SORELL STORMWATER SYSTEM MANAGEMENT PLAN

Volume 4 - Stormwater System Management Plan

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Executive summary

The Sorell Stormwater System Management Plan has been prepared for Sorell Council to assist with meeting the requirements as legislated in the Urban Drainage Act 2013. The SSMP will be used by Council as the basis for future management of the stormwater drainage systems and floodplain risk within the extent of the study area.

This study has been prepared to address three subject areas of interest:

- Sorell – comprising the township of Sorell and catchments immediately north of Sorell
- Midway – comprising the locality of Midway Point; and
- Southern Beaches – comprising the urban areas of Lewisham, Dodges Ferry, Carlton, Primrose Sands, Connellys Marsh and Dunalley.

The Sorell SSMP comprises four reports that address the three subject areas of interest and combined analysis of stormwater management measures and management plan, as follows:

- Volume 1 – Sorell Hydrologic and Hydraulic Capacity Assessment (report ENTURA-11227D)
- Volume 2 – Midway Hydrologic and Hydraulic Capacity Assessment (report ENTURA-112A2B)
- Volume 3 – Southern Beaches Hydrologic and Hydraulic Capacity Assessment (report ENTURA-11316A)
- Volume 4 – Stormwater System Management Plan (this report)

This report details the preparation of the SSMP, comprising analysis of a range of structural and non-structural management measures, culminating with a suite of recommended management measures and associated program for implementation.

Flooding problem locations

The outputs from the *Hydrologic and Hydraulic Capacity Assessments* have been used to identify locations across the areas of interest that are considered to have potential flooding problems (i.e. existing flood risk), particularly where the flooding is likely to result in property damage or present a risk to people.

Existing stormwater management for flood risk

There are a number of current stormwater management activities undertaken by Council where these can be separated into four key categories:

- Council's capital works program as related to stormwater management;
- Policies, strategies, planning controls;
- Community awareness and alerts; and
- Emergency planning and response.

These current activities have been taken into account as part of the process of identifying potential flood risk management measures for inclusion in the SSMP.

Potential flood risk management measures

A range of measures for the management of flood risk have been assessed for the areas of interest to address flooding from stormwater. These measures have been designed with the aim of reducing the social, environmental and economic impacts of flooding. The range of measures assessed in this study have been guided by the *Australian Disaster Resilience Handbook 7 Managing the Floodplain: A Guide to Best Practice in Flood Risk Management* (AIDR, 2017a), where this guide outlines a general range of potential measures that are suitable for the management of flood risk for existing and future development. The design of the measures assessed in the study has also sought to achieve the design standards set out in the *Sorell Interim Planning Scheme 2015*. The recommended suite of management measures includes both structural and non-structural measures.

Economic assessment of management measures

Structural management measures have been modelled to quantify the changes in flooding behaviour, including an estimate of the reduction in economic damages due to flooding. An estimate of the capital cost for these works has also been estimated and combined with the reduction in flood damages to determine a benefit:cost ratio for each structural measure. The cost estimates are commensurate with the level of detail required for this study and must be refined as part of preliminary and detailed design to ensure more accurate costs are obtained. Council should not rely on these figures for budgeting without consideration of all the potential costs and risks, noting that the final constructed cost may be higher than the cost estimates provided herein.

Multi-criteria assessment of management measures

The relative benefits of each management measure have been assessed with a multi-criteria analysis, where the criteria applied cover a range of economic, social and environmental categories. The combination of relative importance of each criterion and weighting assigned to that criterion for each management measure permits a total score to be calculated, permitting a rank to be assigned for each management measure. This rank has been used to infer priorities for implementation as part of the stormwater system management plan.

Water quality assessment

An assessment has been undertaken to understand existing water quality issues for runoff from the stormwater catchments, where this assessment has relied on outputs from the hydraulic modelling exercise and the previous Sorell Stormwater Management Plan prepared in 2011. Excluding strategies that have already been implemented, the strategies from the 2011 study are recommended for adoption in this current SSMP. Additional opportunities and measures for the management of water quality have also been identified where these measures have considered to issues identified in preparing this SSMP and the suite of recommended flood risk management measures.

Recommended Stormwater System Management Plan

The suite of recommended measures for the management of flood risk for the area of interest are summarised in the tables below for:

- Flood modification / structural management measures
- Property-scale management measures
- Community / catchment-scale management measures.

The recommended management measures have been derived through consideration of the results of the multi-criteria analysis (i.e. relative ranking of each potential management measure) and effectiveness of the measures at reducing flood risk. On this basis, some of the potential management measures discussed in Section 5 are not explicitly recommended for inclusion in the stormwater system management plan.

Recommended flood modification/structural management measures

ID	Description	Estimated Capital Cost (NPV)	Priority
	Tasman Highway at Stores Lane #	TBC	High
FM-SOR-01	Drainage Upgrade 1 - Channel Works	($84,000)	
FM-SOR-02	Drainage Upgrade 2 - Channel Works + Cross Drainage	($331,000)	
FM-SOR-03	Detention Basin	($292,000)	
FM-SOR-04	Drainage Upgrade – Devenish Drive to Montagu Street Outfall	$4,523,000	High
FM-SOR-05	Detention basin – south of Valley View Drive	$912,000	High
FM-SBS-01	Drainage Upgrade – Old Forcett Road near Lewisham Scenic Drive	$360,000	Low
FM-SBS-02	Drainage Upgrade – Intersection of Okines Road and Old Forcett Road to outlet	$2,291,000	Medium
FM-SBS-03	Drainage Upgrade – cross-drainage adjacent to 542 Old Forcett Road	$826,000	Low
FM-SBS-04	Drainage Upgrade – combination of FM-SBS-02 and FM-SBS-03	$3,116,000	Medium
FM-SBS-05	Drainage Upgrade –western side of Old Forcett Road at Dodges Ferry Recreation Park	$473,000	Low
FM-SBS-06	Drainage Upgrade – Carlton Beach Road and Seventh Avenue to outfall	$1,385,000	Medium
FM-SBS-07	Drainage Upgrade – Mongana Street to Blue Lagoon, crossing Carlton Beach Road	$1,200,000	Low
FM-SBS-08	Fence removal – flow path west of Signal Hill Road	$0	High
FM-SBS-09	Fence removal – western side of Moomere Street	$0	Medium
FM-SBS-10	Drainage Upgrade – Freedom Close to estuary via new overland flow path	$551,000	Medium
FM-SBS-14	Drainage Upgrade – Primrose Sands Road cross-drainage adjacent to the RSL	$325,000	Low
FM-SBS-15	Warning signage – Fulham Road	$6,000	Medium
FM-SBS-16	Drainage Upgrade – Gilpins Creek cross-drainage culvert at Church Street West	$349,000	Low

Recommended property-scale management measures

ID	Description	Estimated Capital Cost (NPV)	Priority
PS-01	Individual house raising	n/a	Low
PS-03	Flood Proofing of Buildings	n/a	Medium
PS-04	Planning and Development Controls	Staff Time	High

Recommended community/catchment-scale management measures

ID	Description	Estimated Capital Cost (NPV)	Priority
CS-01	Enhanced Flood/Storm Warning	Staff Time	Medium
CS-02	Enhanced Emergency Response	Staff Time	High
CS-03	Community Awareness and Readiness Program	Staff Time	High

Program for implementation

An indicative program for implementation for the recommended measures for managing flood risk has been prepared on the basis that measures with 'high' priority are to be implemented during the first 5-year period, 'medium' priority to be implemented over years 5-15, and 'low' priority over years 15-20 and beyond.

