the river front section has been considered due to the following points:

- existing constraints,
- aesthetics,
- amount of flood warning time available,
- low flood depth from crest to dry side levels
- low height difference for major flood events.

Whilst the length of temporary barrier proposed is quite long, the fact that the majority of the barriers are only in place to provide the additional freeboard above the 1% event, reduces the potential risk of failure to an acceptable level. The other main consideration for the use of the wide use of the temporary barrier system is the small difference (100mm) between the 1% and 0.5% events.

The two types of temporary flood protection that have been proposed are the concrete attachment types and the NOAQ barrier system.

5.4 Temporary Concrete Flood Barrier

The existing concrete walls are 200mm to 250mm wide and the height of the concrete barriers vary in height from surface levels to top of wall on the dry side however generally less than 1m other than at No. 308 where the wall is approximately 1 to 1.5m above the surface level.

The top of the existing concrete wall is typically 100mm lower than the 1% flood level. The 0.5% (1:200 AEP) flood is approximately 100mm above the 1% level.

It is proposed to construct an attachment which sits over the concrete walls as shown on PMC drawings Sheet 3. The attachment involves a galvanised UC section which can clamp onto the existing wall. The clamp can be tightened so any variance in the wall thickness can be managed. There is a minor gap between the 100UC wall and the concrete sleeper which allows for a bend/deflection in the wall of 20degrees. There would be minor amount of seepage through the joins in the sleeper panel therefore it is recommended that a rubber sheet be placed over the wall prior to seating of the attachment. The rubber sheet can then be folded back up against the wall to provide impervious barrier for the full depth.

The depth of water is expected to be only 100mm against the base of the wall in a 1% however the provision of freeboard is required to account for other factors described in section 1.6.

5.4.1 Installation Time

The total length of concrete sleeper retaining wall attachment is 411m over 5 main sites. Installation of the temporary concrete attachments involves the following processes:

Process	Estimated Time
Collection of the wall attachments, rubber matting and concrete sleepers from the storage location. The areas where walls will be dropped off include: • Davidson Street north and south, • end of Hyde Street, • 288-280 via Hyde St, • 272-266 via properties or Coborro St. The equipment would be stored on pallets for ease of loading.	**1 hr** for notification of staff and assembling personnel. **1 hr** for delivery of the equipment to each section.
The rubber matt would be first to be lapped over the wall. It would likely come in 20m rolls of 1.2m width.	**0.5hr** per section to install based on 2 persons.
The galvanised UC attachment is then clamped to the wall over the rubber mat. Expected to be 230 attachments, each will weigh about 10kg. Simply place the attachment over the wall and tighten the bolt.	Based on 2 people working per section the time to attach each wall unit is 1min. Total allowance is **45min per section**.
Installation of the sleepers would be occurring during the placement of the UC attachments to ensure the correct spacing of the attachments. Each sleeper section weighs 77kg therefore would be carried by two people.	Installation of the first row will be most critical. Installation of one row per section is likely to take **1.2hr for two people**.
Finalise the installation of the sleepers.	**2 hrs.** based on 2 people per section
Clamping of the rubber	**0.5hr** per section.
Total time to install the Concrete sleeper system based on 10 people assisting. This system is not complicated to install with basic instructions.	**5 hr and 45min**

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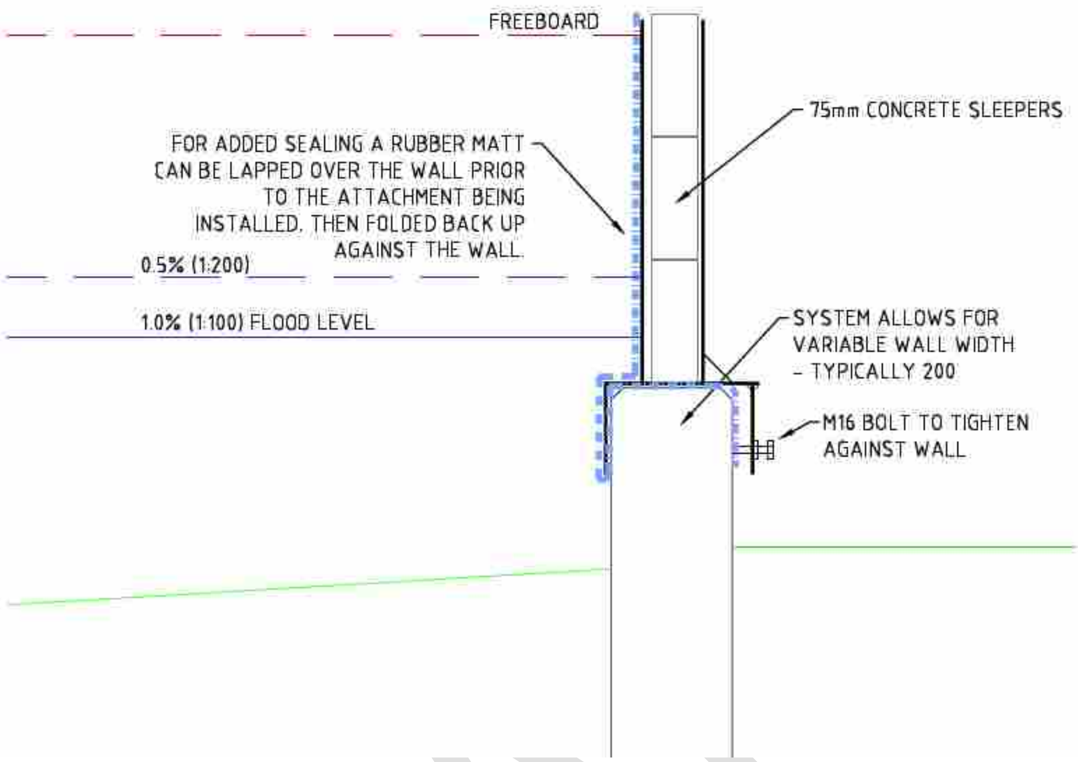
TYPE 5 – TEMPORARY BARRIER SYSTEM – ON CONCRETE WALL



5.5 Temporary Flood Barrier through lawn/yard areas

For the River sections not protected by the concrete wall system the levee is an earthern bank which is generally a grassed bank or simply high ground with relatively flat slopes. The existing levels along these sections of the levee alignment are typically very close to the 1% level. Therefore the depth of protection to provide freeboard is 0.5m. Some isolated locations require topping up to provide an even level for the temporary barrier.

As the exact location of the levee alignment in the lawn areas is difficult to determine it is proposed to install galvanised posts at property boundary lines that intersect the levee. The required flood height plus freeboard would be marked on each post. This will give property owners and Council good reference when the temporary barriers need to be deployed.

There is 551m of temporary barrier to be provided in these sections including section 9 south of Smart Street. It is proposed to use the NOAQ Boxwall due to the extent of temporary barriers and the minimal flood depth needed to provide protection for.

5.5.1 Installation Time

Process	Estimated Time
Collection of the NOAQ wall units from the storage location. 26 units (covering 23m) fit on a standard pallet. Therefore approximately 16 pallets would need to be shifted from storage. The areas where walls will be dropped off include: • North of Davidson Street behind No.340 (30m) • Davidson Street crossing (12m) • Adjacent Conroy Street (58m) • Properties 290-304 near Box Street (135m) • Properties 276+278A (48m) • Properties 254+262 (90m) • Section 9 properties south of Smart Street (178m)	Delivery of the units can occur in conjunction with the transporting of the concrete sleeper barrier system. **1 hr** can be allowed to transport the stacks of units to each site. Depending on equipment availability, the units can be loaded onto trailers or utes and driven to site where they are unloaded individually as the individual units only weigh 6 kg.
Placing the units is relatively straight forward however some time should be allowed to ensure the section is as flat as possible and grass also mowed to minimise any possible seepage. Equipment may include a bob cat if surface is very undulating.	**1.0 hr** should be allowed to ensure the finished surface of each section is adequate.
As the units snap together once they are at site the process of connecting is very fast. The manufacture indicates 200 linear m of wall can be installed in 1 hr with 2 people. The	As it is likely that 10 people would be available to assist in the connection of the walls, the 7 sites should only take **2.0 hr** to assemble.

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installation can again be carried out by volunteers instructed by council representatives.	
Total time to install the NOAQ system based on 10 people assisting Council staff.	**4 hr**

Figure 41: NOAQ Boxwall

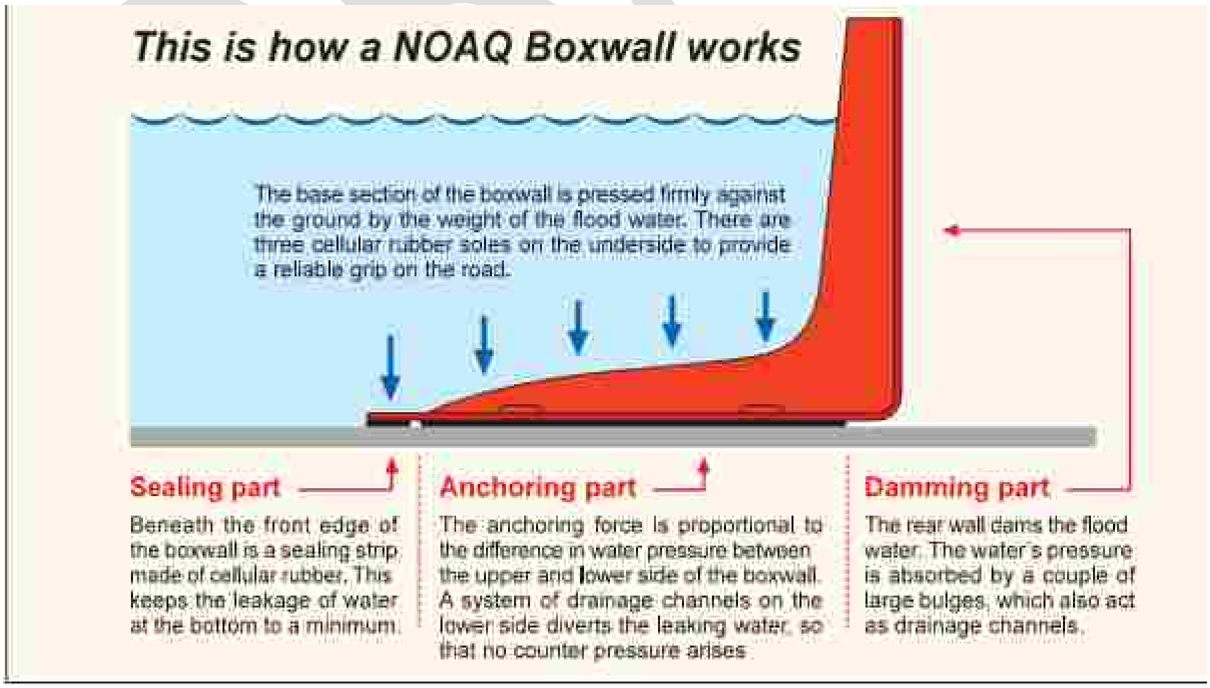

Figure 42: How NOAQ Boxwall Barriers work

The benefits of the NOAQ Boxwall BW52 is it is extremely lightweight, with each section only weighing 6.0kg, making it easy to deploy, and stands firm with no external fastening.

Sections are slotted together and their geometric design allows for curves and corners to be assembled in order to protect existing infrastructure.

The NOAQ Boxwall BW52 is able to dam 0.5m of water and the sections are anchored by the weight of the water itself. It is suitable for use on grass areas however the flatter the surface the less chance of seepage that can occur.

Figure 43: NOAQ Barriers on grass – image from supplier

5.6 Temporary Flood Barrier through lawn/yard areas

NOAQ Boxwall is a freestanding temporary flood barrier designed for fast response threats in an urban environment, on hard and even surfaces like tarmac, paving and concrete, as well as lawns.

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6. Spillway

The section near April and Augustus Street was identified as the preferred location for the spillway using flood modelling conducted by WMA Water. Figure 27 below shows the location of the proposed spillway.

A freeboard of 200mm would be provided to allow controlled overtopping during a very large flood event. Note that the 0.5% flood event is only 100mm higher than the 1% event therefore it is highly unlikely that the spillway will operate unless the event is even greater than the 0.5%.

Due to the very low increase in height with flood event even the larger floods are unlikely to cause a great depth of water over the spillway. Therefore the grassed surface would be sufficient in this instance.

At the proposed spillway location the existing bank needs to be lowered 100mm. The bank would be lowered further to provide crushed rock surface.

Batters are usually flatter on the downstream side of a spillway to lessen the impact of erosion from velocity. The crest formation ideally has a fall downstream or towards the flood to minimise water velocity across the crest. In this instance the existing batters of 4:1 would be sufficient due to the low probability of the spillway operating. Stripped topsoil can be placed on the downstream or property side to flatten the batter.

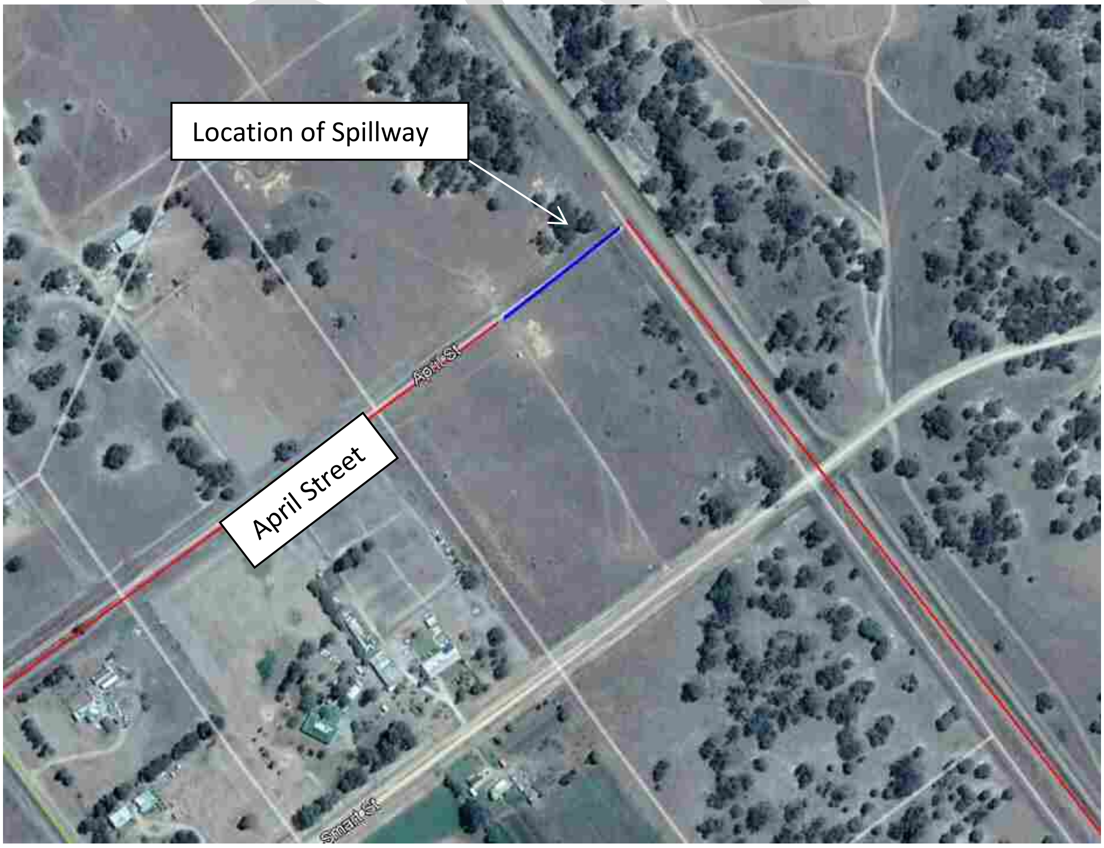

Figure 44: Location of Spillway

7. Geotechnical Analysis

Geotechnical Testing Services (GTS) was commissioned by PMC to undertake a geotechnical investigation of the condition of the existing levee bank in northern Deniliquin.

The purpose was to assess the general subsurface conditions of the site and determine the degree of development required in order to raise the level of the levee. This process involved drilling 22 boreholes to a depth of 1.5 metres. Dynamic Cone Penetrometer (DCP) tests were conducted in all boreholes with samples obtained for laboratory analysis. Full results of this can be found in Appendix B.

The test results showed that the eastern levee sections have been fill material composed of inorganic silty clay of medium to high plasticity. Testing showed that this was satisfactorily compacted when constructed due to the high DCP results. Underlying this, the natural ground surface is composed of silty clay, making up the natural floodplain sediments.