Sources of funding

Implementation of certain elements of the SSMP may be possible with one-off sources of funding at a given point in time (e.g. government grant). However, as suggested by Reese (2017), the successful implementation of the SSMP will require funding that is stable, adequate, flexible and equitable (SAFE), thereby ensuring funding allocated solely for this purpose over the life-cycle of Council's capital works program. It is therefore considered important to seek funding from a range of sources to ensure the successful implementation of the SSMP. Potential sources of funding for further analysis and implementation of the SSMP have been identified.

ID	Locality	Description
FM-SOR-01/02/03	Sorell	Tasman Highway at Stores Lane
FM-SOR-04	Sorell	Drainage Upgrade - Devenish Drive to Montagu Street Outfall
FM-SOR-05	Sorell	Detention Basin - South of Valley View Drive
FM-SOR-06	Sorell	Drainage Upgrade - Weston Hill Road near Valley View Road
FM-SBS-01	Dodges Ferry	Drainage upgrade - Old Forcett Rd near Lewisham Scenic Drive
FM-SBS-02	Dodges Ferry	Drainage upgrade - Intersection of Okines Rd and Old Forcett Rd to outlet
FM-SBS-03	Dodges Ferry	Drainage upgrade - cross-drainage adjacent to 542 Old Forcett Rd
FM-SBS-04	Dodges Ferry	Drainage upgrade - Combination of FM_SBS_02 and FM_SBS_03
FM-SBS-05	Dodges Ferry	Drainage upgrade - Western side of Old Forcett Road at Dodges Ferry Recreation Park
FM-SBS-06	Dodges Ferry	Drainage upgrade - Carlton Beach Road and Seventh Avenue to outfall
FM-SBS-07	Dodges Ferry	Drainage upgrade - Mongana St to Blue Lagoon, crossing Carlton Beach Rd
FM-SBS-08	Dodges Ferry	Fence removal - Flow path west of signal Hill Rd
FM-SBS-09	Carlton	Fence removal - Western side of Moomere St
FM-SBS-10	Carlton	Drainage upgrade - Freedom Close to estuary via new overland flow path
FM-SBS-11	Primrose Sands	Defences - Terrain raising to prevent water spilling across the Esplanade to Tamarix Rd area
FM-SBS-12	Primrose Sands	Drainage upgrade - Increased capacity for Carlton Bluff Rd drainage
FM-SBS-13	Primrose Sands	Defences + drainage upgrade - Combination of FM_SBS_11 and FM_SBS_12
FM-SBS-14	Primrose Sands	Drainage upgrade - Primrose Sands Rd cross-drainage adjacent to the RSL
FM-SBS-15	Dunalley	Warning signage - Fulham Rd
FM-SBS-16	Dunalley	Drainage upgrade - Gilpins Creek cross-drainage culvert at Church St West
PS-01	Municipality-wide	Individual House Raising
PS-02	Municipality-wide	Government House Buyback
PS-03	Municipality-wide	Flood Proofing of Buildings
PS-04	Municipality-wide	Planning and Development Controls
CS-01	Municipality-wide	Enhanced Flood/Storm Warning
CS-02	Municipality-wide	Enhanced Emergency Response
CS-03	Municipality-wide	Community Awareness and Flood Readiness

Program for implementation of recommended measures for managing flood risk

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1. Introduction

Sorell Council is responsible for the provision and management of public stormwater systems within its municipal area. A stormwater system management plan (SSMP) for the Sorell, Midway Point and Southern Beaches area of interest have been prepared to assist with meeting the requirements as legislated in the Urban Drainage Act 2013. The SSMP will be used by Council as the basis for future management of the stormwater drainage systems and floodplain risk across the urban areas of the Sorell municipality.

The Sorell SSMP comprises four reports that address the three subject areas of interest (Sorell, Midway and Southern Beaches) and combined analysis of stormwater management measures and management plan, as follows:

- Volume 1 – Sorell Hydrologic and Hydraulic Capacity Assessment (report ENTURA-1127D)
- Volume 2 – Midway Hydrologic and Hydraulic Capacity Assessment (report ENTURA-112A2B)
- Volume 3 – Southern Beaches Hydrologic and Hydraulic Capacity Assessment (report ENTURA-11316A)
- **Volume 4 – Stormwater System Management Plan (this report)**

This report details the preparation of the SSMP, comprising analysis of a range of structural and non-structural management measures, culminating with a suite of recommended management measures and associated program for implementation.

1.1 The Urban Drainage Act 2013

The Urban Drainage Act of 2013 (the Act) replaces the Drains Act of 1954 and provides for the management of urban drainage, stormwater systems and infrastructure in Tasmania. It expands on the traditional view of stormwater management as solely concerned with the collection and removal of runoff to minimise urban flooding to also be sustainable and environmentally responsible. This means that stormwater will be considered in the context of catchment management, ecosystem health, safety and social amenity.

To achieve this, the Act clearly establishes that the responsibility of urban drainage lies with the relevant council. They are required to develop a SSMP which gives a clear strategy for the delivery of stormwater services, flood risk identification, asset management and other matters.

1.2 Study area location

The three areas of interest are shown in Figure 1.1, with the modelled extents for each shown in Figure 1.2 (Sorell), Figure 1.3 (Midway) and Figure 1.4 (Southern Beaches).

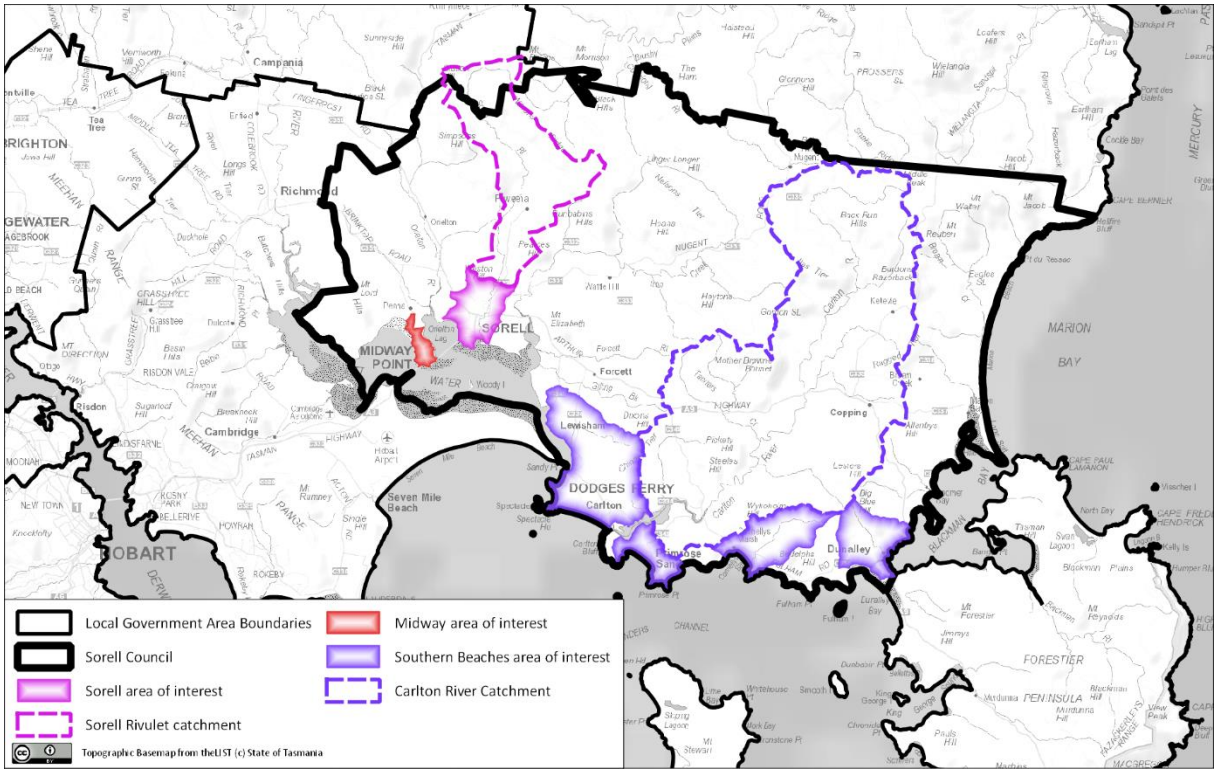

Figure 1.1: Sorell SSMP areas of interest

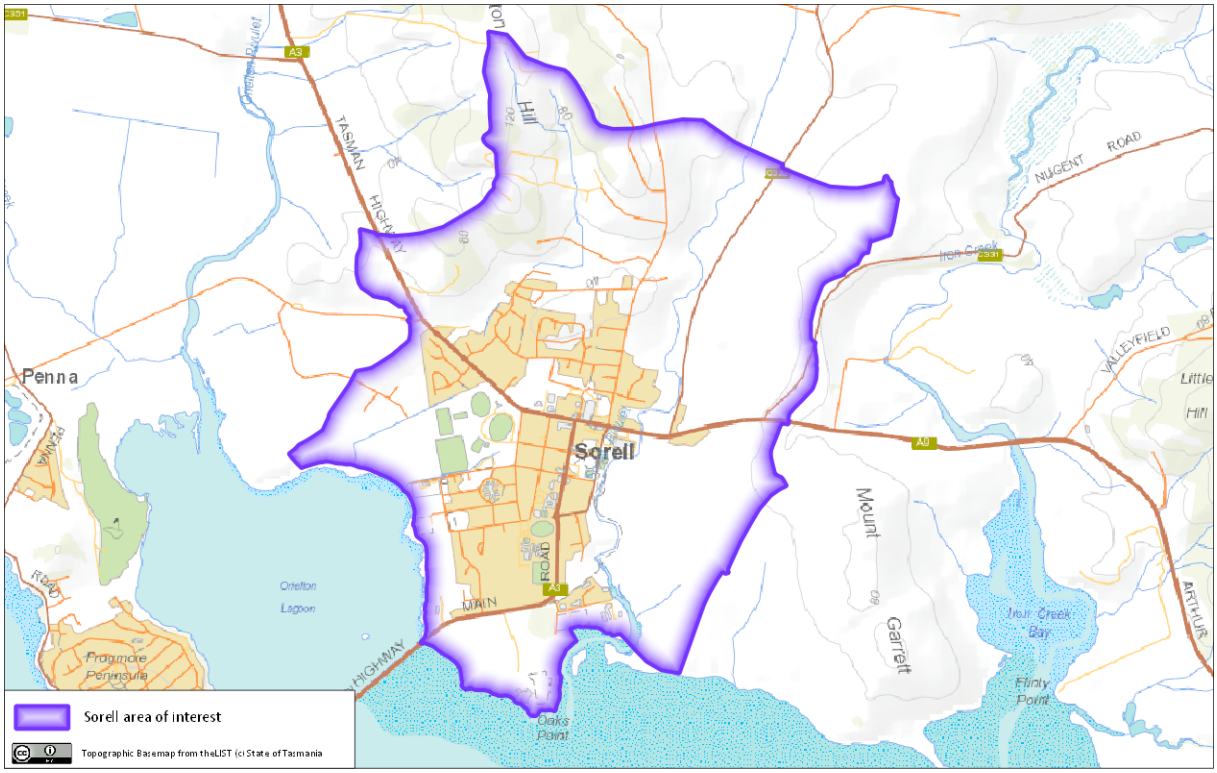

Figure 1.2: Sorell area of interest

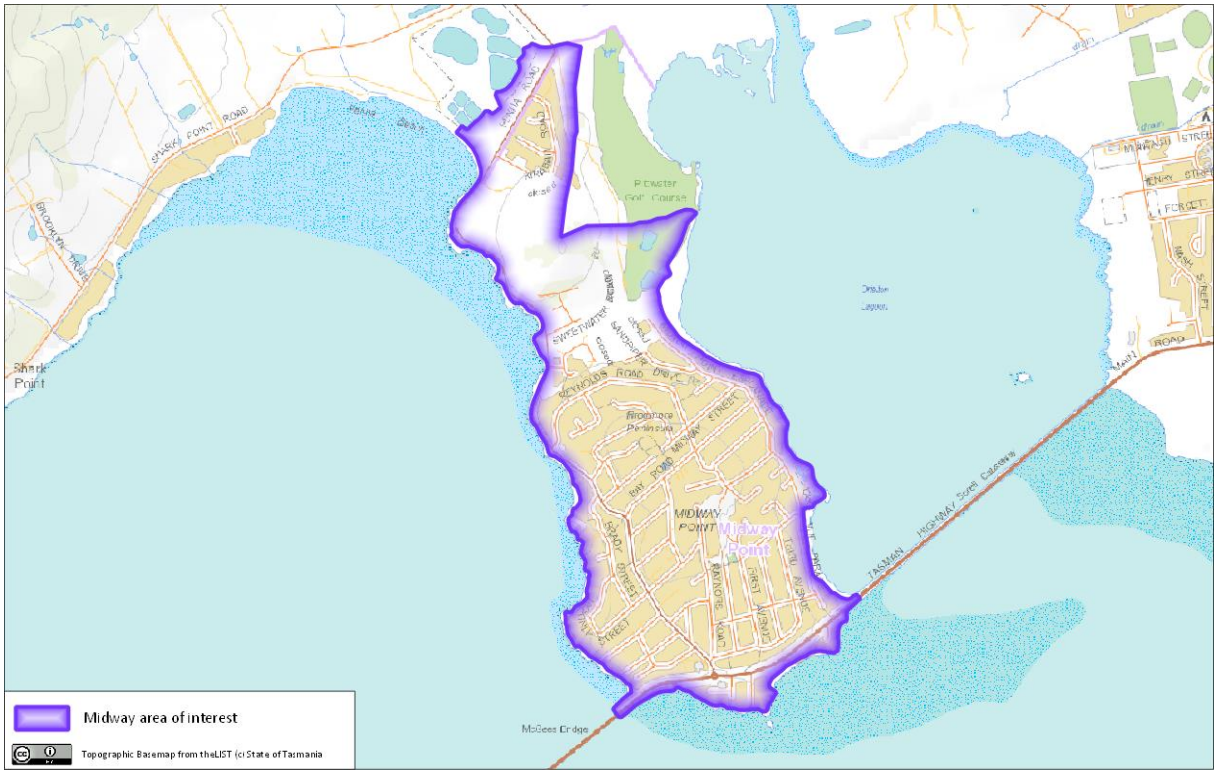

Figure 1.3: Midway area of interest

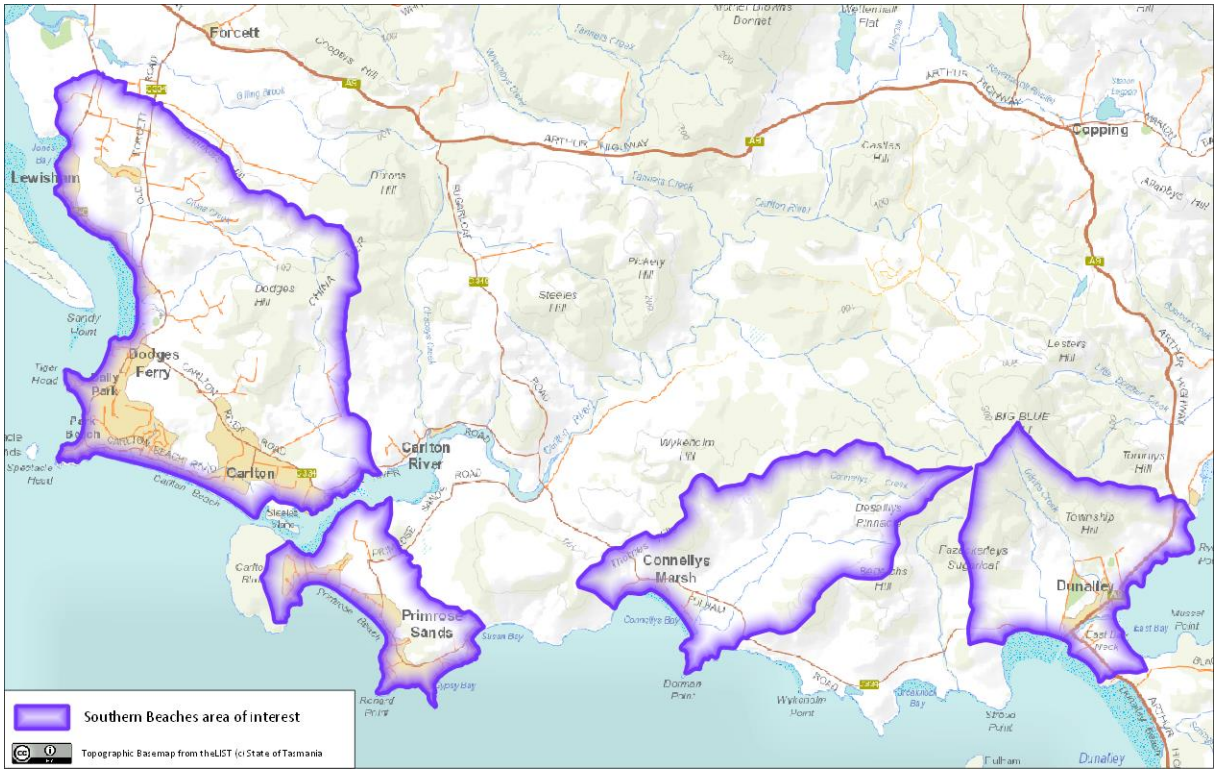

Figure 1.4: Southern Beaches area of interest

1.3 Study objectives

The purpose of developing the SSMP is to ensure there is an appropriate level of understanding and management of the flood risk and public stormwater systems across the urban areas of the Sorell municipality. The SSMP will be used as the basis for developing and prioritising future capital works and potential developer contributions, forecasting and preparing budgets and specifying cost apportionment arrangements between Council, State Government and other stakeholders (e.g. developers).

To ensure these outcomes are achieved the SSMPs shall:

- Set out clearly the objectives for managing stormwater in urban catchments;
- Define the existing and future flood behaviour from the local catchment runoff;
- Identify the overland flow paths and associated flood affected (flood prone) land within the catchment;
- Identify specific works, measures or actions to manage and mitigate flooding from overland flow paths, whilst also providing justification for these measures;
- Provide estimates of the capital and recurrent costs of works, measures or actions, with priorities and timeframes assigned to each of these measures;
- Define the obligation of the relevant stakeholders in funding, implementing and communicating the plans.

A key component of the SSMP is the development of detailed hydrologic and hydraulic models that incorporate the piped stormwater drainage systems and overland flow paths across the catchments. These models and the other outputs of the SSMP will adhere to the core principles outlined by Council, namely to:

- Understand the level of risk in the public stormwater system within the urban area;
- Apply a risk management framework for flood mitigation and stormwater renewal works based on analysis of defined flood events;
- Ensure stormwater systems are planned, designed and built with appropriate consideration of stormwater management principles by making better use of the statutory development and planning system;
- Build resilience and consider climate change impacts to address future demands on the urban stormwater system;
- Integrate stormwater management into the urban water cycle to achieve the goals of social, environmental and economic sustainability; and
- Enhance community awareness of, and participation in, the appropriate management of stormwater.

2. The study area

2.1 Introduction

This report section summarises key characteristics and details of each of the defined areas of interest, where these details have been taken from the respective Hydrology and Hydraulic Assessment reports (refer to Section 1 for document references).