Recommendations according to the GTS report conclude the existing levee bank is suitable to remain with additional material placed on top to increase the height. To ensure the satisfactory construction of the levee re construction, it is recommended that the following procedure be undertaken:

- Strip the gravel layer from the crest and stockpile separately as this may be re-used on the reconstructed crest;
- Strip topsoil/vegetation and rootzone soil from the banks that are to have new material placed on the exposed surfaces should be tyned a minimum depth of 50mm and moisture conditioned (wet up) to allow the subsequent layer to bind;
- Layers of suitable Silty Clay material should be placed in layers no greater than 200mm and compacted to a minimum density ratio of 95% Standard;
- The layers should be finished with a pad foot roller or tyned a depth of 50mm so the surface is roughened to allow the next layer to bind;
- On completion, the topsoil should be placed on batters to assist in vegetation and minimise the potential for erosion of the surface with the previously removed gravel placed on the crest to allow for vehicular access.

For long term stability of the embankments, it is recommended that a batter slope of 3:1 (horizontal: vertical) be implemented.

These comments have been incorporated into the drawings.

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9. Appendix A

VEGETATION ASSESSMENT, DENILIQUIN LEVEE UPGRADE

HAMILTON ENVIRONMENTAL SERVICES

DRAFT

Hamilton Environmental Services
ABN: 89 108 410 911

VEGETATION ASSESSMENT, DENILIQUIN LEVEE UPGRADE

Vegetation Assessment, Deniliquin Levee Upgrade

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Version 1, 13th October 2019

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Cover Photo: Looking north-east along Section 9 east of the Finley Road.

TABLE OF CONTENTS

1. INTRODUCTION

Edwards River Council is seeking to raise the level of an existing levee around Deniliquin that was constructed around 10 years ago by approximately 300 mm (Mark Carter pers. comm. 2019).

The existing levee of 5.5 km in length is a combination of stand-alone levee alignments and existing roadways, and protects areas east of the Edward River bisected north-south by the Cobb and Riverina Highways in the east of the town, and some woody vegetation has established itself on the 10-year-old levee; this vegetation would need to be removed to facilitate the refurbishment of the levee alignment (Mark Carter pers. comm. 2019).

In July 2019, Hamilton Environmental Services (HES) was engaged through Price Merrett Consulting to undertake a native vegetation assessment of the levee alignment, and to advise on any strategies to avoid or minimise native vegetation loss.

Dr. Steve Hamilton undertook field evaluation of the levee alignment on the 16th August 2019, and this report presents the collective findings from these field investigations.

2. BACKGROUND

2.1 Section Locations

For the purposes of assessment, the existing levee alignment was defined in 10 sections of variable length (see Fig. 2-1):

- Section 1 runs along the eastern bank of the Edward River between Davidson and Coborro Streets, generally at the boundary of a number of freehold residential parcels; this section of the levee is not to be permanently upgraded – in the event of flooding, road crossing points will be raised temporarily, or series of temporary portable or concrete barriers will be erected;
- Section 2 runs north-south from Smart Street to April Street. This Section will be partly upgrade in height and a section of roadway will be raised;
- Section 3 runs along a section of April Street north-east to the Hay Road. The road surface will be raised in this Section;
- Section 4 runs along the April Street alignment east of the Hay Road in a north-easterly direction, and then turns south-east to Smart Street. This Section will be upgraded;
- Section 5 runs south-east from Smart Street parallel to the west of Flanagans Channel to Wanderer Street. This Section will be upgraded;
- Section 6 continues to run parallel to the west of Flanagans Channel from Wanderer Street to Augustus Street. No works are proposed for this section;
- Section 7 runs south-west from Augustus Street along the Hyde Street alignment, and then turns south-east along Charles Street to Yarra Street. No works are proposed for this section;
- Section 8 runs south-east from Yarra Street to Coborro Street. No works are proposed for this section;
- Section 9 runs south-east and then south-west from Coborro Street to the Riverina Highway. This Section will be upgraded;
- Section 10 runs south-east parallel to the Cobb Highway and then south-west towards River Street. This Section will be upgraded.

Figure 2-1 **Aerial image of the location of the ten sections of the proposed levee bank upgrade at Deniliquin (Image copyright NSW Land and Property Information 2019).**

Figure 2-2 **Overview Plan of the Proposed Levee Upgrade Project (Price Merrett Consulting dated 10th May 2019).**

1

The Overview Plan for the proposed levee upgrade can be seen in Fig. 2-2.

3. METHOD

The field assessment took place on the 16th August 2019. On this day, air temperatures were between 8 and 13°C, the sky was overcast, and winds were light (Bureau of Meteorology 2019).

The 5.5 km levee alignment was assessed on foot, with continuous active searching for flora and fauna conducted over a total period of 3 hours, with the following assessments undertaken:

- Compilation of a detailed flora species list, including the attribution of cover/abundance to each species;
- Individual recording of the species location and diameter of all indigenous trees, including their geo-location by GPS. Additionally for indigenous trees, dbh, their health and presence of hollows were recorded, and an image taken;
- Recording of issues related to land management, such as noxious weed or pest animal infestations, etc.

Vascular plants were identified according to the Flora of New South Wales (Harden 1990, 1991, 1992, 1993), and *PlantNet Flora On-line* (Royal Botanic Gardens Sydney 2019).

One hundred and eleven (111) images were taken during the assessment.

4. RESULTS AND DISCUSSION

4.1 General vegetation description

There were scattered individuals and clumps of indigenous woody trees and shrubs such as Weeping Myall (*Acacia pendula*), Cooba (*A. salicina*), Hakea Wattle (*Acacia hakeoides*), Black Box (*Eucalyptus largiflorens*) and River Red Gum (*E. camaldulensis*) found growing on the existing levee alignment or in close proximity to it; however, the individuals found on the actual levee bank were juvenile individuals and were less than 10 years of age.

Other than several clumps of Hakea Wattle, individuals of all species were isolated, and the alignments have been predominantly cleared of indigenous vegetation, and as established structures less than 10 years-of-age, are highly disturbed.

Planted exotic and non-indigenous native tree and shrub individuals such as Radiata Pine (*Pinus radiata*), Red Mallee (*E. oleosa*), Lemon-scented Gum (*E. citriodora*), Spotted Gum (*E. maculata*) and Silky Oak (*Grevillea robusta*) were encountered in proximity to the levee alignment in various locations.

Individuals and patches of the woody weed African Boxthorn (*Lycium ferocissimum*) were encountered in multiple locations in proximity to the levee alignment.

There were no rare or threatened species observed along the alignment (Environment and Heritage 2019a).

All sections assessed were dominated by introduced species at ground level, such as Capeweed (*Arctotheca calendula*), Common Crowfoot (*Erodium cicutarium*), Wimmera Ryegrass (*Lolium rigidum*), Great Brome (*Bromus diandrus*), White Clover (*Trifolium repens*), Paterson's Curse (*Echium plantigeneum*), Wild Oat (*Avena fatua*), Soursob (*Oxalis pes-caprae*), Small-flowered Mallow (*Malva parvifolium*) and Barley Grass (*Hordeum leporinum*)(on average 70 % projective foliage cover).

There were occasional individuals and small patches of indigenous understorey species encountered along the levee alignment, such as Nitre Bush (*Nitraria billardierei*), Black Rolypoly (*Sclerolaena* *muricata*), Ruby Saltbush (*Enchylaena tomentosa*), Climbing Saltbush (*Einadia nutans*), Rough Spear-grass (*Austrostipa scabra*), Curly Windmill Grass (*Enteropogon acicularis*) and Spreading Crassula (*Crassula decumbens*); however, these were generally in very low abundance on or in close proximity to the alignment (< 1 % projective foliage cover).

4.2 Vegetation Types

Mapping of vegetation communities provided in the *State Vegetation Type Map Riverina Region version 1.2* (Environment and Heritage 2019c), indicates that the vegetation west of the Riverina Highway is former or modified *River Red Gum-sedge dominated very tall open forest in frequently flooded forest wetland along major rivers and floodplains in south-western NSW* (Plant Community Type (PCT) 2), while the vegetation community east of the Cobb Highway is former or modified *Black Box grassy open woodland wetland of rarely flooded depressions in south western NSW (mainly Riverina Bioregion and Murray Darling Depression Bioregion)*(PCT 16).

4.3 Significant Trees

A total of 59 trees, either on the existing levee alignment or in close proximity to it, were separately recorded across the assessed sections.

The location of all trees recorded are shown in Figures 4-1 to 4-12.

4.4 Native vegetation Patches

There were three patches or clumps of native vegetation observed and mapped across the levee alignment; these have been labelled as Patches A to C, and all were of Hakea Wattle – it is likely that all of these patches have formed by sucker regrowth. Patches A and B are found in Section 5, and Patch C along Section 10.

4.5 Impacts of Development

4.5.1 Development footprint

It is likely that there will be an expansion in the base of the existing levee where height is to be upgraded by 300 mm; assuming that batter slopes will be kept at a similar angle, this will likely result in an increase in the base width of the levee bank by up to 4 m. In terms of impact on native vegetation, the location of this increased base can be restricted to one side of the existing structure to avoid trees and patches as required (Mark Carter pers. comm. 2019).

It has been assumed that the majority of heavy vehicle impact during the construction process will be based from the surface of the existing levee top, which will therefore obviate the need for new parallel construction vehicle access tracks to the existing levee alignment. This will greatly reduce the potential impact on native vegetation in proximity to the existing levee bank, and therefore, mature trees adjacent to the existing structure can most likely be avoided in all instances (Mark Carter pers. comm. 2019).

4.5.2 Tree Protection Zones (TPZs)

Development projects that involve earthworks can cause indirect losses of native vegetation that are retained during construction due to root damage and soil modification within the zone where roots occur. Of particular concern is the longer-term impact of soil compaction and excavation (e.g. trenching for pipelines) close to trees and the effects of this on immediate and longer-term tree health. Guidance and clarity has been provided, and a definition of an acceptable distance for tree retention in order to prevent indirect losses of native vegetation during and after construction activities as a guiding principle has been developed. These designated *Tree Protection Zones* (TPZs) should be implemented for the duration of construction activities (Standards Australia 2009) as part of the development conditions. A TPZ is a specific area above and below the ground, with a radius 12 times the Diameter at Breast Height (dbh; 1.3 m) of any individual tree; the TRZ of trees should be no less than 2 m or greater than 15 m, and it is recommended that physical barriers be erected to delineate the TPZ during construction activities (Standards Australia 2009). Encroachment of < 10 % of the TPZ is considered unlikely to have any influence on the survival and health of the tree provided the lost area is compensated for elsewhere in the TPZ, and that the loss is not within the tree's Structural Root Zone (SRZ), which is a 4 m radius from the tree truck for a tree of 150 cm dbh (Standards Australia 2009). However, encroachment of more than 10 % of the TPZ area of any tree results in that tree being considered a loss (even if it remains standing during and after the development activity), requiring it to be offset.

Particular consideration must be given to minimising any vehicle or excavation impacts on the TPZ of any indigenous trees that may occur in proximity to levee enhancement works.

4.6 Levee Sections

4.6.1 Section 1

This Section of 1,200 m length runs along the eastern bank of the Edward River between Davidson and Coborro Streets, generally at the boundary of a number of freehold residential parcels; this section of the levee is not to be permanently upgraded – in the event of flooding, road crossing points will be raised temporarily, or series of temporary portable or concrete barriers will be erected (Figures 4-1).

Given the nature of the proposed temporary structures to be developed, there were no issues in regards to impact on native vegetation along the alignment.

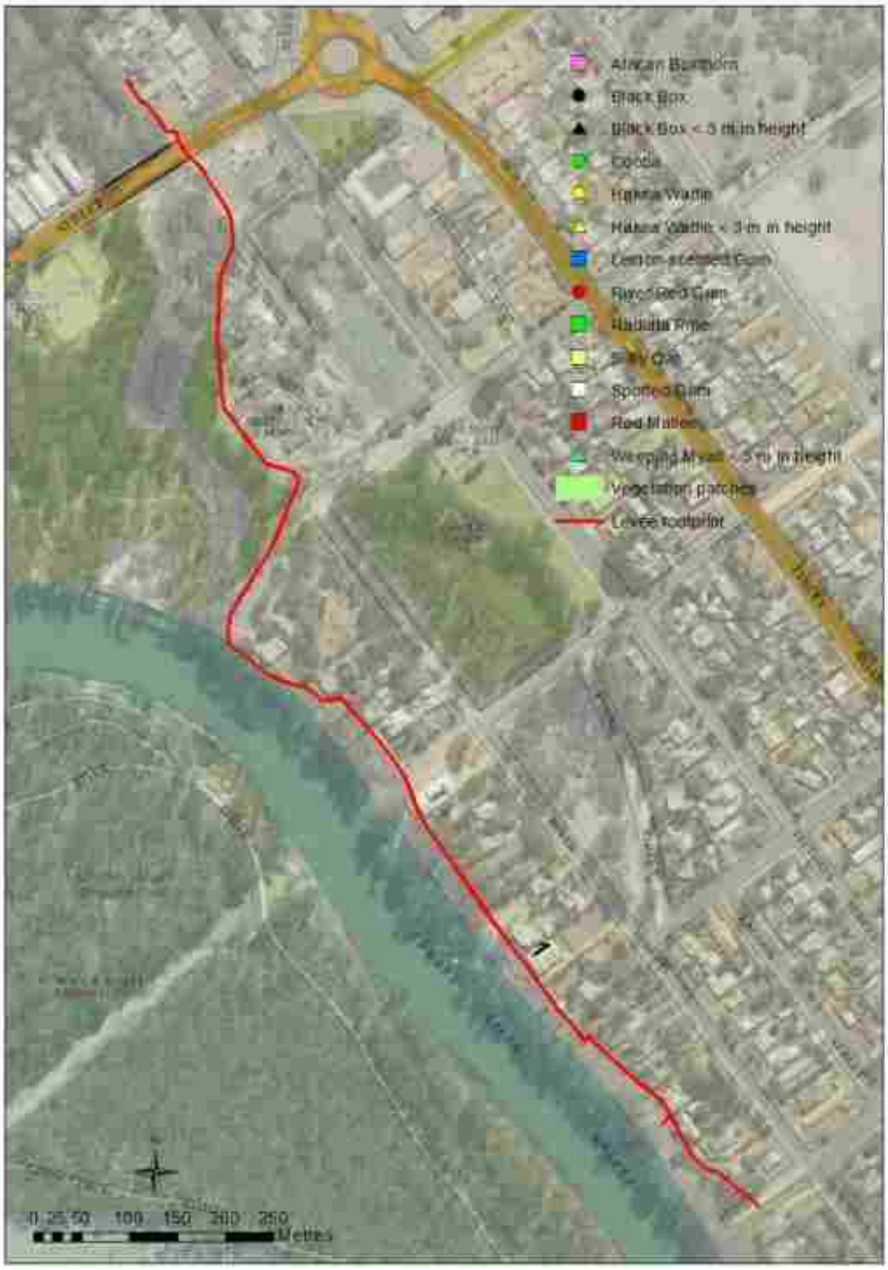

Figure 4-1 **Aerial image of Section 1 (Image copyright NSW Land and Property Information 2019).**

4.6.2 Sections 2 and 3

These Sections of 280 and 140 m length, respectively, run north-south from Smart Street to April Street (Section 2), and runs along a section of April Street north-east to the Hay Road (Section 3)(Fig. 4-2).

Section 2 will be partly upgraded in height and a section of roadway will be raised, while the road surface will be raised in Section 3.

Typical views of the Sections can be seen in Plate 4-1.

In Section 2, Trees 1 to 4 are all mature remnant River Red Gums on the eastern side of the existing levee in Section 2 (see Fig. 4-2), and the TPZs of all of these trees should be avoided by upgrading the height and levee base on the western side of the existing levee.

In Section 2, Trees 5 to 10 are all regrowth indigenous trees less than 10 years of age.

In Section 2, Tree 11 is a Cooba individual where impact could be avoided by upgrading the height and levee base on the eastern side of the existing levee.

In Section 2, Trees 12 to 16 are planted exotic and non-indigenous native species, but impact on these individuals can probably be avoided.

There are no vegetation issues in Section 3.

Plate 4-1 General views of Sections 2 and 3: the central part of Section 2 (top left), the northern end of Section 2 (top left), the eastern end of Section 3 (bottom left), and the western end of Section 3 (bottom right).