2.2 Catchment description and known flooding problems

2.2.1 Sorell area of interest

The Sorell area of interest includes the Sorell Rivulet, the township of Sorell and the immediate surrounding areas to the north of the township, which contains multiple farm dams in sequence.

The Sorell stormwater catchment has an approximate area of approximately 800 ha. The catchment comprises predominantly General Residential and Low Residential land-use zones, but also has large areas zoned Rural Resource, Rural Living, General Business and Community Purpose. Sorell Rivulet passes along the eastern side of Sorell and has a catchment area of approximately 4,150 ha.

Known flooding and/or stormwater drainage issues include:

- Inadequate flow carrying capacity of the stormwater network comprising piped and open channel elements in the vicinity of Valley View Close, Pennington Drive and Devenish Drive, creating a potential flooding risk for existing infrastructure, houses and people;
- Potential failure of farm dams located north of Valley View Close;
- All stormwater outfalls within the Sorell area of interest discharge to RAMSAR protected waterways;
- Acid sulphate soils / tunnel erosion affecting outfalls in areas surrounding Orielton Lagoon;
- Existing structures on Sorell Rivulet that may affect flooding (including Arthur Highway Bridge, pedestrian footbridge, weir at Pioneer Park, causeway).

2.2.2 Midway area of interest

The Midway area of interest comprises the locality of Midway Point which occupies the Frogmore Peninsula, and is bounded by the Orielton Lagoon to the east and Pitt Water to the south and west. The area of interest has an area of approximately 190 hectares and comprises predominantly General Residential land-use zones, with some small areas of community purpose, open space and recreation.

There are no known flooding and/or stormwater drainage issues across the Midway area of interest.

2.2.3 Southern Beaches area of interest

The Southern Beaches area of interest includes the localities of Lewisham, Dodges Ferry, Carlton, Primrose Sands, Connellys Marsh and Dunalley, and developed areas fronting the lower reaches of the Carlton River.

Excluding the Carlton River catchment, the Southern Beaches area of interest as modelled in this study has a combined catchment area of 4,580 ha. The catchment comprises predominately Rural Resource and Rural living land-use zones, however within each of the localities there are areas of General Residential and Low-Density Residential land-use zones. The Carlton River discharges to Frederick Henry Bay at the south-eastern extent of Carlton Beach, and has a catchment area of approximately 160 km^2 (calculated to the upstream modelled extent of the stormwater catchments).