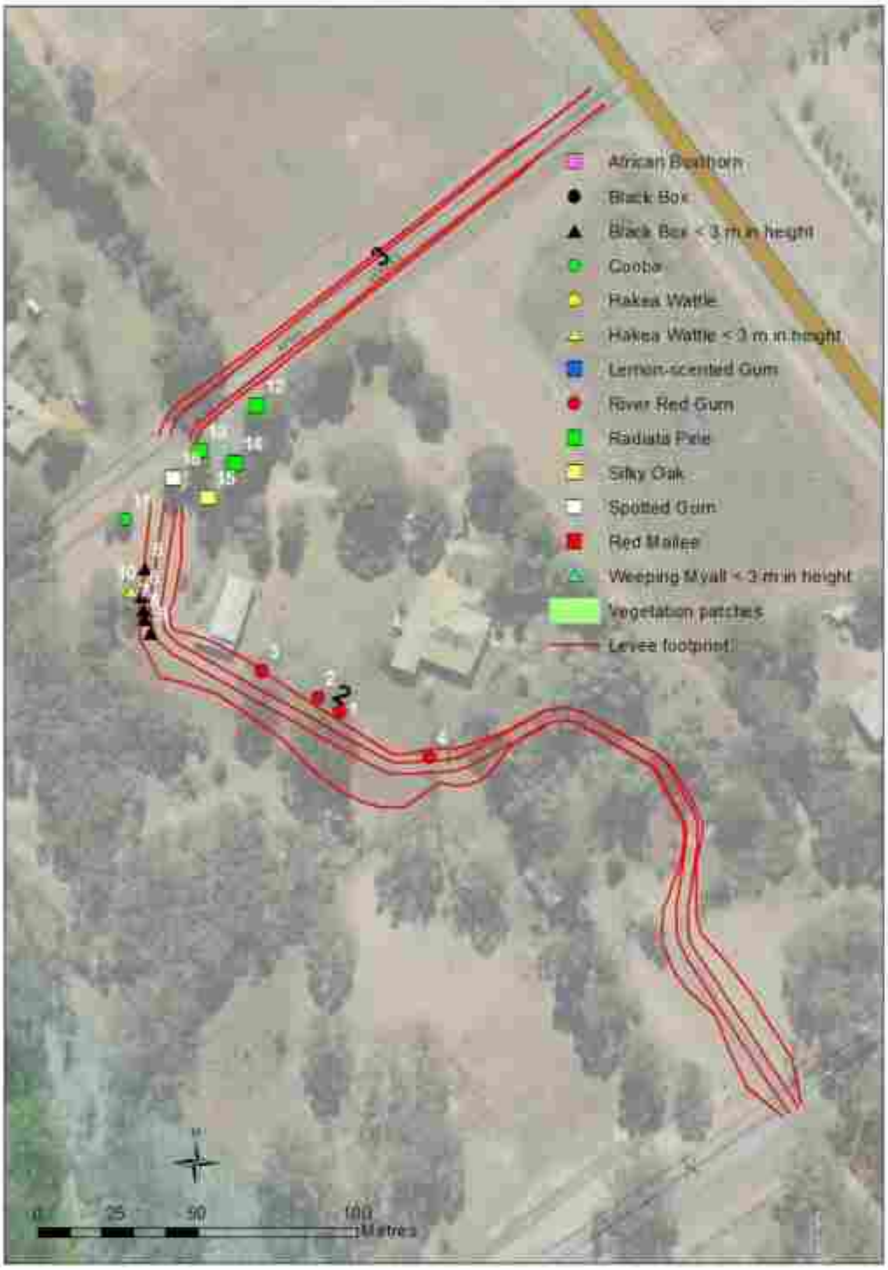

Figure 4-2 **Aerial image of Sections 2 and 3 (Image copyright NSW Land and Property Information 2019).**

4.6.3 Section 4

This Section of 800 m length runs along the April Street alignment east of the Hay Road in a north-easterly direction, and then turns south-east to Smart Street. This Section will be upgraded (Fig. 4-3).

Typical views of the Section can be seen in Plate 4-2.

Plate 4-2 Views of Section 4: the western end looking east (top right), at the southern end, looking north (top right), at the corner, looking south (bottom left), and at the corner, looking west (bottom right).

Trees 17 and 18 are all regrowth indigenous Black Box trees less than 10 years of age and less than 3 m in height.

Figure 4-3 **Aerial image of Section 4 (Image copyright NSW Land and Property Information 2019).**

4.6.4 Section 5

This Section of 1,160 m length runs south-east from Smart Street parallel to the west of Flanagans Channel to Wanderer Street. This Section will be upgraded (Figures 4-4 to 4-6).

Typical views of the Section can be seen in Plate 4-3.

Plate 4-3 Views of Section 5: the central northern part, looking north-west (top left), the central northern part, looking south-east (top right), at the northerly bend, looking north (middle left), at the northerly bend, looking east (middle right), at the southerly bend, looking south-east (bottom left), and from the southern end, looking north-west.

Trees 19 to 23 are all remnant Black Box trees on the western side of the existing levee close to the boundary fence with the adjacent parcel (see Figures 4-4 and 4-5), and the TPZs of all of these trees should be avoided by upgrading the height and levee base on the eastern side of the existing levee.

Trees 24 and 25 are regrowth indigenous trees less than 10 years of age (see Fig. 4-6).

Patches A and B are found on the existing levee and are wholly composed of regrowth Hakea Wattle < 10 year-of-age (see Fig. 4-6).

Figure 4-4 **Aerial image of Section 5 (Image copyright NSW Land and Property Information 2019).**

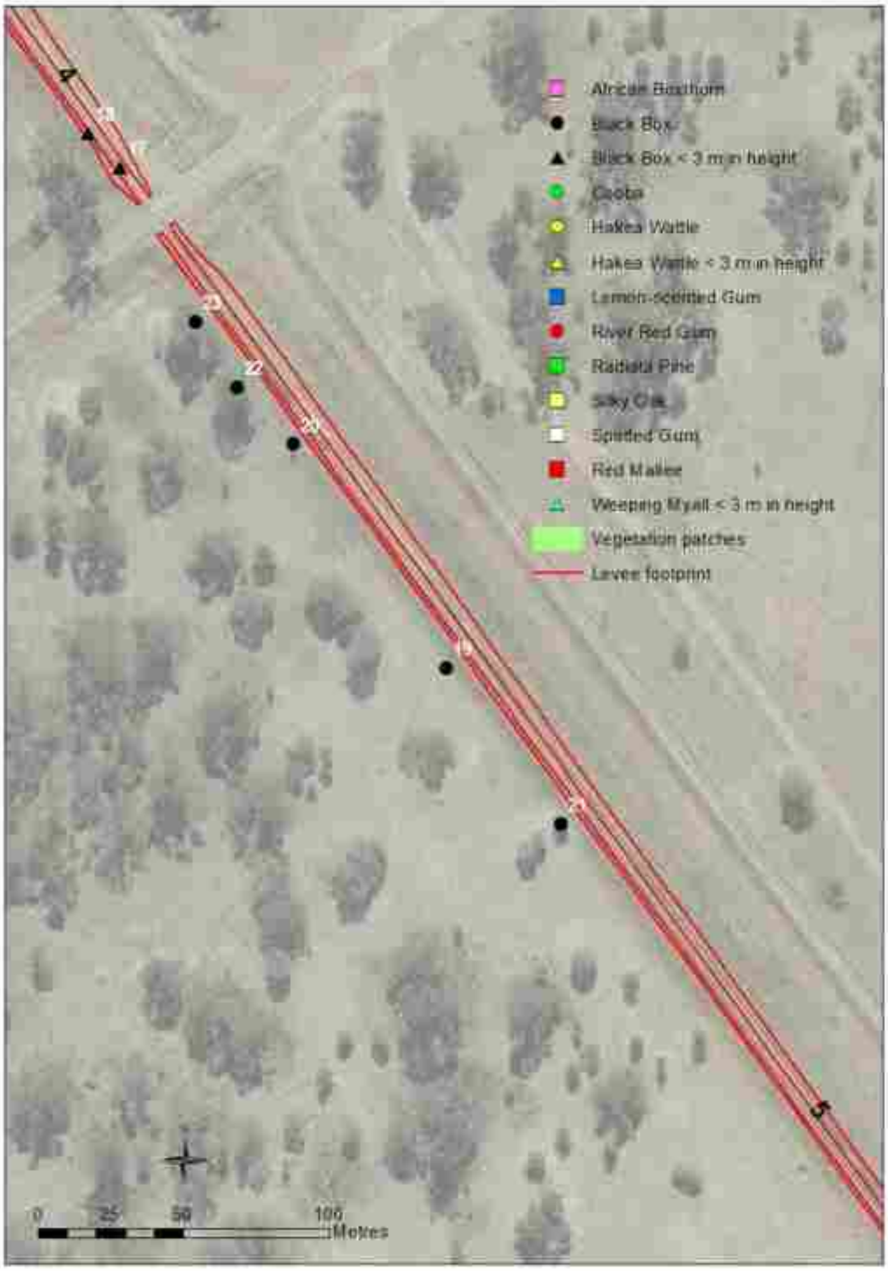

Figure 4-5 **Aerial image of the northern part of Section 5 (Image copyright NSW Land and Property Information 2019).**

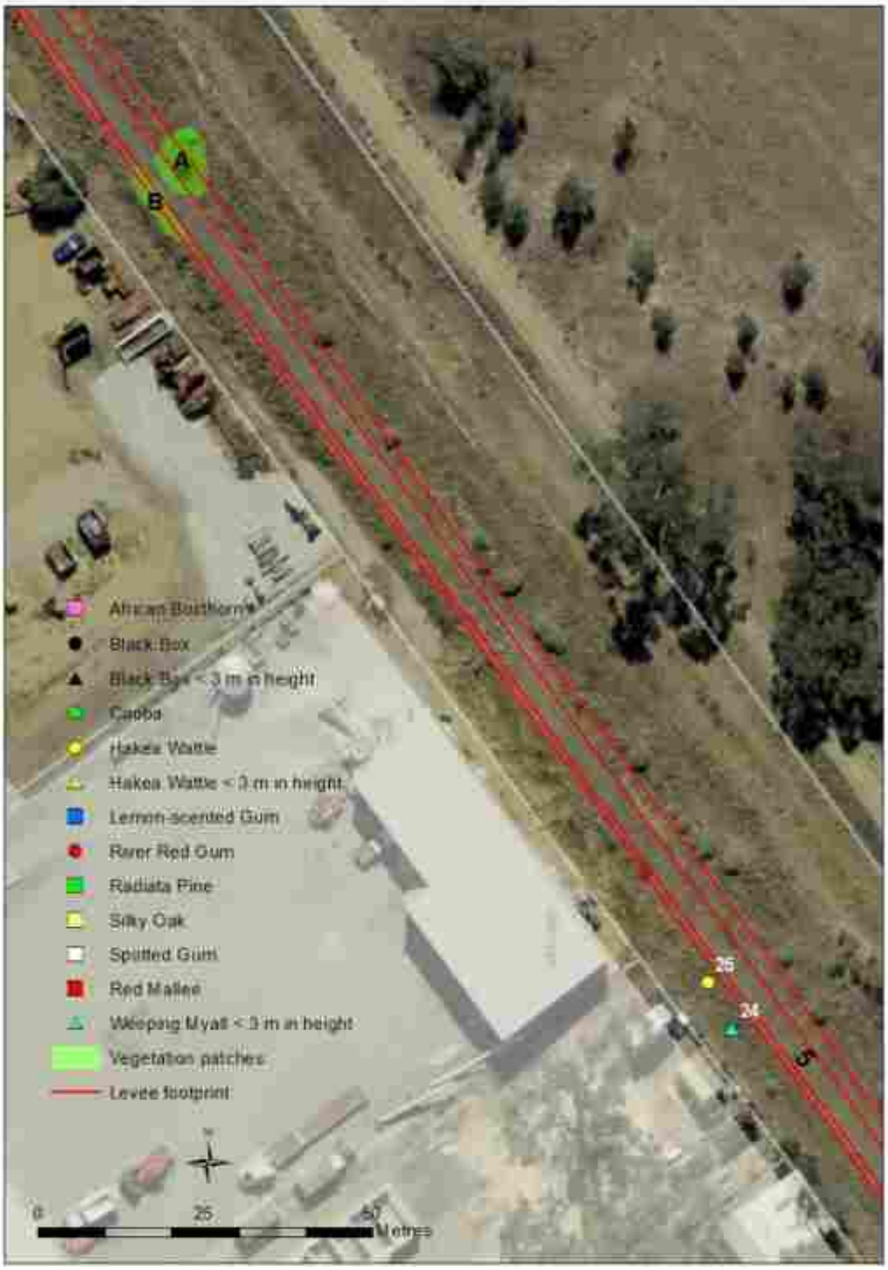

Figure 4-6 **Aerial image of the southern part of Section 5 (Image copyright NSW Land and Property Information 2019).**

4.6.5 Sections 6 and 7

These Sections of 370 and 670 m length respectively continues to run parallel to the west of Flanagans Channel from Wanderer Street to Augustus Street (Section 6), and runs south-west from Augustus Street along the Hyde Street alignment, and then turns south-east along Charles Street to Yarra Street (Section 7)(Fig. 4-7).

No works are proposed for these sections, but they were assessed for completion and due diligence.

Typical views of the Sections can be seen in Plate 4-4.

In Section 6, Tree 26 is regrowth indigenous tree less than 10 years of age.

Plate 4-4 **Views of Sections 6 and 7: from the northern end of Section 6, looking south-east top left), from the western end of Section 6, looking north-east (top right), from the eastern end of Section 7, looking south-west (middle left), from the bend in Section 7, looking north-east (middle right), and from the bend in Section 7 looking south-east (bottom).**

Figure 4-7 **Aerial image of Sections 6 and 7 (Image copyright NSW Land and Property Information 2019).**

4.6.6 Section 8

This Section of 220 m length runs south-east from Yarra Street to Coborro Street (Fig. 4-8).

No works are proposed for this section, but it was assessed for completion and due diligence.

Typical views of the Section can be seen in Plate 4-5.

Plate 4-5 Views of Section 8: from the northern end looking south-east (left), and from the southern end looking north-west (right).

Trees 27 and 28 are remnant Black Box trees on the western side of the existing levee close to the boundary fence with the adjacent parcel, and the TPZs of these trees should be avoided by upgrading the height and levee base on the eastern side of the existing levee if this is eventually undertaken.

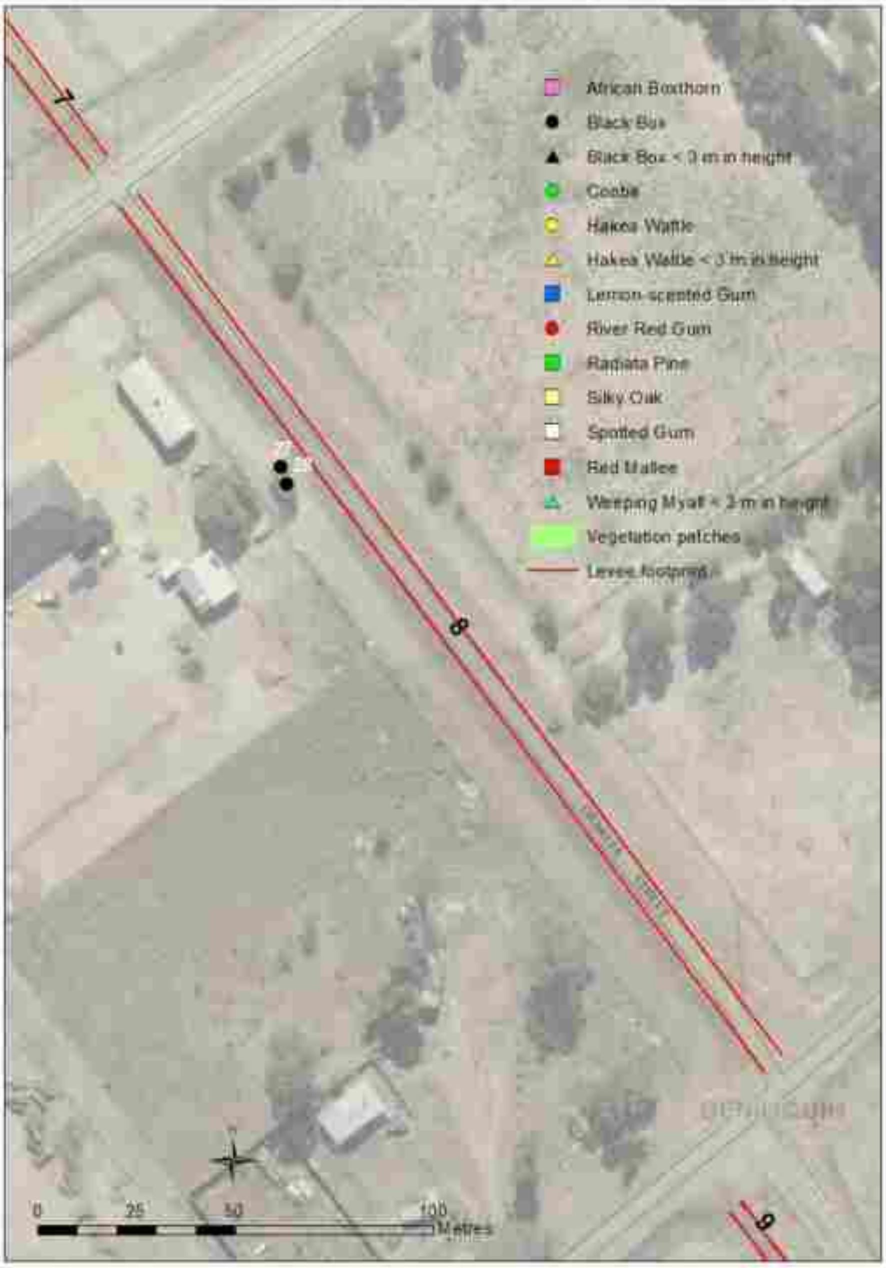

Figure 4-8 **Aerial image of Section 8 (Image copyright NSW Land and Property Information 2019).**

4.6.7 Section 9

This Section of 560 m length runs south-east and then south-west from Coborro Street to the Riverina Highway (Figures 4-9 to 4-11).

This Section will be upgraded.

Typical views of the Section can be seen in Plate 4-6.

Plate 4-6 Views of Section 9: from the northern end looking south-east (top left), from the northerly bend, looking north-west (top right), from the northerly bend looking south-west (middle left), looking south-west in the central part of the section (middle right), looking south-west in the southern part from the southern end (bottom left), and looking south-west towards the tree patch (bottom right).

Trees 29 to 40, and Trees 42 to 54 are all regrowth indigenous trees less than 10 years of age that are growing on the existing levee alignment; there are no mature indigenous trees in close proximity to the levee alignment that will be impacted by any construction activity.

Trees 40 and 41 are individuals of the woody weed African Boxthorn that are growing on the existing levee alignment.

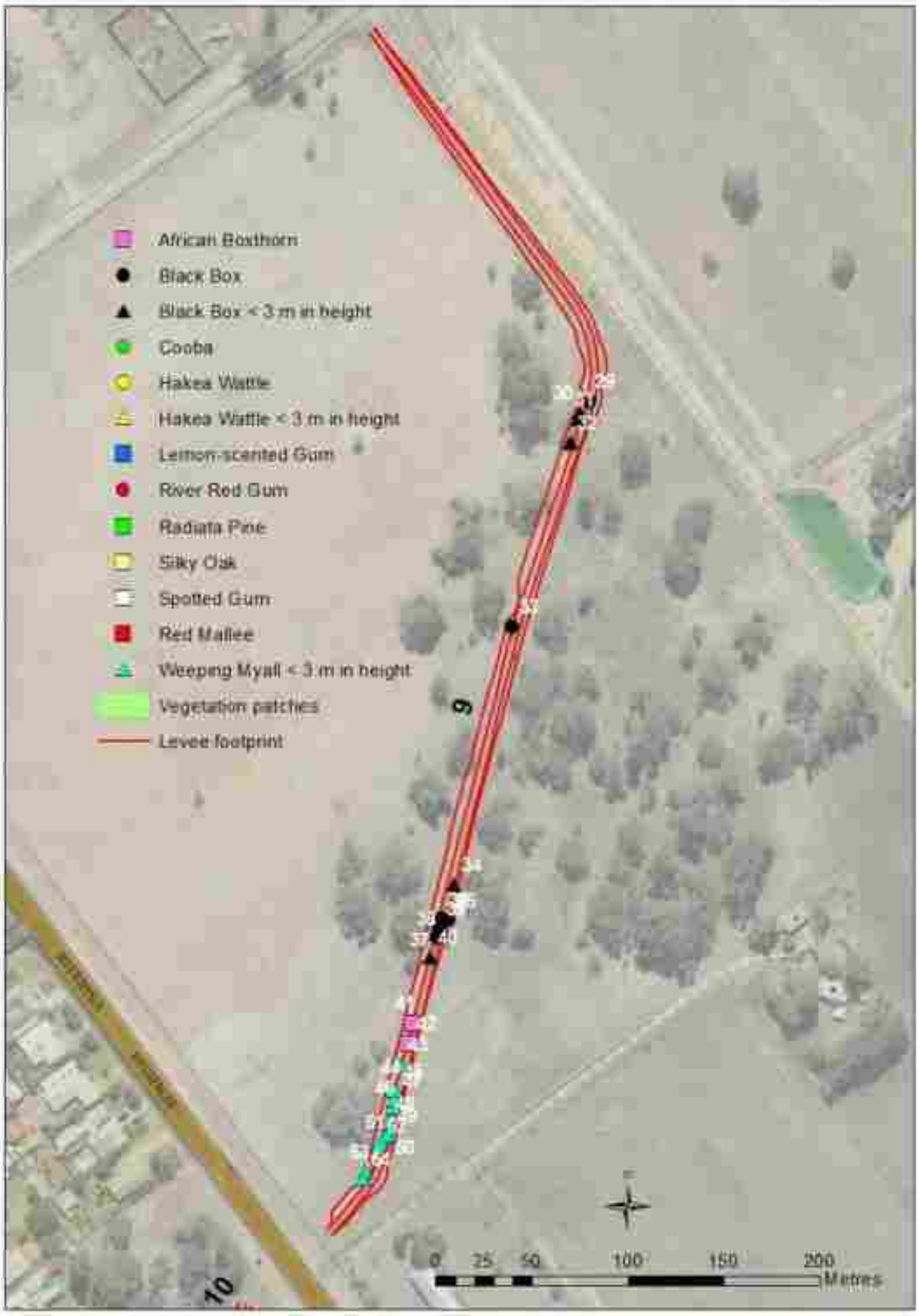

Figure 4-9 **Aerial image of Section 9 (Image copyright NSW Land and Property Information 2019).**

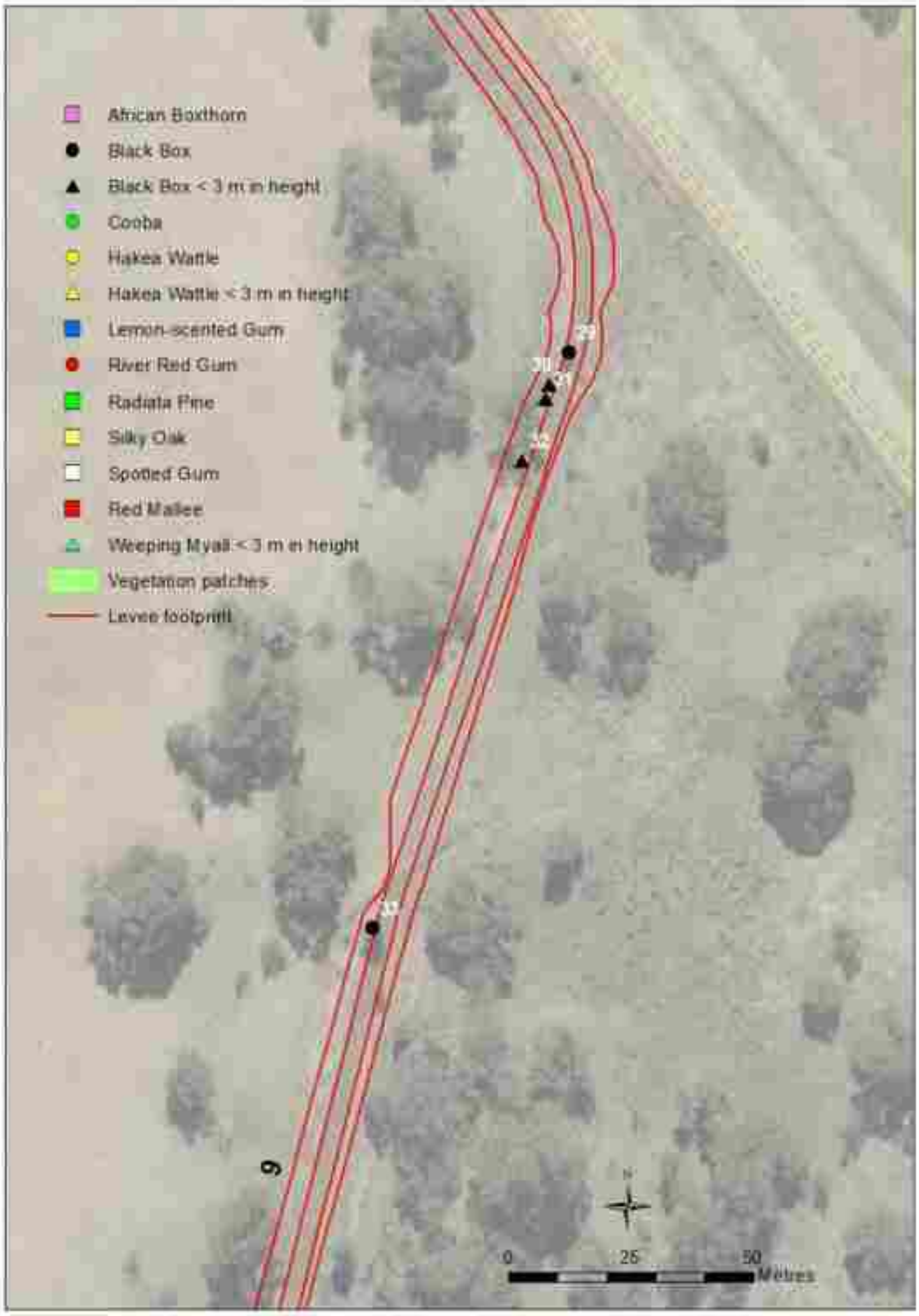

Figure 4-10 **Aerial image of the northern part of Section 9 (Image copyright NSW Land and Property Information 2019).**

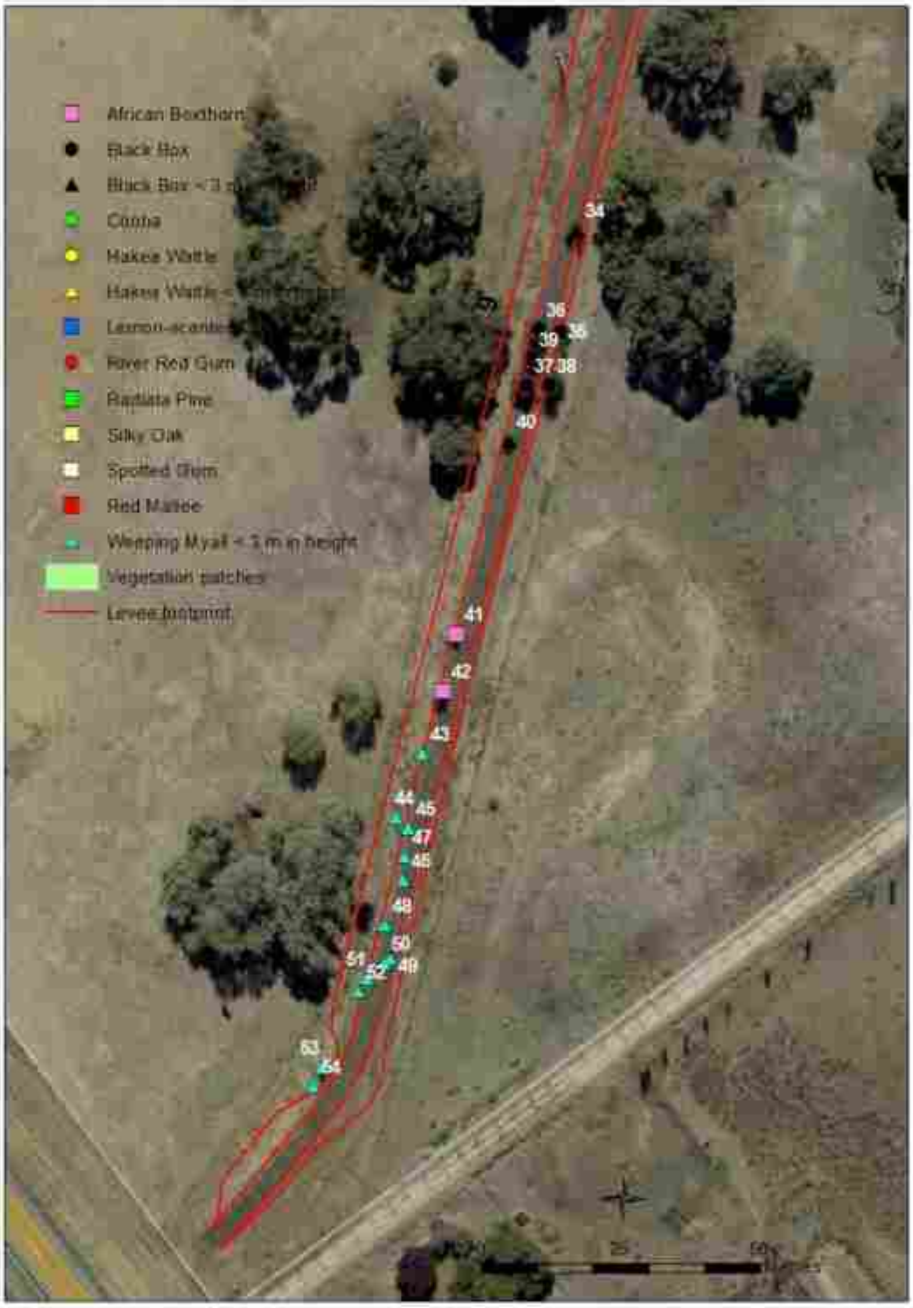

Figure 4-11 **Aerial image of the southern part of Section 9 (Image copyright NSW Land and Property Information 2019).**

4.6.8 Section 10

This Section of 205 m length runs south-east parallel to the Cobb Highway and then south-west towards River Street (Fig. 4-12).

This Section will be upgraded.

Typical views of the Section can be seen in Plate 4-7.

Plate 4-7 Views of Section 10: from the northern end looking south-east (top left), looking north-east towards the bend (top right), looking south-west from the bend (middle left), looking south-west towards Patch C (middle right), and the southern end looking south-west (bottom).

Patch C is found on the existing levee and is wholly composed of regrowth Hakea Wattle < 10 year-of-age (see Fig. 4-12).

Tree 11 is a Hakea Wattle individual where impact could be avoided by upgrading the height and levee base on the northern side of the existing levee.

Trees 55 and 58 are planted non-indigenous native species, but impact on these individuals can probably be avoided.

Tree 55 is a mature remnant River Red Gum on the northern side of the existing levee, and the TPZ of this tree should be avoided by upgrading the height and levee base on the southern side of the existing levee.

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Figure 4-12 **Aerial image of Section 10 (Image copyright NSW Land and Property Information 2019).**

5. CONCLUSION

The impact of the proposed upgrade of the levee can avoid any impact on the TPZs of any mature indigenous trees by the judicious placement of the expanded base of the levee with increased height on one side of the existing structure as specified.

A number of indigenous trees < 10 years-of-age that are growing as individuals or in patches on the existing levee structure will require removal for the upgrade of the levee.

According to Clause 50, Division 7 of *SEPP (Infrastructure) 2007*, development for the purpose of flood mitigation work may be carried out by or on behalf of a public authority without consent on any land. Furthermore, according to Clause 5 of *SEPP (Infrastructure) 2007*, if development for a particular purpose that may be carried out without consent includes construction works, the following works or activities are (subject to and without limiting that provision) taken to be construction works if they are carried out for that purpose:

"(f) clearing of vegetation (including any necessary cutting, lopping, ringbarking or removal of trees) and associated rectification and landscaping".

Therefore, while native vegetation clearance for the purposes of upgrading the levee will be kept to the minimum extent necessary, especially of mature trees, Council are able to undertake works on the levee without consent, and can clear any native vegetation without consent where required to ensure the satisfactory completion of works.

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10. Appendix B

GEOTECHNICAL REPORT

GTS

Proposed Levee Bank Extension
Deniliquin

Geotechnical Investigation for
Price Merrett Consulting

Report 19C 0796
November, 2019

GTS

Proposed Levee Bank Extension
Deniliquin

Geotechnical Investigation
for
Price Merrett Consulting

Revision

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APPENDIX

1 INTRODUCTION

Price Merrett Consulting commissioned Geotechnical Testing Services (GTS) to undertake a geotechnical investigation of the existing levee bank in Deniliquin.

The purpose of the investigation was to assess general subsurface conditions at the site with a view to providing comments and suitability of the site for the proposed raising of the levee bank.