Known flooding and/or stormwater drainage issues include:

- General lack of roadside drainage in areas which were predominantly shacks or non-permanent residences and are now full-time permanent residences (e.g. Primrose Sands and Carlton River);
- Residential roads that have been sealed with no stormwater infrastructure and some houses below the road level that receive runoff from the road (e.g. Fifth Avenue, Eighth Avenue (Dodges Ferry); Kestrel Street, (Primrose Sands));
- Undersized driveway culverts;
- Erosion of steep unsealed driveways leading to blockage of stormwater infrastructure further downstream;
- Development encroaching to low lying areas (e.g. Lewis Court, Kannah Street (Blue Lagoon), Carlton Beach Road, River Street and Tamarix Road);
- Areas of development in trapped sag points, including areas landwards of dune systems;
- Acid sulphate soils / tunnel erosion affecting infrastructure in areas surrounding Carlton River, Primrose Sands and Connellys Marsh; and
- Potential for future water quality issues arising from inadequate waste disposal infrastructure.

2.3 Development trends

The municipality of Sorell is experiencing one of the highest growth rates in Tasmania, with the population expected to increase by approximately 26% in the next 20 years. Council has recognised the importance that enough land is available to house these additional residents, and has previously commissioned the development of a Land Supply Strategy (Ancell et al., 2017) to address:

- Land supply and demand analysis for residential, industrial and commercial land;
- Potential expansion options for residential, industrial and commercial land; and
- Preparation of masterplans for the identified expansion options.

This expected increase in population and resulting new development is likely to result in an increase in both infill and greenfield development. It follows that this future increase in developed land will impact the existing stormwater drainage system and should be planned for accordingly.

The Southern Beaches area of interest differs from the Sorell and Midway areas of interest as it comprises predominantly rural properties and former shack/holiday dwellings now occupied by permanent residents. Any future increase in population in this area of interest will place further pressure on the limited existing infrastructure in the region which has typically been developed in an ad hoc manner.

2.4 Climate and impacts of climate change

Tasmania has a temperate maritime climate. Data published by the Bureau of Meteorology[1] indicates that the maximum average temperature for the study area varies between 12.4°C in July and 22.5°C in January. The average annual rainfall across the study area is around 550mm.

It is widely accepted that climate change is happening on a global scale. The Climate Futures for Tasmania report of general climate impacts (ACE CRC, 2010) summarises the known changes in Tasmania's climate up to 2010 as follows:

- Tasmanian temperatures have risen since the 1950s, though at a slower rate than mainland Australia;
- There has been a reduction in total annual rainfall in Tasmania and a change in year-to-year rainfall variability since 1975. This reduction has been greatest in autumn, and is similar to other regions of southern Australia;
- There have been shifts in the large-scale climate drivers over the Australasian region in the last fifty years, with some studies showing that the subtropical ridge of high pressure north of Tasmania has moved southward and has intensified in recent decades. There has been an increase in the frequency of El Niño events and a strengthening of the Southern Annular Mode. Atmospheric blocking in summer has also increased; and
- Changes in Tasmania's rainfall appear to be linked to these climate drivers, although the contribution from each driver and the combination of drivers is still not fully understood.

The same report also summarises the likely future climate conditions (relevant to this study) as follows:

- Over the 21st century, Tasmanian temperature is projected to rise by between 1.6°C and 2.9°C. This is less than the projected global average temperature rise due to the moderating influence of the Southern Ocean;
- Projections of future rainfall patterns across Tasmania indicate increased rainfall over the coastal regions, and reduced rainfall over central Tasmania and in the north-west of Tasmania; and
- The frequency and intensity of extreme events (including rainfall/floods) are likely to increase.

The Southern Tasmania Regional Land Use Framework Background Report No. 3: A Changing Climate (Southern Tasmania Councils Authority, 2011) identifies the likely hazards arising from future climate change (as derived from The State of the Environment Report for Tasmania 2009 (Tasmanian Planning Commission, 2009)) which include:

- Rising sea levels;
- Changed nature and frequency of exceptional climatic events;

[1] http://www.bom.gov.au/climate/

- Changes in short-term climatic cycles; and
- An increased number of high rainfall events.

Whilst the projected changes to the climate (specifically, temperature, rainfall and evaporation) will have long-term consequences for the Sorell area of interest, it will be through extreme weather events that the impacts of climate change will be most experienced. It is likely that compared with the current climate, the future climate will result in prolonged dry periods followed by more intense storms, and that these storms will occur more frequently.

There is uncertainty about the future climate, with different climate models and assumptions about human behaviour leading to different results in terms of changes in rainfall and sea levels. Notwithstanding, there is agreement about the magnitude of changes over the next 80 years.

2.5 Soils and underlying geology

Characteristics of the soils and geology across the study area are summarised in the *Hydrology and Hydraulic Assessment* reports (refer to Section 1 for document references).

2.6 Tidal conditions

Flooding of the lower elevations of the study area with reference to tidal interaction is characterised for the defined areas of interest as follows:

- Sorell area of interest: Lower elevations generally characterised by the shoreline fronting Orielton Lagoon, Pitt Water and the lower reaches of Sorell Rivulet, where flooding is influenced by elevated water levels within these bodies of water;
- Midway area of interest: Lower elevations generally characterised by the shoreline fronting Orielton Lagoon and Pitt Water, where flooding is influenced by elevated water levels within these bodies of water; and
- Southern Beaches area of interest: Lower elevations generally characterised by the shoreline fronting Fredrick Henry Bay, Pitt Water and the lower reaches of the Carlton River, where flooding is influenced by elevated water levels within these bodies of water.

In the event of concurrent elevated water levels within the receiving waters and rainfall on a given stormwater catchment, the capacity of the stormwater drainage network discharging to the receiving waters may be reduced which may result in broader flood inundation extents and longer times of inundation.

Whilst this stormwater management plan considers the tidal condition and its effect on the drainage network, this study considers neither extreme tidal conditions (which includes storm surge) nor relative timings of the tidal signal and runoff from stormwater catchments.

2.7 Existing stormwater drainage network

2.7.1 Formalised drainage network

A summary of the formalised drainage network applicable to each area of interest is provided in the *Hydrology and Hydraulic Assessment* reports (refer to Section 1 for document references).

Applicable to the entire study area, the existing stormwater drainage network typically extends from the higher elevations of the developed areas of the study area, providing drainage through to the receiving water. In addition to numerous stormwater outfalls, there are a number of watercourses across the study area, where some of these effectively form a major element of the stormwater system.

Rain falling on the catchment initially flows as sheet flow until there is a concentration of runoff within the existing gullies and flow paths. In the upper regions of the study area catchment, flow continues along these gullies to the upstream limit of development which generally coincides with the upstream extent of the pipe drainage network. At these locations flow typically enters the pipe via either a headwall structure with the pipe laid at the base of the gully or low point, or via an inlet pit.

Typically located within the road network across the developed portions of the study area, inlet pits have been built to intercept surface water runoff and convey the runoff to the pipe drainage. These inlet pits have a range of configurations typically composed of one of the following:

- Grated inlet pit;
- Side-entry inlet pit; or
- Combination of grated and side-entry inlet pit.

The dimensions of the grates and lintels associated with the side-entry pits vary across the entire study area.

The drainage network generally follows the natural overland flow paths through the developed areas of the catchment, with the major trunk drainage pipes generally increasing in size with distance downstream as the contributing catchment increases. For the Sorell and Southern Beaches areas of interest, there are a number of formed open channels that convey flow in lieu of a piped drainage network.

A requirement of this study is to include all pipes with a diameter of 300mm and greater. It therefore follows that minor pipes (which includes drainage connections to buildings) have not been considered as part of this study. However, there are some instances where pipes smaller than 300mm diameter have been included where required to ensure there is connectivity through the entire network.

2.7.2 Overland flow paths

In instances when the capacity of the piped or channelised drainage network has been exceeded (i.e. during a given rainfall event), excess surface water is conveyed downstream as uncontrolled flow via overland flow paths, where some of these overland flow paths coincide with the road network. However, in some areas of the catchment the overland flow path passes through properties creating a flood risk with potential for flooding of buildings or areas of high hazard that pose a risk to the community.

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3. Hydrologic and hydraulic capacity assessment

3.1 Introduction

The hydrologic and hydraulic capacity assessment for each of the three defined areas of interest has been reported separately, with this report addressing potential management measures across all three areas (refer to Section 1 for document identification).

The hydrology and hydraulic assessment reports provides details of the following for each area of interest:

- Description of the area of interest (study area) and characteristics relevant to this study;
- Data sources used in the preparation of the studies;
- Hydrologic modelling methodology;
- Hydraulic model development;
- Model calibration and verification;
- Design flood modelling;
- Sensitivity analysis;
- Climate change analysis;
- Fully developed catchment analysis; and
- Property inundation and flood damage assessment.

The hydrology and hydraulic assessment reports form part of the SSMP and must be read in conjunction with the analysis provided herein.

3.2 Flooding problem locations

As part of the hydrology and hydraulic assessments, results of the hydraulic modelling have been used to identify a number of flooding problem locations, where these locations are reprised in this report section.

3.2.1 Sorell area of interest

Table 3.1: Sorell area of interest - potential flooding problem locations

ID	Location	Potential flooding problem	Associated management measure
1	Valley View Close to Gatehouse Drive	Flow from the catchment north of Valley View Close drains generally southwards through properties marked for future residential development, with some development currently under construction along Gatehouse Drive. Potential for under-construction and future buildings to be flood-affected. Overland flow along the proposed road alignment has a predicted hazard category of up to H5.	FM-SOR-05
2	Gatehouse Drive to Devenish Drive	Excess overland flow from north of Gatehouse Drive flows toward the existing detention pond then continues southwards in the direction of Devenish Drive. Existing properties along this route are potentially flood affected.	FM-SOR-04
3	Devenish Drive south of Pennington Drive	Water flows south along Devenish Drive with a hazard category of up to H5. There is also flooding to properties on the eastern side of Devenish Drive.	FM-SOR-04
4	Attunga Drive Area	Overland flow crosses the Tasman Highway that originates from Devenish Drive, and then flows generally in a south-westerly direction and ponds up behind the existing embankment that runs along the western boundary of the residential development in the Attunga Drive area. There is predicted flood hazard of up to H3 affecting some properties.	FM-SOR-04
5	Pennington Drive and Dubs and Co Drive to Tasman Highway	Overland flow draining south from Pennington Drive and west from Dubs and Co Drive flows generally in a south-westerly direction before crossing the Tasman Highway. There are some areas with a predicted flood hazard category of H2.	FM-SOR-04
6	West of Dodges Court to west of Nash Street	Ponding in trapped low points and overland flow along the surface depression with some flow being trapped behind the existing embankment that runs along the western boundary of the residential development (i.e. west of Nash Street). Predicted flood hazard category of up to H1.	(refer to Appendix A.1)
7	North-Western side of the Tasman Highway opposite Stores Lane	There is significant ponding predicted on the north-western side of the Tasman Highway opposite the intersection with Stores Lane (Giblin Drive). Existing constrictions in the stormwater drainage network exacerbate the ponding where the predicted flood hazard category is up to H3.	FM-SOR-01 FM-SOR-02 FM-SOR-03
8	Runoff being directed onto TasWater land	Stormwater drainage on Giblin Drive directs runoff onto TasWater land south of Giblin Drive affecting the treatment ponds.	(refer to Appendix A.1)
9	Property at 3 Weston Hill Road	Runoff ponds in private land at 3 Weston Hill Road with hazard category up to H2.	(refer to Appendix A.1)
10	Weston Hill Road at Valley View Close	Runoff ponds on the western side of Weston Hill Road, most likely due to an under-capacity pipe. The predicted flood hazard category is up to H4.	FM-SOR-06