2 SITE AND GEOLOGY

2.1 SITE LOCATION AND GENERAL CONDITIONS

The existing levee is located on the eastern edge of the Deniliquin township and extends from Pony Club Road/Smart St to Augustus St and follows Flanagan's Channel, then along Hyde St, Charles St, through the vacant land and finishing at Melon St.

The site is relatively flat with the raised levee bank having a crest suitable for vehicular access.

2.2 GEOLOGY

The New South Wales Government's online "NSWGeologyPlus" map shows the site to be underlain by Cainozoic aged sedimentary deposits of the Shepparton formation with this generally confirmed by the field data.

3 FIELDWORK

The geotechnical investigation was conducted on the 17th and 18th September 2019 and involved the drilling of 22 boreholes by a Gemco drilling rig to depths of 1.5 metres. Dynamic Cone Penetrometer (DCP) tests were conducted in all boreholes with disturbed samples obtained for further laboratory analysis.

The field investigation was conducted by a technician under the direction of a Geotechnical Engineer, who logged the subsurface profile and determined the testing program. The engineering logs are included in the Appendix with their locations as designated by the client shown on the enclosed site plan.

The field investigation indicated that the soil profile is slightly variable across the site but may be summarized as follows:

FILL: Gravel, fine to coarse, grey, ,
to depths of between 0.05 and 0.2 metres
Overlying
FILL: Silty CLAY, high plasticity, brown, pale grey, pale brown, dark brown, very stiff
to depths of 0.9 metres and termination
Overlying
Silty CLAY, high plasticity, dark brown, brown, very stiff,
To termination depths

There are some minor variations to the above including the absence of surface gravel at some locations. Therefore, reference should be made to the appended engineering logs for a full description of subsurface conditions at each location.

Groundwater inflow was not encountered over the investigated depths.

The Dynamic Cone Penetrometer (DCP) tests indicated that the levee bank fill material was of very stiff consistency and appears to have been compacted satisfactorily when constructed.

4 LABORATORY TESTING

Samples of the existing levee material at the site were obtained and returned to our NATA accredited laboratory. The testing consisted of atterberg limits, particle size distribution and emerson class with a summary of the results included in the following table and full NATA accredited reports in the Appendix.

Table 1: Material Properties

Sample	BH1 0.4-1.0m	BH2 0.4-1.0m	BH5 0.4-1.0m	BH7 0.4-1.0m	BH9 0.4-1.0m	BH11 0.4-1.0m
Liquid Limit (%)	46	52	48	44	49	44
Plastic Limit (%)	15	18	16	16	15	15
Plasticity Index (%)	31	34	32	28	34	29
Linear Shrinkage (%)	13.0	13.0	10.5	12.5	14.5	12.0
% Passing 0.075mm	73	8	81	79	82	85
Emerson Class	2	2	2	2	3	3
Moisture Content (%)	14.7	14.2	12.7	15.0	14.5	14.1

Sample	BH13 0.4-1.0m	BH15 0.4-1.0m	BH17 0.4-1.0m	BH19 0.4-1.0m	BH21 0.4-1.0m	BH22 0.4-1.0m
Liquid Limit (%)	44	53	54	47	50	50
Plastic Limit (%)	15	16	16	16	15	16
Plasticity Index (%)	29	37	38	31	35	34
Linear Shrinkage (%)	12.0	15.0	12.5	11.0	13.5	11.0
% Passing 0.075mm	80	85	90	83	88	88
Emerson Class	3	2	3	3	3	2
Moisture Content (%)	14.4	13.4	15.9	15.1	17.4	17.8

5 ENGINEERING RECOMMENDATIONS

It is understood that the proposed development will consist of raising the existing levee bank.

It is noted that for a levee bank, the permeability is not as critical as a dam bank due to the temporary retardation of the water. As such, it needs to be a clay material that can be compacted satisfactorily to retain its shape and integrity over time.

Based on the results of this investigation, the existing levee bank is constructed of a high plasticity Silty Clay that has suitable properties for use in a levee bank. The insitu strength tests showed the fill material to be very stiff and therefore has been compacted sufficiently at the time of construction.

As such, the existing levee bank is suitable to remain with additional material placed to increase the height. To ensure the satisfactory construction of the levee raising, it is recommended that the following procedure be undertaken:

- Strip the gravel layer from the crest and stockpile separately as this may be re-used on the reconstructed crest
- Strip topsoil/vegetation and rootzone soil from the banks that are to have new material placed on.
- The exposed surfaces should be tyned a minimum depth of 50mm and moisture conditioned (wet up) to allow the subsequent layer to bind
- Layers of suitable Silty Clay material should be placed in layers no greater than 200mm and compacted to a minimum density ratio of 95% Standard
- The layers should be finished with a pad foot roller or tyned a depth of 50mm so the surface is roughened to allow the next layer to bind

- On completion, the topsoil should be placed on batters to assist in vegetation and minimise the potential for erosion of the surface with the previously removed gravel placed on the crest to allow for vehicular access.

For long term stability of the embankments, it is recommended that a batter slope of 3:1 (horizontal: vertical) be implemented.

6 IMPORTANT NOTES ABOUT THIS REPORT

Material types and quality in areas away from the test locations are inferred only and may vary from those encountered during the investigation. It is recommended that the base of all excavations are inspected by a Geotechnical Engineer to ensure the material strength requirements referenced herein are met. If further variations in descriptions in soil types, colour or depths are discovered during construction, this office should be notified immediately so that potential influence on the construction may be assessed.

The results from this investigation relate to the specified sites labelled throughout this document, and hence the information obtained may need to be extrapolated to the rest of the designated area. While care has been taken throughout this investigation, soil conditions can vary between each individual test site and at depths greater than that drilled during this investigation. The soil colours provided in the borelogs attached may vary with soil moisture content and individual interpretation, therefore colour alone should not be used to identify these soils. Strength characteristics of soils often exhibit a large variation between wet and dry conditions. Soil characteristics of a soil profile are given on the soil conditions at the time of the investigation.

7 DISCLAIMER

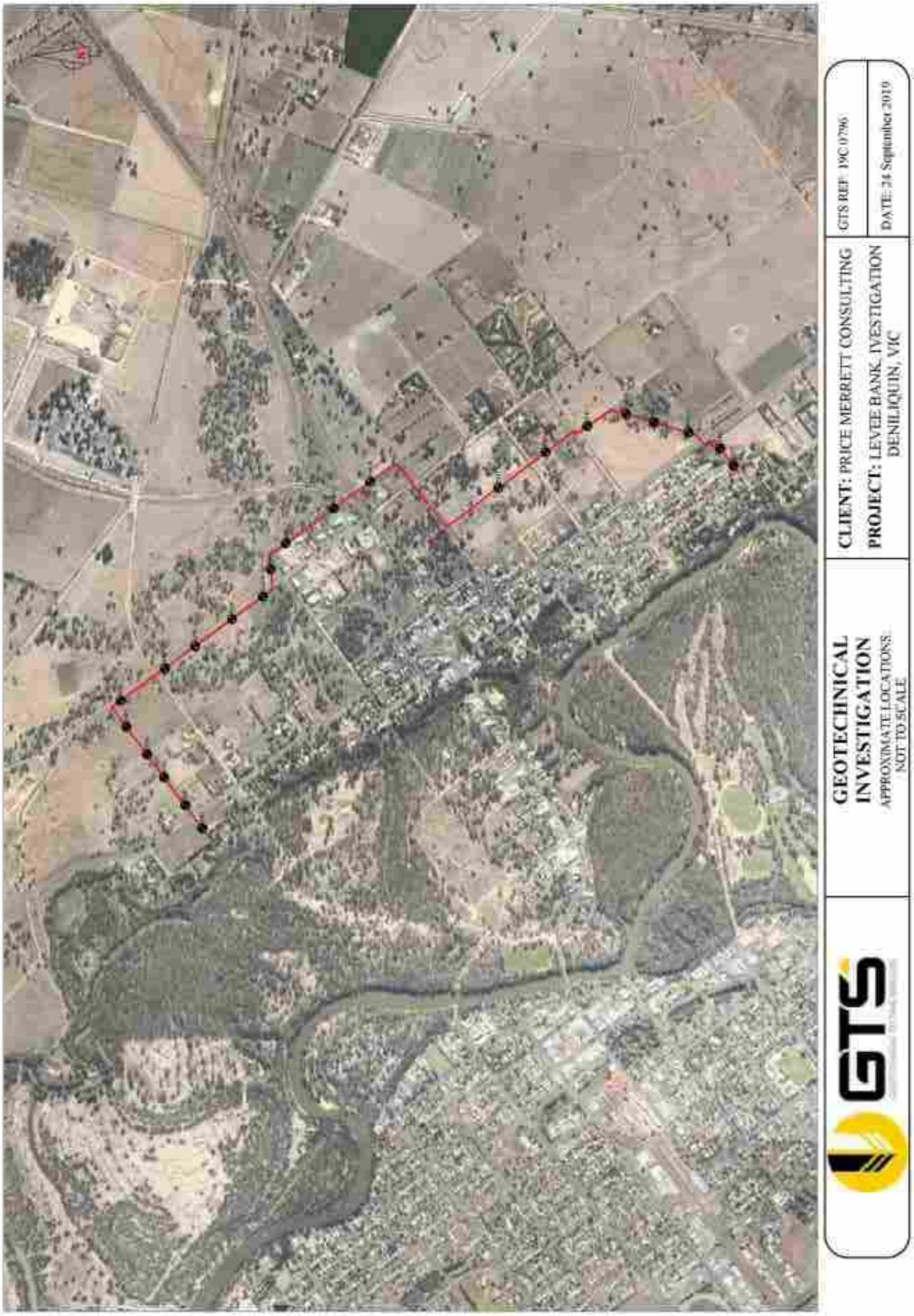
This investigation has been carried out in goodwill and under the instructions of Price Merrett Consulting. The investigation has been undertaken with the care and skill of competent personnel as defined within Geotechnical Testing Services quality system. It is not a comprehensive investigation but a guide to the conditions throughout the designated area.

This document has been prepared for Price Merrett Consulting, and hence no responsibility or liability is being accepted to any third party, where any part of the report is used in either isolation or without consideration of the whole document. This document is not appropriate where there has been a significant change in the project or either for the specific needs of the reader.

Please, don't hesitate to contact the undersigned, if you require any further information or assistance.

Shane Hampton (BE (Hons))
Principal Geotechnical Engineer

APPENDIX


GEOTECHNICAL INVESTIGATION
APPROXIMATE LOCATIONS NOT TO SCALE
CLIENT: PRICE MERRETT CONSULTING
PROJECT: LEVEE BANK IVESTIGATION DENILIQUIN, VIC
GTS REF: 19C0796
DATE: 24 September 2019

ENGINEERING BOREHOLE LOG

PO Box 13, Strathdale 3550
Ph (03) 54414881 Fax (03) 5441 5089

Borehole no. 1
Sheet no. 1 of 1
Job no. 19C 0796

Client :	Price Merrett Consulting	Date:	17/09/2019
Project :	Levee Bank Investigation	Logged by:	RC & PB
Location :	Deniliquin		
Drill model :	Gemco HS7	Slope 90 deg	RL surface: *Not measured*
Hole diameter :	100mm	Bearing - deg	Datum : -

Material Description	Depth (m)	Graphic log	Water	Moisture condition	Consistency density index	Structure, additional observations	Notes Samples Tests	Method	Support
FILL: GRAVEL (GW), fine to coarse, grey. 200mm				D	M/D	FILL			
FILL: Silty CLAY (CH), high platicity, mottled, pale brown, grey, brown, traves of fine to coarse gravel. 1200mm	0.25			M	Vst	FILL			
						DCP at 0.3m	DCP=7		
							DCP=7		
	0.50						DCP=5		
							DCP=5		
	0.75						DCP=5		
							DCP=7		
	1.00								
Silty CLAY (CH), high plasticity, dark brown. 1500mm	1.25			M	Vst	Soil Profile			
	1.50								
BH1 terminated at 1.5 metres									
	1.75								
	2.00								

ENGINEERING BOREHOLE LOG

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Borehole no. 2
Sheet no. 1 of 1
Job no. 19C 0796

Client :	Price Merrett Consulting	Date:	17/09/2019
Project :	Levee Bank Investigation	Logged by:	RC & PB
Location :	Deniliquin		
Drill model :	Gemco HS7	Slope 90 deg	RL surface: *Not measured*
Hole diameter :	100mm	Bearing - deg	Datum : -

Material Description	Depth (m)	Graphic log	Water	Moisture condition	Consistency density index	Structure, additional observations	Notes Samples Tests	Method	Support
FILL: Silty CLAY (CH), dark brown, pale brown. 1300mm				M	Vst	FILL			
	0.25								
						DCP at 0.3m	DCP=6		
							DCP=5		
	0.50						DCP=12		
							DCP=16		
	0.75						DCP=16		
							DCP=16		
	1.00								
	1.25								
Silty CLAY (CH), high plasticity, dark brown. 1500mm						Soil Profile			
	1.50								
BH2 terminated at 1.5 metres									
	1.75								
	2.00								

ENGINEERING BOREHOLE LOG

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Borehole no. 3
Sheet no. 1 of 1
Job no. 19C 0796

Client :	Price Merrett Consulting			Date:	17/09/2019
Project :	Levee Bank Investigation			Logged by:	RC & PB
Location :	Deniliquin				
Drill model :	Gemco HS7	Slope	90 deg	RL surface:	*Not measured*
Hole diameter :	100mm	Bearing	- deg	Datum :	-

Material Description	Depth (m)	Graphic log	Water	Moisture condition	Consistency density index	Structure, additional observations	Notes Samples Tests	Method	Support
FILL: GRAVEL (GW), fine to coarse, grey. 100mm				D	M/D	FILL			
FILL: Silty CLAY (CH), high plasticity, pale brown, brown, dark brown. 900mm				M	Vst	FILL			
	0.25								
						DCP at 0.3m	DCP=10		
							DCP=10		
	0.50						DCP=14		
							DCP=17		
	0.75						DCP=16		
Silty CLAY (CH), high plasticity, dark brown. 1500mm				M	Vst	Soil Profile			
	1.00								
	1.25								
	1.50								
BH3 terminated at 1.5 metres									
	1.75								
	2.00								

ENGINEERING BOREHOLE LOG

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Borehole no. 4
Sheet no. 1 of 1
Job no. 19C 0796

Client :	Price Merrett Consulting	Date:	17/09/2019
Project :	Levee Bank Investigation	Logged by:	RC & PB
Location :	Deniliquin		
Drill model :	Gemco HS7	Slope 90 deg	RL surface: *Not measured*
Hole diameter :	100mm	Bearing - deg	Datum : -

Material Description	Depth (m)	Graphic log	Water	Moisture condition	Consistency density index	Structure, additional observations	Notes Samples Tests	Method	Support
FILL: GRAVEL (GW), fine to coarse, grey 100mm				D	M/D	FILL			
FILL: Silty CLAY (CH), high plasticity, pale brown, dark brown, brown, 1200mm				M	Vst	FILL			
	0.25								
						DCP at 0.3m	DCP=11		
							DCP=9		
	0.50								
							DCP=18		
							DCP=ref		
	0.75								
	1.00								
Silty CLAY (CH), high plasticity, dark brown 1500mm	1.25			M	Vst	Soil Profile			
	1.50								
BH4 terminated at 1.5 metres									
	1.75								
	2.00								

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Borehole no. 5
Sheet no. 1 of 1
Job no. 19C 0796

Client :	Price Merrett Consulting	Date:	17/09/2019
Project :	Levee Bank Investigation	Logged by:	RC & PB
Location :	Deniliquin		
Drill model :	Gemco HS7 Slope 90 deg	RL surface:	*Not measured*
Hole diameter :	100mm Bearing - deg	Datum :	-

Material Description	Depth (m)	Graphic log	Water	Moisture condition	Consistency density index	Structure, additional observations	Notes Samples Tests	Method	Support
FILL: GRAVEL (GW), fine to coarse, grey 100mm				D	M/D	FILL			
FILL: Silty CLAY (CH), high plasticity, pale brown, brown, dark brown. 1500mm				M	Vst	FILL			
	0.25								
						DCP at 0.3m	DCP=15		
							DCP=17		
	0.50						DCP=16		
	0.75								
	1.00								
	1.25								
	1.50								
BH5 terminated at 1.5 metres									
	1.75								
	2.00								

ENGINEERING BOREHOLE LOG

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Borehole no. 6
Sheet no. 1 of 1
Job no. 19C 0796