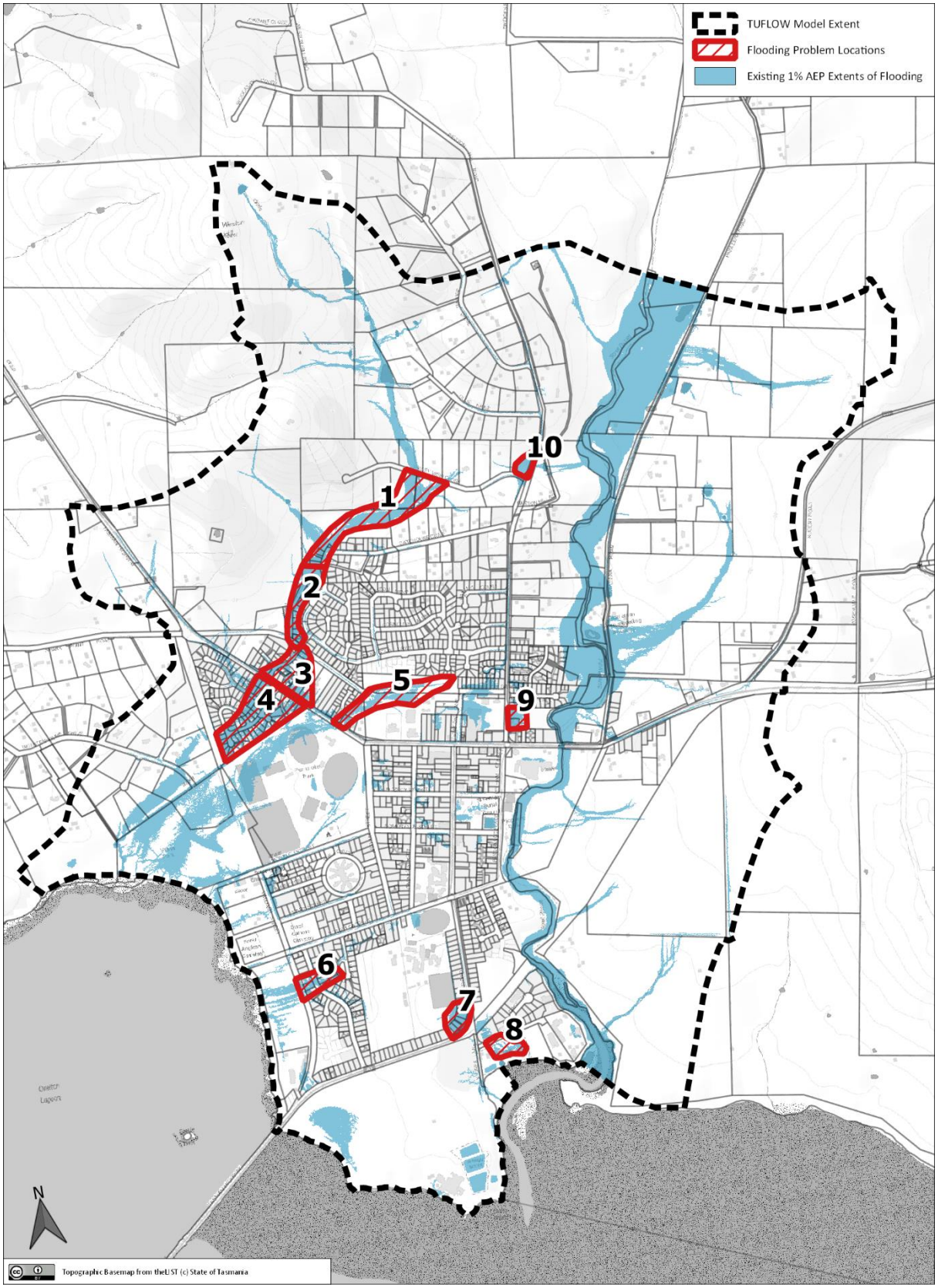

Figure 3.1: Potential flooding problem locations – Sorell area of interest

3.2.2 Midway area of interest

Table 3.2: Midway area of interest - potential flooding problem locations

ID	Location	Potential flooding problem	Associated management measure
1	Tasman Highway at Penna Road	Overland flow from multiple flow paths that generally follow the road network converge at the intersection of the Tasman Highway and Penna Road. The lower pipes along these flow paths reach capacity in events with magnitude less than 18% AEP (5 year ARI). Excess surface water floods the southern-most part of Penna Road before flooding across the Tasman Highway. Water continues both westwards along the highway and southwards through property to Pitt Water.	(refer to Appendix A.2)
2	Lake View Parade at Suncrest Street	Overland flow from multiple flow paths that generally follow the road network converge at the intersection of Lake View Parade and Suncrest Street. The lower pipes along these flow paths reach capacity in events with magnitude less than 18% AEP (5 year ARI). Excess surface water floods the eastern-most part of Suncrest Avenue and its intersection with Lake View Parade before discharging to Orielton Lagoon via overland flow.	(refer to Appendix A.2)
3	Suva Street and Kessarios Park through to outfall	Runoff flows along the length of Suva Street, with some water flowing through residential properties to then cross Penna Road at Kessarios Park. Flow continues along the length of Kessarios Park, crossing Brady Street then ultimately discharging to Pitt Water. In the 1% AEP event, there is a maximum flood hazard category of H1 across all parts of the overland flow path.	(refer to Appendix A.2)
4	Penna Road north of Penna Beach Street	Runoff from catchments to the east crosses Penna Road via two separate cross-drainage pipes, where both have a headwall within the longitudinal drainage ditch along the eastern side of Penna Road. In the 1% AEP event, runoff exceeds the capacity of these pipes with water spilling across Penna Road with a maximum depth of approximately 0.60m and flood hazard category of H1.	(refer to Appendix A.2)

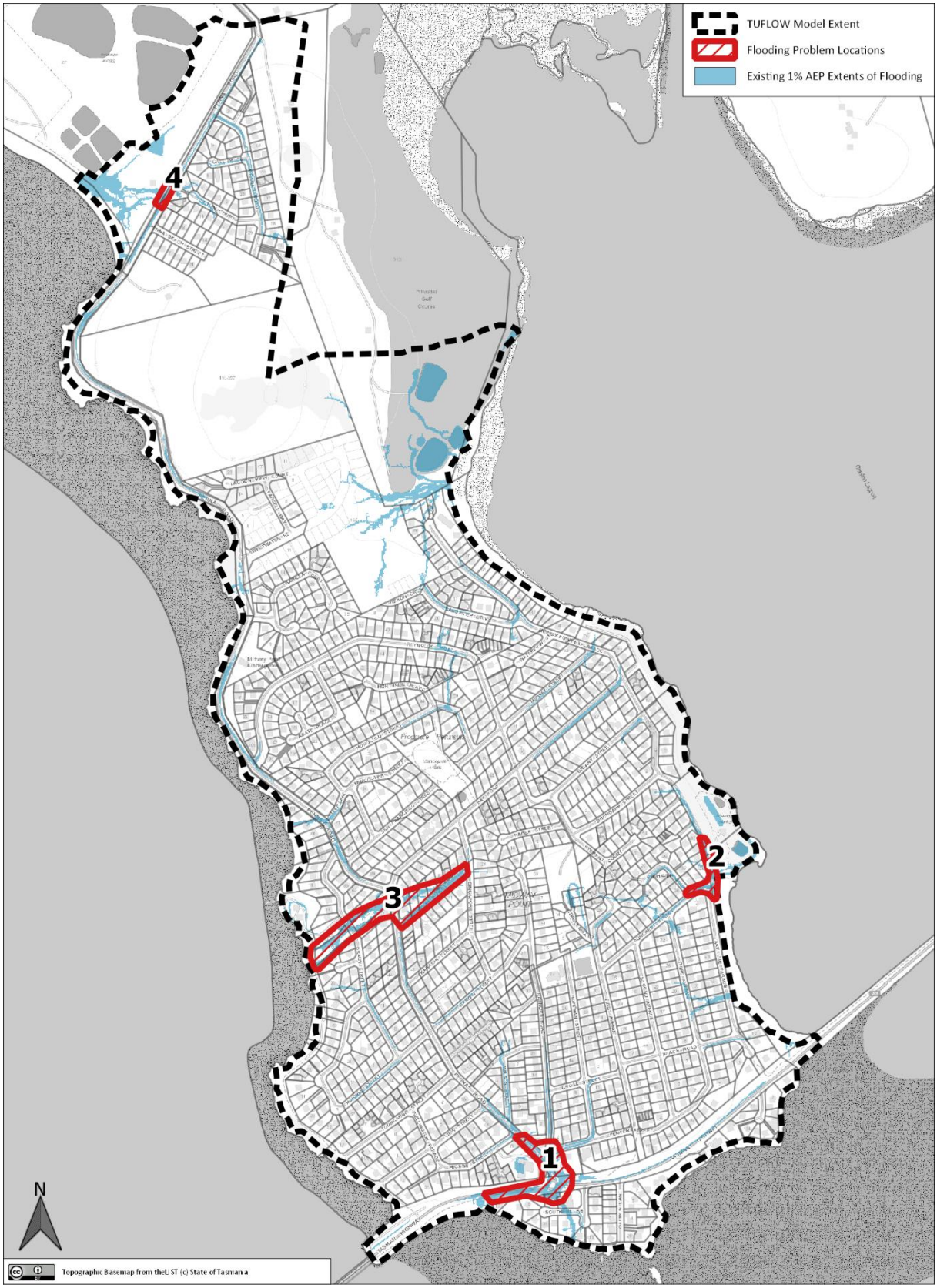

Figure 3.2: Potential flooding problem locations – Midway area of interest

3.2.3 Southern Beaches area of interest

Problem flood locations for the southern Beaches area of interest have been delineated on a locality basis.