Client :	Price Merrett Consulting	Date:	17/09/2019
Project :	Levee Bank Investigation	Logged by:	RC & PB
Location :	Deniliquin		
Drill model :	Gemco HS7	Slope 90 deg	RL surface: *Not measured*
Hole diameter :	100mm	Bearing - deg	Datum : -

Material Description	Depth (m)	Graphic log	Water	Moisture condition	Consistency density index	Structure, additional observations	Notes Samples Tests	Method	Support
FILL: GRAVEL (GW), fine to coarse, grey 100mm				D	M/D	FILL			
FILL: Silty CLAY (CH), high plasticity, pale brown, brown, dark brown. 1500mm				M	Vst	FILL			
	0.25								
						DCP at 0.3m	DCP=8		
							DCP=5		
	0.50						DCP=5		
							DCP=14		
	0.75						DCP=14		
							DCP=16		
	1.00								
	1.25								
	1.50								
BH6 terminated at 1.5 metres									
	1.75								
	2.00								

ENGINEERING BOREHOLE LOG

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Borehole no.	7
Sheet no.	1 of 1
Job no.	19C 0796

Client :	Price Merrett Consulting			Date:	17/09/2019
Project :	Levee Bank Investigation			Logged by:	RC & PB
Location :	Deniliquin				
Drill model :	Gemco HS7	Slope	90 deg	RL surface:	*Not measured*
Hole diameter :	100mm	Bearing	- deg	Datum :	-

Material Description	Depth (m)	Graphic log	Water	Moisture condition	Consistency density index	Structure, additional observations	Notes Samples Tests	Method	Support
FILL: GRAVEL (GW), fine to coarse, grey. 100mm				D	M/D	FILL			
FILL: Silty CLAY (CI-CH), medium to high plasticity, pale brown, brown, dark brown. 1500mm	0.25			M	Vst	FILL			
						DCP at 0.3m	DCP=4		
							DCP=6		
	0.50						DCP=7		
							DCP=10		
	0.75						DCP=7		
							DCP=9		
	1.00								
	1.25								
	1.50								
BH7 terminated at 1.5 metres									
	1.75								
	2.00								

ENGINEERING BOREHOLE LOG

GTS

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Borehole no. 8
Sheet no. 1 of 1
Job no. 19C 0796

Client :	Price Merrett Consulting	Date:	17/09/2019
Project :	Levee Bank Investigation	Logged by:	RC & PB
Location :	Deniliquin		
Drill model :	Gemco HS7 Slope 90 deg	RL surface:	*Not measured*
Hole diameter :	100mm Bearing - deg	Datum :	-

Material Description	Depth (m)	Graphic log	Water	Moisture condition	Consistency density index	Structure, additional observations	Notes Samples Tests	Method	Support
FILL: GRAVEL (GW), fine to coarse, grey. 100mm				D	M/D	FILL			
FILL: Silty CLAY (CI-CH), medium to high plasticity, pale brown, brown, dark brown. 1200mm	0.25			M	Vst	FILL			
						DCP at 0.3m	DCP=7		
							DCP=6		
	0.50						DCP=4		
							DCP=6		
	0.75						DCP=16		
							DCP=13		
	1.00								
Silty CLAY (CH), high plasticity, dark brown. 1500mm	1.25			M	Vst	Soil Profile			
	1.50								
BH8 terminated at 1.5 metres									
	1.75								
	2.00								

GTS

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Borehole no. 9
Sheet no. 1 of 1
Job no. 19C 0796

Client :	Price Merrett Consulting	Date:	17/09/2019
Project :	Levee Bank Investigation	Logged by:	RC & PB
Location :	Deniliquin		
Drill model :	Gemco HS7 Slope 90 deg	RL surface:	*Not measured*
Hole diameter :	100mm Bearing - deg	Datum :	-

Material Description	Depth (m)	Graphic log	Water	Moisture condition	Consistency density index	Structure, additional observations	Notes Samples Tests	Method	Support
FILL: GRAVEL (GW), fine to coarse, grey. 100mm				D	M/D	FILL			
FILL: Silty CLAY (CI-CH), medium to high plasticity, pale brown, brown, dark brown. 1200mm	0.25			M	Vst	FILL			
						DCP at 0.3m	DCP=15		
							DCP=14		
	0.50						DCP=13		
							DCP=11		
	0.75						DCP=14		
							DCP=14		
	1.00								
Silty CLAY (CH), high plasticity, dark brown. 1500mm	1.25			M	Vst	Soil Profile			
	1.50								
BH9 terminated at 1.5 metres									
	1.75								
	2.00								

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Borehole no. 10
Sheet no. 1 of 1
Job no. 19C 0796

Client :	Price Merrett Consulting	Date:	17/09/2019
Project :	Levee Bank Investigation	Logged by:	RC & PB
Location :	Deniliquin		
Drill model :	Gemco HS7	Slope 90 deg	RL surface: *Not measured*
Hole diameter :	100mm	Bearing - deg	Datum : -

Material Description	Depth (m)	Graphic log	Water	Moisture condition	Consistency density index	Structure, additional observations	Notes Samples Tests	Method	Support
FILL: GRAVEL (GW), fine to coarse, grey. 100mm				D	M/D	FILL			
FILL: Silty CLAY (CH), high plasticity, dark brown. 1000mm				M	Vst	FILL			
	0.25								
						DCP at 0.3m	DCP=15		
							DCP=12		
	0.50						DCP=14		
							DCP=12		
	0.75						DCP=14		
							DCP=15		
	1.00								
Silty CLAY (CH), high plasticity, brown. 1500mm				M	Vst	Soil Profile			
	1.25								
	1.50								
BH10 terminated at 1.5 metres									
	1.75								
	2.00								

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Borehole no. 11
Sheet no. 1 of 1
Job no. 19C 0796

Client :	Price Merrett Consulting	Date:	17/09/2019
Project :	Levee Bank Investigation	Logged by:	RC & PB
Location :	Deniliquin		
Drill model :	Gemco HS7	Slope 90 deg	RL surface: *Not measured*
Hole diameter :	100mm	Bearing - deg	Datum : -

Material Description	Depth (m)	Graphic log	Water	Moisture condition	Consistency density index	Structure, additional observations	Notes Samples Tests	Method	Support
FILL: GRAVEL (GW), fine to coarse, grey. 100mm				D	M/D	FILL			
FILL: Silty CLAY (CI-CH), medium to high plasticity, pale brown, brown, dark brown. 1500mm	0.25			M	Vst	FILL			
						DCP at 0.3m	DCP=7		
							DCP=13		
	0.50						DCP=16		
							DCP=20		
	0.75								
	1.00								
	1.25								
	1.50								
BH11 terminated at 1.5 metres									
	1.75								
	2.00								

ENGINEERING BOREHOLE LOG

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Borehole no. 12
Sheet no. 1 of 1
Job no. 19C 0796

Client :	Price Merrett Consulting	Date:	17/09/2019
Project :	Levee Bank Investigation	Logged by:	RC & PB
Location :	Deniliquin		
Drill model :	Gemco HS7 Slope 90 deg	RL surface:	*Not measured*
Hole diameter :	100mm Bearing - deg	Datum :	-

Material Description	Depth (m)	Graphic log	Water	Moisture condition	Consistency density index	Structure, additional observations	Notes Samples Tests	Method	Support
FILL: GRAVEL (GW), fine to coarse, grey 100mm				D	M/D	FILL			
FILL: Silty CLAY (CI-CH), medium to high plasticity, pale brown, brown, dark brown. 1500mm	0.25			M	Vst	FILL			
						DCP at 0.3m	DCP=14		
	0.50						DCP=16		
							DCP=16		
							DCP=15		
	0.75						DCP=19		
	1.00								
	1.25								
	1.50								
BH12 terminated at 1.5 metres									
	1.75								
	2.00								

ENGINEERING BOREHOLE LOG

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Borehole no. 13
Sheet no. 1 of 1
Job no. 19C 0796

Client :	Price Merrett Consulting	Date:	17/09/2019
Project :	Levee Bank Investigation	Logged by:	RC & PB
Location :	Deniliquin		
Drill model :	Gemco HS7	Slope 90 deg	RL surface: *Not measured*
Hole diameter :	100mm	Bearing - deg	Datum : -

Material Description	Depth (m)	Graphic log	Water	Moisture condition	Consistency density index	Structure, additional observations	Notes Samples Tests	Method	Support
FILL: GRAVEL (GW), fine to coarse, grey 100mm				D	M/D	FILL			
FILL: Silty CLAY (CI-CH), medium to high plasticity, pale brown, brown, dark brown. 1500mm	0.25			M	Vst	FILL			
						DCP at 0.3m	DCP=6		
							DCP=8		
	0.50						DCP=10		
							DCP=10		
	0.75						DCP=10		
							DCP=11		
	1.00								
	1.25								
	1.50								
BH12 terminated at 1.5 metres									
	1.75								
	2.00								

ENGINEERING BOREHOLE LOG

PO Box 13, Strathdale 3550
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Borehole no. 14
Sheet no. 1 of 1
Job no. 19C 0796

Client :	Price Merrett Consulting	Date:	17/09/2019
Project :	Levee Bank Investigation	Logged by:	RC & PB
Location :	Deniliquin		
Drill model :	Gemco HS7 Slope 90 deg	RL surface:	*Not measured*
Hole diameter :	100mm Bearing - deg	Datum :	-

Material Description	Depth (m)	Graphic log	Water	Moisture condition	Consistency density index	Structure, additional observations	Notes Samples Tests	Method	Support
FILL: GRAVEL (GW), fine to coarse, grey. 100mm				D	M/D	FILL			
FILL: Silty CLAY (CI-CH), medium to high plasticity, pale brown, brown, dark brown. 1500mm	0.25			M	Vst	FILL			
						DCP at 0.3m	DCP=12		
							DCP=13		
	0.50						DCP=20		
	0.75								
	1.00								
	1.25								
	1.50								
BH12 terminated at 1.5 metres									
	1.75								
	2.00								

ENGINEERING BOREHOLE LOG

PO Box 13, Strathdale 3550
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Borehole no. 15
Sheet no. 1 of 1
Job no. 19C 0796

Client :	Price Merrett Consulting	Date:	17/09/2019
Project :	Levee Bank Investigation	Logged by:	RC & PB
Location :	Deniliquin		
Drill model :	Gemco HS7	Slope 90 deg	RL surface: *Not measured*
Hole diameter :	100mm	Bearing - deg	Datum : -

Material Description	Depth (m)	Graphic log	Water	Moisture condition	Consistency density index	Structure, additional observations	Notes Samples Tests	Method	Support
FILL: (GW), fine to coarse, grey. 50mm				D	M/D	FILL			
FILL: Silty CLAY (CI-CH), medium to high plasticity, pale brown, brown, dark brown. 1500mm				M	Vst	FILL			
	0.25								
						DCP at 0.3m	DCP=16		
							DCP=12		
	0.50								
							DCP=14		
							DCP=10		
	0.75						DCP=4		
							DCP=6		
							DCP=6		
	1.00								
	1.25								
	1.50								
BH15 terminated at 1.5 metres									
	1.75								
	2.00								

ENGINEERING BOREHOLE LOG

Borehole no. 16
Sheet no. 1 of 1
Job no. 19C 0796

PO Box 13, Strathdale 3550
Ph (03) 54414881 Fax (03) 5441 5089

Client :	Price Merrett Consulting	Date:	17/09/2019
Project :	Levee Bank Investigation	Logged by:	RC & PB
Location :	Deniliquin		
Drill model :	Gemco HS7	Slope 90 deg	RL surface: *Not measured*
Hole diameter :	100mm	Bearing - deg	Datum : -

Material Description	Depth (m)	Graphic log	Water	Moisture condition	Consistency density index	Structure, additional observations	Notes Samples Tests	Method	Support
FILL: GRAVEL (GW), fine to coarse, grey, pale brown. 100mm				D	M/D	FILL			
FILL: silty CLAY (CI-CH), medium to high plasticity, pale brown, brown, dark brown. 1500mm				M	Vst	FILL			
	0.25					DCP at 0.2m	DCP=6		
							DCP=6		
							DCP=6		
	0.50						DCP=5		
							DCP=11		
	0.75						DCP=9		
							DCP=10		
	1.00								
	1.25								
	1.50								
BH16 terminated at 1.5 metres									
	1.75								
	2.00								

ENGINEERING BOREHOLE LOG

PO Box 13, Strathdale 3550
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Borehole no. 17
Sheet no. 1 of 1
Job no. 19C 0796

Client :	Price Merrett Consulting	Date:	17/09/2019
Project :	Levee Bank Investigation	Logged by:	RC & PB
Location :	Deniliquin		
Drill model :	Gemco HS7	Slope 90 deg	RL surface: *Not measured*
Hole diameter :	100mm	Bearing - deg	Datum : -

Material Description	Depth (m)	Graphic log	Water	Moisture condition	Consistency density index	Structure, additional observations	Notes Samples Tests	Method	Support
FILL: GRAVEL (GW), fine to coarse, grey. 100mm				D	M/D	FILL			
FILL: Silty CLAY (CH), medium to high plasticity, dark brown. 1200mm	0.25			M	Vst	FILL			
						DCP at 0.3m	DCP=7		
	0.50						DCP=9		
							DCP=10		
							DCP=8		
	0.75						DCP=8		
							DCP=10		
	1.00								
Silty CLAY (CH), high plasticity, brown. 1500mm	1.25			M	Vst	Soil Profile			
	1.50								
BH17 terminated at 1.5 metres									
	1.75								
	2.00								

ENGINEERING BOREHOLE LOG

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Borehole no. 18
Sheet no. 1 of 1
Job no. 19C 0796

Client :	Price Merrett Consulting	Date:	17/09/2019
Project :	Levee Bank Investigation	Logged by:	RC & PB
Location :	Deniliquin		
Drill model :	Gemco HS7	Slope 90 deg	RL surface: *Not measured*
Hole diameter :	100mm	Bearing - deg	Datum : -

Material Description	Depth (m)	Graphic log	Water	Moisture condition	Consistency density index	Structure, additional observations	Notes Samples Tests	Method	Support
FILL: GRAVEL (GW), fine to coarse, grey. 100mm				D	M/D	FILL			
FILL: Silty CLAY (CH), high plasticity, brown. 1500mm				M	Vst	FILL			
	0.25								
						DCP at 0.3m	DCP=5		
							DCP=9		
	0.50						DCP=11		
							DCP=9		
	0.75						DCP=10		
							DCP=10		
	1.00								
	1.25								
	1.50								
BH18 terminated at 1.5 metres									
	1.75								
	2.00								

ENGINEERING BOREHOLE LOG

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Borehole no. 19
Sheet no. 1 of 1
Job no. 19C 0796

Client :	Price Merrett Consulting	Date:	17/09/2019
Project :	Levee Bank Investigation	Logged by:	RC & PB
Location :	Deniliquin		
Drill model :	Gemco HS7	Slope 90 deg	RL surface: *Not measured*
Hole diameter :	100mm	Bearing - deg	Datum : -

Material Description	Depth (m)	Graphic log	Water	Moisture condition	Consistency density index	Structure, additional observations	Notes Samples Tests	Method	Support
FILL: GRAVEL (GW), fine to coarse, grey. 100mm				D	M/D	FILL			
FILL: Silty CLAY (CH), high plasticity, brown. 1500mm				M	Vst	FILL			
	0.25								
						DCP at 0.3m	DCP=10		
							DCP=7		
	0.50								
							DCP=6		
							DCP=5		
	0.75						DCP=5		
							DCP=6		
							DCP=10		
	1.00								
	1.25								
	1.50								
BH19 terminated at 1.5 metres									
	1.75								
	2.00								

ENGINEERING BOREHOLE LOG

PO Box 13, Strathdale 3550
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Borehole no. 20
Sheet no. 1 of 1
Job no. 19C 0796

Client :	Price Merrett Consulting	Date:	17/09/2019
Project :	Levee Bank Investigation	Logged by:	RC & PB
Location :	Deniliquin		
Drill model :	Gemco HS7 Slope 90 deg	RL surface:	*Not measured*
Hole diameter :	100mm Bearing - deg	Datum :	-

Material Description	Depth (m)	Graphic log	Water	Moisture condition	Consistency density index	Structure, additional observations	Notes Samples Tests	Method	Support
FILL: GRAVEL (GW), fine to coarse, grey 200mm				D	M/D	FILL			
FILL: Silty CLAY (CH), high plasticity, brown 1500mm	0.25			M	Vst	FILL			
						DCP at 0.3m	DCP=6		
							DCP=6		
	0.50						DCP=8		
							DCP=11		
	0.75						DCP=11		
							DCP=11		
	1.00								
	1.25								
	1.50								
BH20 terminated at 1.5 metres									
	1.75								
	2.00								

ENGINEERING BOREHOLE LOG

PO Box 13, Strathdale 3550
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Borehole no. 21
Sheet no. 1 of 1
Job no. 19C 0796

Client :	Price Merrett Consulting	Date:	17/09/2019
Project :	Levee Bank Investigation	Logged by:	RC & PB
Location :	Deniliquin		
Drill model :	Gemco HS7 Slope 90 deg	RL surface:	*Not measured*
Hole diameter :	100mm Bearing - deg	Datum :	-

Material Description	Depth (m)	Graphic log	Water	Moisture condition	Consistency density index	Structure, additional observations	Notes Samples Tests	Method	Support
FILL: GRAVEL (GW), fine to coarse, grey. 300mm	0.25			D	M/D	FILL			
FILL: Silty CLAY (CH), high plasticity, brown. 1500mm	0.50, 0.75, 1.00, 1.25, 1.50			M	Vst	DCP at 0.3m FILL	DCP=6 DCP=4 DCP=3 DCP=4 DCP=4 DCP=4 DCP=4		
BH21 terminated at 1.5 metres	1.75, 2.00								

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ENGINEERING BOREHOLE LOG

Borehole no. 22
Sheet no. 1 of 1
Job no. 19C 0796

PO Box 13, Strathdale 3550
Ph (03) 54414881 Fax (03) 5441 5089

Client :	Price Merrett Consulting			Date:	17/09/2019
Project :	Levee Bank Investigation			Logged by:	RC & PB
Location :	Deniliquin				
Drill model :	Gemco HS7	Slope	90 deg	RL surface:	*Not measured*
Hole diameter :	100mm	Bearing	- deg	Datum :	-

Material Description	Depth (m)	Graphic log	Water	Moisture condition	Consistency density index	Structure, additional observations	Notes Samples Tests	Method	Support
FILL: GRAVEL (GW), fine to coarse, grey 200mm				D	M/D	FILL			
FILL: Silty CLAY (CH), high plasticity, brown. 1500mm	0.25			M	Vst	FILL			
						DCP at 0.3m	DCP=4		
							DCP=5		
	0.50						DCP=6		
							DCP=6		
	0.75						DCP=9		
							DCP=8		
	1.00								
	1.25								
	1.50								
BH22 terminated at 1.5 metres									
	1.75								
	2.00								

Material Test Report

Report Number:	**19C 0796-1**
Issue Number:	1
Date Issued:	08/10/2019
Client:	Price Merrett Consulting P.O Box 313 , Kerang Vic 3579 VIC 3579
Project Number:	19C 0796
Project Name:	Levee Bank Investigation
Project Location:	Deniliquin
Work Request:	4978
Sample Number:	B19-4978A
Date Sampled:	18/09/2019
Dates Tested:	20/09/2019 - 08/10/2019
Sampling Method:	AS1289 1.2.1 6.5.3 - Power auger drilling
Sample Location:	**BH1 (400-1000m)**
Material:	Refer to Engineering Borehole Log

Geotechnical Testing Services (Southern)
Bendigo Soil and Concrete Testing Laboratory
Gate 7, Sharon Street Bendigo VIC 3550
Phone: (03) 5441 4881
Email: jeffm@gts.com.au

Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory: Jeffrey Mulholland
NATA Accredited Laboratory Number: 19556

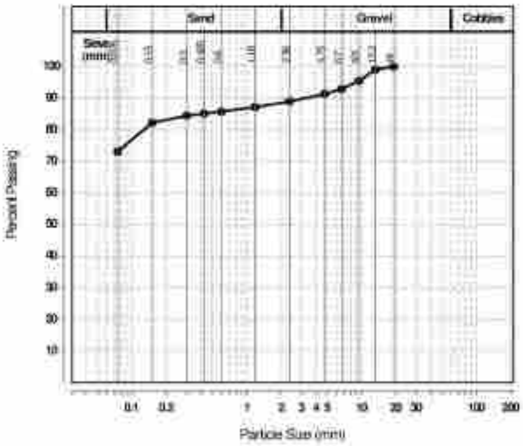
Particle Size Distribution (AS1289 3.6.1)						
Sieve	Passed %	Passing Limits		Retained %	Retained Limits	
19 mm	**100**			0		
13.2 mm	**99**			1		
9.5 mm	**95**			4		
6.7 mm	**93**			3		
4.75 mm	**91**			2		
2.36 mm	**89**			2		
1.18 mm	**87**			2		
0.6 mm	**86**			1		
0.425 mm	**85**			1		
0.3 mm	**84**			1		
0.15 mm	**82**			2		
0.075 mm	**73**			9		

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Sample History	Oven Dried		
Preparation Method	Dry Sieve		
Liquid Limit (%)	46		
Plastic Limit (%)	15		
Plasticity Index (%)	**31**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	13.0		
Cracking Crumbling Curling	Curling		

Emerson Class Number of a Soil (AS 1289 3.8.1)		Min	Max
Emerson Class	**2**		
Soil Description	Refer to Engineering Borehole Log		
Nature of Water	DISTILLED		
Temperature of Water (°C)	19		

Particle Size Distribution



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Material Test Report

Report Number:	**19C 0796-1**
Issue Number:	1
Date Issued:	08/10/2019
Client:	Price Merrett Consulting P.O Box 313 , Kerang Vic 3579 VIC 3579
Project Number:	19C 0796
Project Name:	Levee Bank Investigation
Project Location:	Deniliquin
Work Request:	4978
Sample Number:	B19-4978B
Date Sampled:	18/09/2019
Dates Tested:	20/09/2019 - 08/10/2019
Sampling Method:	AS1289 1.2.1 6.5.3 - Power auger drilling
Sample Location:	**BH2 (400-1000m)**
Material:	Refer to Engineering Borehole Log

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Approved Signatory: Jeffrey Mulholland
NATA Accredited Laboratory Number: 19556

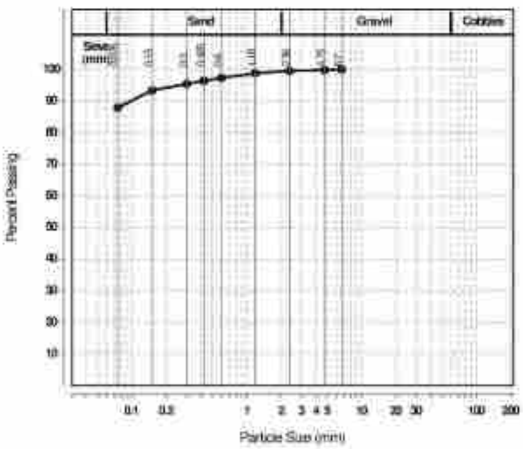
Particle Size Distribution (AS1289 3.6.1)							
Sieve	Passed %	Passing Limits		Retained %	Retained Limits		
6.7 mm	**100**			0			
4.75 mm	**100**			0			
2.36 mm	**100**			0			
1.18 mm	**99**			1			
0.6 mm	**97**			1			
0.425 mm	**96**			1			
0.3 mm	**95**			1			
0.15 mm	**93**			2			
0.075 mm	**88**			6			

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Sample History	Oven Dried		
Preparation Method	Dry Sieve		
Liquid Limit (%)	52		
Plastic Limit (%)	18		
Plasticity Index (%)	**34**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	13.0		
Cracking Crumbling Curling	Cracking & Curling		

Emerson Class Number of a Soil (AS 1289 3.8.1)		Min	Max
Emerson Class	**2**		
Soil Description	Refer to Engineering Borehole Log		
Nature of Water	DISTILLED		
Temperature of Water (°C)	19		

Particle Size Distribution



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Material Test Report

Report Number:	**19C 0796-1**
Issue Number:	1
Date Issued:	08/10/2019
Client:	Price Merrett Consulting P.O Box 313 , Kerang Vic 3579 VIC 3579
Project Number:	19C 0796
Project Name:	Levee Bank Investigation
Project Location:	Deniliquin
Work Request:	4978
Sample Number:	B19-4978C
Date Sampled:	18/09/2019
Dates Tested:	20/09/2019 - 08/10/2019
Sampling Method:	AS1289 1.2.1 6.5.3 - Power auger drilling
Sample Location:	**BH5 (400-1000m)**
Material:	Refer to Engineering Borehole Log

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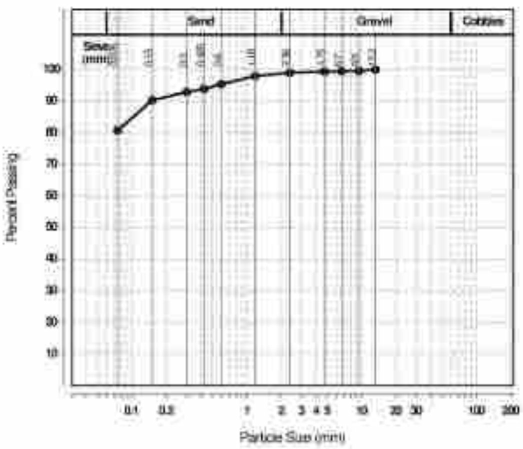
Particle Size Distribution (AS1289 3.6.1)						
Sieve	Passed %	Passing Limits		Retained %	Retained Limits	
13.2 mm	**100**			0		
9.5 mm	**100**			0		
6.7 mm	**99**			0		
4.75 mm	**99**			0		
2.36 mm	**99**			0		
1.18 mm	**98**			1		
0.6 mm	**95**			3		
0.425 mm	**94**			2		
0.3 mm	**93**			1		
0.15 mm	**90**			3		
0.075 mm	**81**			10		

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Sample History	Oven Dried		
Preparation Method	Dry Sieve		
Liquid Limit (%)	48		
Plastic Limit (%)	16		
Plasticity Index (%)	**32**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	10.5		
Cracking Crumbling Curling	Cracking & Curling		

Emerson Class Number of a Soil (AS 1289 3.8.1)		Min	Max
Emerson Class	**2**		
Soil Description	Refer to Engineering Borehole Log		
Nature of Water	DISTILLED		
Temperature of Water (°C)	19		

Particle Size Distribution



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Material Test Report

Report Number:	19C 0796-1
Issue Number:	1
Date Issued:	08/10/2019
Client:	Price Merrett Consulting P.O Box 313 , Kerang Vic 3579 VIC 3579
Project Number:	19C 0796
Project Name:	Levee Bank Investigation
Project Location:	Deniliquin
Work Request:	4978
Sample Number:	B19-4978D
Date Sampled:	18/09/2019
Dates Tested:	20/09/2019 - 08/10/2019
Sampling Method:	AS1289 1.2.1 6.5.3 - Power auger drilling
Sample Location:	**BH7 (400-1000m)**
Material:	Refer to Engineering Borehole Log

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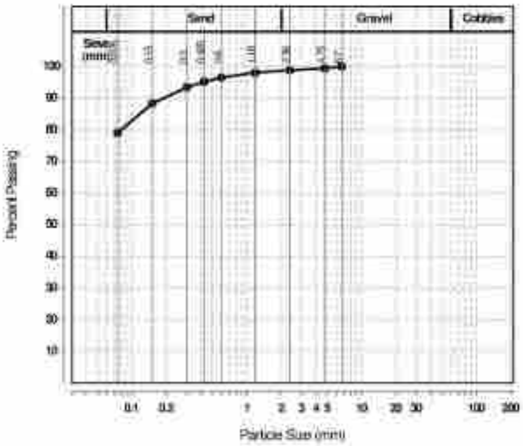
Particle Size Distribution (AS1289 3.6.1)						
Sieve	Passed %	Passing Limits		Retained %	Retained Limits	
6.7 mm	**100**			0		
4.75 mm	**99**			1		
2.36 mm	**99**			1		
1.18 mm	**98**			1		
0.6 mm	**97**			2		
0.425 mm	**95**			1		
0.3 mm	**93**			2		
0.15 mm	**88**			5		
0.075 mm	**79**			9		

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Sample History	Oven Dried		
Preparation Method	Dry Sieve		
Liquid Limit (%)	44		
Plastic Limit (%)	16		
Plasticity Index (%)	**28**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	12.5		
Cracking Crumbling Curling	Curling		

Emerson Class Number of a Soil (AS 1289 3.8.1)		Min	Max
Emerson Class	**2**		
Soil Description	Refer to Engineering Borehole Log		
Nature of Water	DISTILLED		
Temperature of Water (°C)	19		

Particle Size Distribution



Material Test Report

Report Number:	**19C 0796-1**
Issue Number:	1
Date Issued:	08/10/2019
Client:	Price Merrett Consulting P.O Box 313 , Kerang Vic 3579 VIC 3579
Project Number:	19C 0796
Project Name:	Levee Bank Investigation
Project Location:	Deniliquin
Work Request:	4978
Sample Number:	B19-4978E
Date Sampled:	18/09/2019
Dates Tested:	20/09/2019 - 08/10/2019
Sampling Method:	AS1289 1.2.1 6.5.3 - Power auger drilling
Sample Location:	**BH9 (400-1000m)**
Material:	Refer to Engineering Borehole Log

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NATA Accredited Laboratory Number: 19536

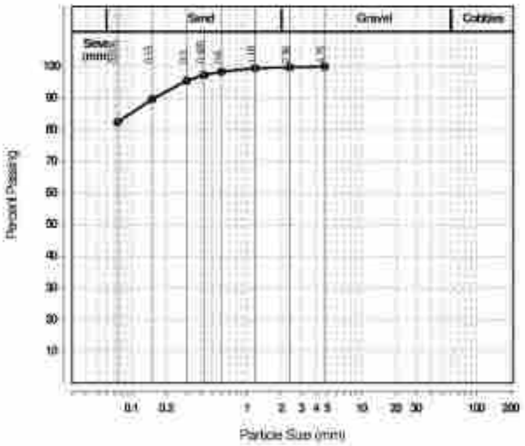
Particle Size Distribution (AS1289 3.6.1)						
Sieve	Passed %	Passing Limits		Retained %	Retained Limits	
4.75 mm	**100**			0		
2.36 mm	**100**			0		
1.18 mm	**99**			0		
0.6 mm	**98**			1		
0.425 mm	**97**			1		
0.3 mm	**96**			2		
0.15 mm	**90**			6		
0.075 mm	**82**			7		

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Sample History	Oven Dried		
Preparation Method	Dry Sieve		
Liquid Limit (%)	49		
Plastic Limit (%)	15		
Plasticity Index (%)	**34**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	14.5		
Cracking Crumbling Curling	Cracking & Curling		

Emerson Class Number of a Soil (AS 1289 3.8.1)		Min	Max
Emerson Class	**3**		
Soil Description	Refer to Engineering Borehole Log		
Nature of Water	DISTILLED		
Temperature of Water (°C)	19		

Particle Size Distribution



Material Test Report

Report Number:	19C 0796-1
Issue Number:	1
Date Issued:	08/10/2019
Client:	Price Merrett Consulting P.O Box 313 , Kerang Vic 3579 VIC 3579
Project Number:	19C 0796
Project Name:	Levee Bank Investigation
Project Location:	Deniliquin
Work Request:	4978
Sample Number:	B19-4978F
Date Sampled:	18/09/2019
Dates Tested:	20/09/2019 - 08/10/2019
Sampling Method:	AS1289 1.2.1 6.5.3 - Power auger drilling
Sample Location:	**BH11 (400-1000m)**
Material:	Refer to Engineering Borehole Log

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Approved Signatory: Jeffrey Mulholland
NATA Accredited Laboratory Number: 19596

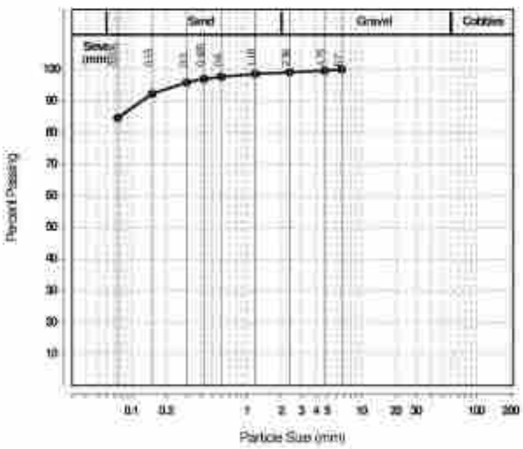
Particle Size Distribution (AS1289 3.6.1)						
Sieve	Passed %	Passing Limits		Retained %	Retained Limits	
6.7 mm	**100**			0		
4.75 mm	**100**			0		
2.36 mm	**99**			0		
1.18 mm	**99**			1		
0.6 mm	**98**			1		
0.425 mm	**97**			1		
0.3 mm	**96**			1		
0.15 mm	**92**			4		
0.075 mm	**85**			8		

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Sample History	Oven Dried		
Preparation Method	Dry Sieve		
Liquid Limit (%)	44		
Plastic Limit (%)	15		
Plasticity Index (%)	**29**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	12.0		
Cracking Crumbling Curling	Curling		

Emerson Class Number of a Soil (AS 1289 3.8.1)		Min	Max
Emerson Class	**3**		
Soil Description	Refer to Engineering Borehole Log		
Nature of Water	DISTILLED		
Temperature of Water (°C)	19		

Particle Size Distribution



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Material Test Report

Report Number: 19C 0796-1
Issue Number: 1
Date Issued: 08/10/2019
Client: Price Merrett Consulting
P.O Box 313 , Kerang Vic 3579 VIC 3579
Project Number: 19C 0796
Project Name: Levee Bank Investigation
Project Location: Deniliquin
Work Request: 4978
Sample Number: B19-4978G
Date Sampled: 18/09/2019
Dates Tested: 20/09/2019 - 08/10/2019
Sampling Method: AS1289 1.2.1 6.5.3 - Power auger drilling
Sample Location: **BH13 (400-1000m)**
Material: Refer to Engineering Borehole Log

Geotechnical Testing Services (Southern)
Bendigo Soil and Concrete Testing Laboratory
Gate 7, Sharon Street Bendigo VIC 3550
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Approved Signatory: Jeffrey Mulholland
NATA Accredited Laboratory Number: 19556

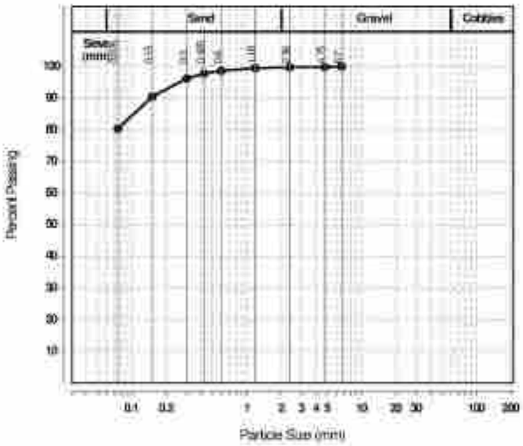
Particle Size Distribution (AS1289 3.6.1)							
Sieve	Passed %	Passing Limits		Retained %	Retained Limits		
6.7 mm	**100**			0			
4.75 mm	**100**			0			
2.36 mm	**100**			0			
1.18 mm	**99**			0			
0.6 mm	**99**			1			
0.425 mm	**98**			1			
0.3 mm	**96**			2			
0.15 mm	**90**			6			
0.075 mm	**80**			10			

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Sample History	Oven Dried		
Preparation Method	Dry Sieve		
Liquid Limit (%)	44		
Plastic Limit (%)	15		
Plasticity Index (%)	**29**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	12.0		
Cracking Crumbling Curling	Curling		

Emerson Class Number of a Soil (AS 1289 3.8.1)		Min	Max
Emerson Class	**3**		
Soil Description	Refer to Engineering Borehole Log		
Nature of Water	DISTILLED		
Temperature of Water (°C)	19		

Particle Size Distribution



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Material Test Report

Report Number:	19C 0796-1
Issue Number:	1
Date Issued:	08/10/2019
Client:	Price Merrett Consulting P.O Box 313 , Kerang Vic 3579 VIC 3579
Project Number:	19C 0796
Project Name:	Levee Bank Investigation
Project Location:	Deniliquin
Work Request:	4978
Sample Number:	B19-4978H
Date Sampled:	18/09/2019
Dates Tested:	20/09/2019 - 08/10/2019
Sampling Method:	AS1289 1.2.1 6.5.3 - Power auger drilling
Sample Location:	**BH15 (400-1000m)**
Material:	Refer to Engineering Borehole Log

Geotechnical Testing Services (Southern)
Bendigo Soil and Concrete Testing Laboratory
Gate 7, Sharon Street Bendigo VIC 3550
Phone: (03) 5441 4881
Email: jeffm@gts.com.au

Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory: Jeffrey Mulholland
NATA Accredited Laboratory Number: 19596

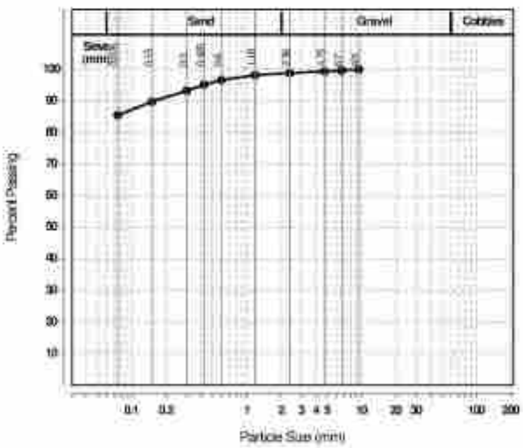
Particle Size Distribution (AS1289 3.6.1)						
Sieve	Passed %	Passing Limits		Retained %	Retained Limits	
9.5 mm	**100**			0		
6.7 mm	**100**			0		
4.75 mm	**99**			0		
2.36 mm	**99**			1		
1.18 mm	**98**			1		
0.6 mm	**97**			2		
0.425 mm	**95**			1		
0.3 mm	**93**			2		
0.15 mm	**90**			3		
0.075 mm	**85**			4		

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Sample History	Oven Dried		
Preparation Method	Dry Sieve		
Liquid Limit (%)	53		
Plastic Limit (%)	16		
Plasticity Index (%)	**37**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	15.0		
Cracking Crumbling Curling	Curling		

Emerson Class Number of a Soil (AS 1289 3.8.1)		Min	Max
Emerson Class	**2**		
Soil Description	Refer to Engineering Borehole Log		
Nature of Water	DISTILLED		
Temperature of Water (°C)	19		

Particle Size Distribution



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Material Test Report

Report Number:	**19C 0796-1**
Issue Number:	1
Date Issued:	08/10/2019
Client:	Price Merrett Consulting P.O Box 313 , Kerang Vic 3579 VIC 3579
Project Number:	19C 0796
Project Name:	Levee Bank Investigation
Project Location:	Deniliquin
Work Request:	4978
Sample Number:	B19-4978I
Date Sampled:	18/09/2019
Dates Tested:	20/09/2019 - 08/10/2019
Sampling Method:	AS1289 1.2.1 6.5.3 - Power auger drilling
Sample Location:	**BH17 (400-1000m)**
Material:	Refer to Engineering Borehole Log

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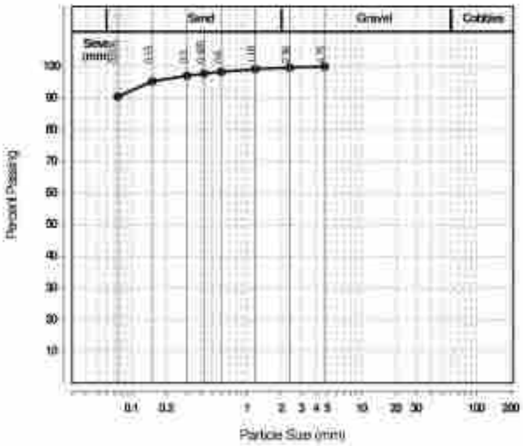
Particle Size Distribution (AS1289 3.6.1)						
Sieve	Passed %	Passing Limits		Retained %	Retained Limits	
4.75 mm	**100**			0		
2.36 mm	**100**			0		
1.18 mm	**99**			1		
0.6 mm	**98**			1		
0.425 mm	**98**			1		
0.3 mm	**97**			1		
0.15 mm	**95**			2		
0.075 mm	**90**			5		

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Sample History	Oven Dried		
Preparation Method	Dry Sieve		
Liquid Limit (%)	54		
Plastic Limit (%)	16		
Plasticity Index (%)	**38**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	12.5		
Cracking Crumbling Curling	Curling		

Emerson Class Number of a Soil (AS 1289 3.8.1)		Min	Max
Emerson Class	**3**		
Soil Description	Refer to Engineering Borehole Log		
Nature of Water	DISTILLED		
Temperature of Water (°C)	19		

Particle Size Distribution



Material Test Report

Report Number: 19C 0796-1
Issue Number: 1
Date Issued: 08/10/2019
Client: Price Merrett Consulting
P.O Box 313 , Kerang Vic 3579 VIC 3579
Project Number: 19C 0796
Project Name: Levee Bank Investigation
Project Location: Deniliquin
Work Request: 4978
Sample Number: B19-4978J
Date Sampled: 18/09/2019
Dates Tested: 20/09/2019 - 08/10/2019
Sampling Method: AS1289 1.2.1 6.5.3 - Power auger drilling
Sample Location: **BH19 (400-1000m)**
Material: Refer to Engineering Borehole Log

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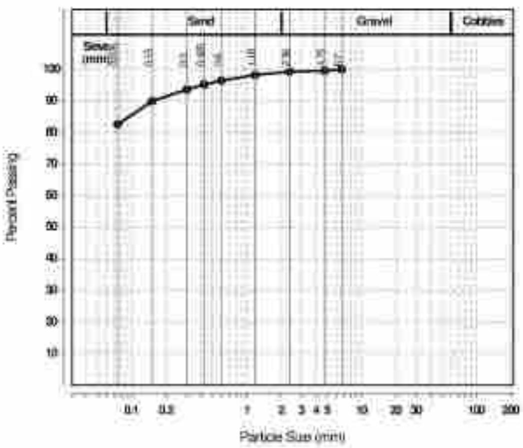
Particle Size Distribution (AS1289 3.6.1)						
Sieve	Passed %	Passing Limits		Retained %	Retained Limits	
6.7 mm	**100**			0		
4.75 mm	**100**			0		
2.36 mm	**99**			0		
1.18 mm	**98**			1		
0.6 mm	**96**			2		
0.425 mm	**95**			1		
0.3 mm	**94**			2		
0.15 mm	**90**			4		
0.075 mm	**83**			7		

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Sample History	Oven Dried		
Preparation Method	Dry Sieve		
Liquid Limit (%)	47		
Plastic Limit (%)	16		
Plasticity Index (%)	**31**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	11.0		
Cracking Crumbling Curling	Curling		

Emerson Class Number of a Soil (AS 1289 3.8.1)		Min	Max
Emerson Class	**3**		
Soil Description	Refer to Engineering Borehole Log		
Nature of Water	DISTILLED		
Temperature of Water (°C)	19		

Particle Size Distribution



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Material Test Report

Report Number:	19C 0796-1
Issue Number:	1
Date Issued:	08/10/2019
Client:	Price Merrett Consulting P.O Box 313 , Kerang Vic 3579 VIC 3579
Project Number:	19C 0796
Project Name:	Levee Bank Investigation
Project Location:	Deniliquin
Work Request:	4978
Sample Number:	B19-4978K
Date Sampled:	18/09/2019
Dates Tested:	20/09/2019 - 08/10/2019
Sampling Method:	AS1289 1.2.1 6.5.3 - Power auger drilling
Sample Location:	**BH21 (400-1000m)**
Material:	Refer to Engineering Borehole Log

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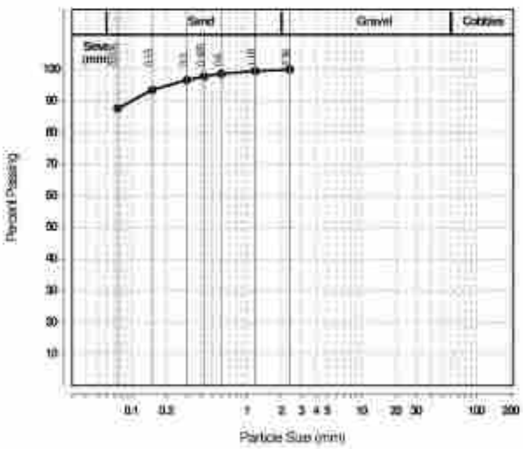
Particle Size Distribution (AS1289 3.6.1)						
Sieve	Passed %	Passing Limits		Retained %	Retained Limits	
2.36 mm	**100**			0		
1.18 mm	**100**			0		
0.6 mm	**99**			1		
0.425 mm	**98**			1		
0.3 mm	**97**			1		
0.15 mm	**94**			3		
0.075 mm	**88**			6		

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Sample History	Oven Dried		
Preparation Method	Dry Sieve		
Liquid Limit (%)	50		
Plastic Limit (%)	15		
Plasticity Index (%)	**35**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	13.5		
Cracking Crumbling Curling	Cracking & Curling		

Emerson Class Number of a Soil (AS 1289 3.8.1)		Min	Max
Emerson Class	**3**		
Soil Description	Refer to Engineering Borehole Log		
Nature of Water	DISTILLED		
Temperature of Water (^{o}C)	19		

Particle Size Distribution



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Material Test Report

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Issue Number:	1
Date Issued:	08/10/2019
Client:	Price Merrett Consulting P.O Box 313 , Kerang Vic 3579 VIC 3579
Project Number:	19C 0796
Project Name:	Levee Bank Investigation
Project Location:	Deniliquin
Work Request:	4978
Sample Number:	B19-4978L
Date Sampled:	18/09/2019
Dates Tested:	20/09/2019 - 08/10/2019
Sampling Method:	AS1289.1.2.1 6.5.3 - Power auger drilling
Sample Location:	**BH22 (400-1000m)**
Material:	Refer to Engineering Borehole Log

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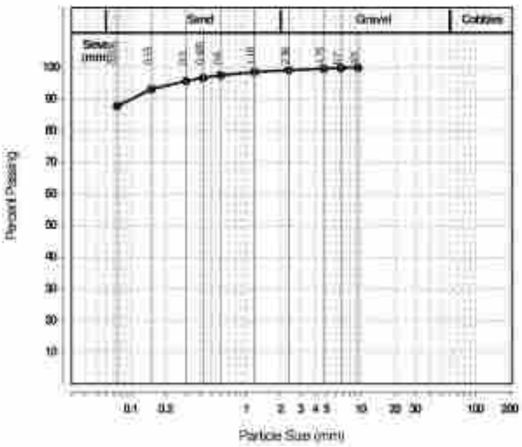
Particle Size Distribution (AS1289 3.6.1)							
Sieve	Passed %	Passing Limits		Retained %	Retained Limits	
9.5 mm	**100**			0		
6.7 mm	**100**			0		
4.75 mm	**100**			0		
2.36 mm	**99**			0		
1.18 mm	**99**			1		
0.6 mm	**98**			1		
0.425 mm	**97**			1		
0.3 mm	**96**			1		
0.15 mm	**93**			3		
0.075 mm	**88**			5		

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Sample History	Oven Dried		
Preparation Method	Dry Sieve		
Liquid Limit (%)	50		
Plastic Limit (%)	16		
Plasticity Index (%)	**34**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	11.0		
Cracking Crumbling Curling	Curling		

Emerson Class Number of a Soil (AS 1289 3.8.1)		Min	Max
Emerson Class	**2**		
Soil Description	Refer to Engineering Borehole Log		
Nature of Water	DISTILLED		
Temperature of Water (°C)	19		

Particle Size Distribution



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Material Test Report

Report Number: 19C 0796-1
Issue Number: 1
Date Issued: 08/10/2019
Client: Price Merrett Consulting
P.O Box 313 , Kerang Vic 3579 VIC 3579
Project Number: 19C 0796
Project Name: Levee Bank Investigation
Project Location: Deniliquin
Work Request: 4978
Dates Tested: 20/09/2019 - 20/09/2019

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Moisture Content AS 1289 2.1.1

Sample Number	Sample Location	Moisture Content (%)	Material
B19-4978A	BH1 (400-1000m)	14.7 %	Refer to Engineering Borehole Log
B19-4978B	BH2 (400-1000m)	14.2 %	Refer to Engineering Borehole Log
B19-4978C	BH5 (400-1000m)	12.7 %	Refer to Engineering Borehole Log
B19-4978D	BH7 (400-1000m)	15.0 %	Refer to Engineering Borehole Log
B19-4978E	BH9 (400-1000m)	14.5 %	Refer to Engineering Borehole Log
B19-4978F	BH11 (400-1000m)	14.1 %	Refer to Engineering Borehole Log
B19-4978G	BH13 (400-1000m)	14.4 %	Refer to Engineering Borehole Log
B19-4978H	BH15 (400-1000m)	13.4 %	Refer to Engineering Borehole Log
B19-4978I	BH17 (400-1000m)	15.9 %	Refer to Engineering Borehole Log
B19-4978J	BH19 (400-1000m)	15.1 %	Refer to Engineering Borehole Log
B19-4978K	BH21 (400-1000m)	17.4 %	Refer to Engineering Borehole Log
B19-4978L	BH22 (400-1000m)	17.8 %	Refer to Engineering Borehole Log

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