3.2.3.1 Lewisham

Table 3.3: Southern Beaches area of interest – potential flooding problem locations – Lewisham

ID	Location	Potential flooding problem	Associated management measure
1	Intersection of Lewisham Road and Quarry Road at Townsends Lagoon	Multiple flow paths converge near the intersection which lies at the north-west corner of Townsends Lagoon. Flooding of the road occurs due to combination of water backing up from the lagoon and under-capacity cross-drainage culverts. Maximum on-road flood hazard category of H2.	(refer to Appendix A.3)
2	Flow path downstream of Townsends Lagoon	Water flows through light industrial business and across Lewisham Road. Existing drainage infrastructure in this area was not surveyed for this study; however the estimated drainage features appear to be under-capacity. Maximum on-road flood hazard category of H2.	(refer to Appendix A.3)
3	Lewis Court (China creek floodplain)	A number of properties are flood affected from runoff in the China Creek catchment, indicating a mainstream flooding problem and not a stormwater issue. Maximum flood hazard category of H4 affecting existing property.	(refer to Appendix A.3)
4	Lower reach of China Creek	A number of properties within the China Creek floodplain are flood affected directly from China Creek, suggesting this is a mainstream flooding problem and not a stormwater issue. Maximum flood hazard category of H3 affecting existing property.	(refer to Appendix A.3)

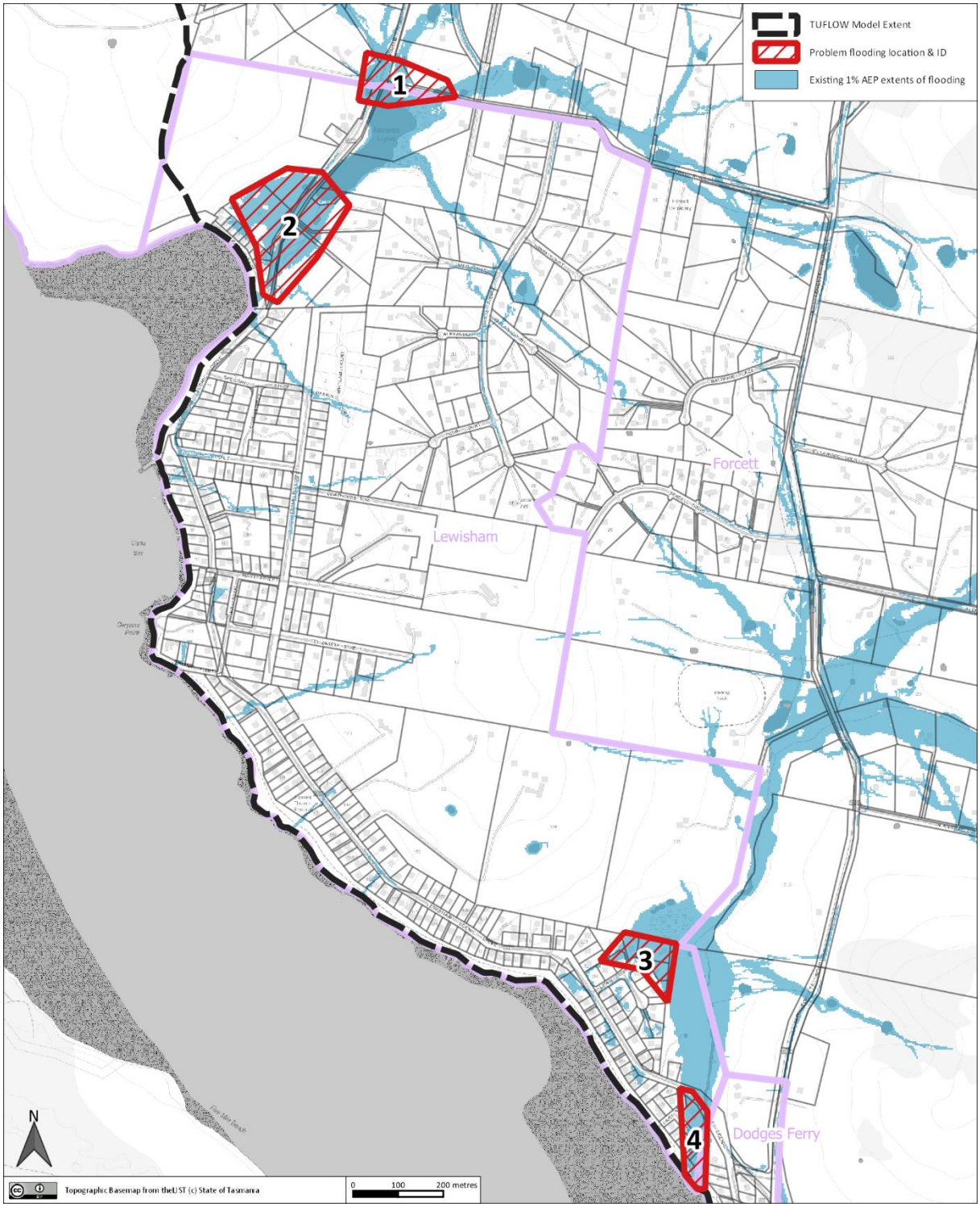

Figure 3.3: Potential flooding problem locations – Lewisham (Southern Beaches area of interest)

3.2.3.2 Dodges Ferry

Table 3.4: Southern Beaches area of interest – potential flooding problem locations – Dodges Ferry

ID	Location	Potential flooding problem	Associated management measure
5	Old Forcett Road near intersection with Lewisham Rd	Runoff from the eastern side of Old Forcett Road ponds on the eastern side of Old Forcett Road leading to flooding of the road. Maximum on-road flood hazard category of H1.	FM-SBS-01
6	Rantons Road	Runoff from east of Old Forcett Road flows through a Council Reserve to Rantons Road via a minor watercourse. The passage of water may be affected by filling on the northern side of Rantons Road and under-capacity culvert and downstream channel. Maximum on-road flood hazard category of H2, and H4 affecting existing property.	FM-SBS-02 FM-SBS-04
7	Old Forcett Road near Okines Road	Multiple flow paths drain to the area at the intersection of Okines Road and Old Forcett Road via a series of minor drainage ditches and culverts. Existing cross-drainage structures appear to be under-capacity resulting in flooding of existing commercial property and Old Forcett Road. Maximum on-road flood hazard category of H2, and H1 affecting existing property.	FM-SBS-02 FM-SBS-04
8	Old Forcett Road south of Dodges Ferry Primary School	Old Forcett Road and private property are flooded at this location with runoff from multiple flow paths. Maximum on-road flood hazard category of H5, and H3 affecting existing property.	FM-SBS-02 FM-SBS-03 FM-SBS-04
9	Dodges Ferry Primary School	Part of the school grounds are predicted to be flooded with water originating from the Okines Road area. Maximum flood hazard category of H1.	FM-SBS-02 FM-SBS-04 FM-SBS-05
10	Carlton Beach Road and Seventh Avenue	Water flowing from east of Carlton Beach Road floods the road and continues westerly through private property, generally following Seventh Avenue. Maximum on-road flood hazard category of H1, and H2 affecting existing property.	FM-SBS-06
11	Mongana Street and Carlton Beach Road	Excess water flowing along the existing overland flow path west of Signal Hill Road to Mongana Street continues in the direction of Blue Lagoon after flooding across Carlton Beach Road, combined with runoff from further north-east along Carlton Beach Road. Maximum on-road flood hazard category of H1, also affecting existing property.	FM-SBS-07
12	Blue Lagoon, including Kannah Street	Water levels in the ephemeral Blue Lagoon pond up such that Kannah Street is entirely inundated, leading to flooding of the lower areas of the properties at this location. Maximum on-road flood hazard category of H3, and H2 affecting existing property.	(refer to Appendix A.3)
13	Carlton Beach Road west of Bally Park Road	Runoff draining eastwards towards Carlton floods the lower areas (i.e. trapped sag points) adjacent to Carlton Beach Road. Maximum flood hazard category of H3 affecting existing property.	(refer to Appendix A.3)

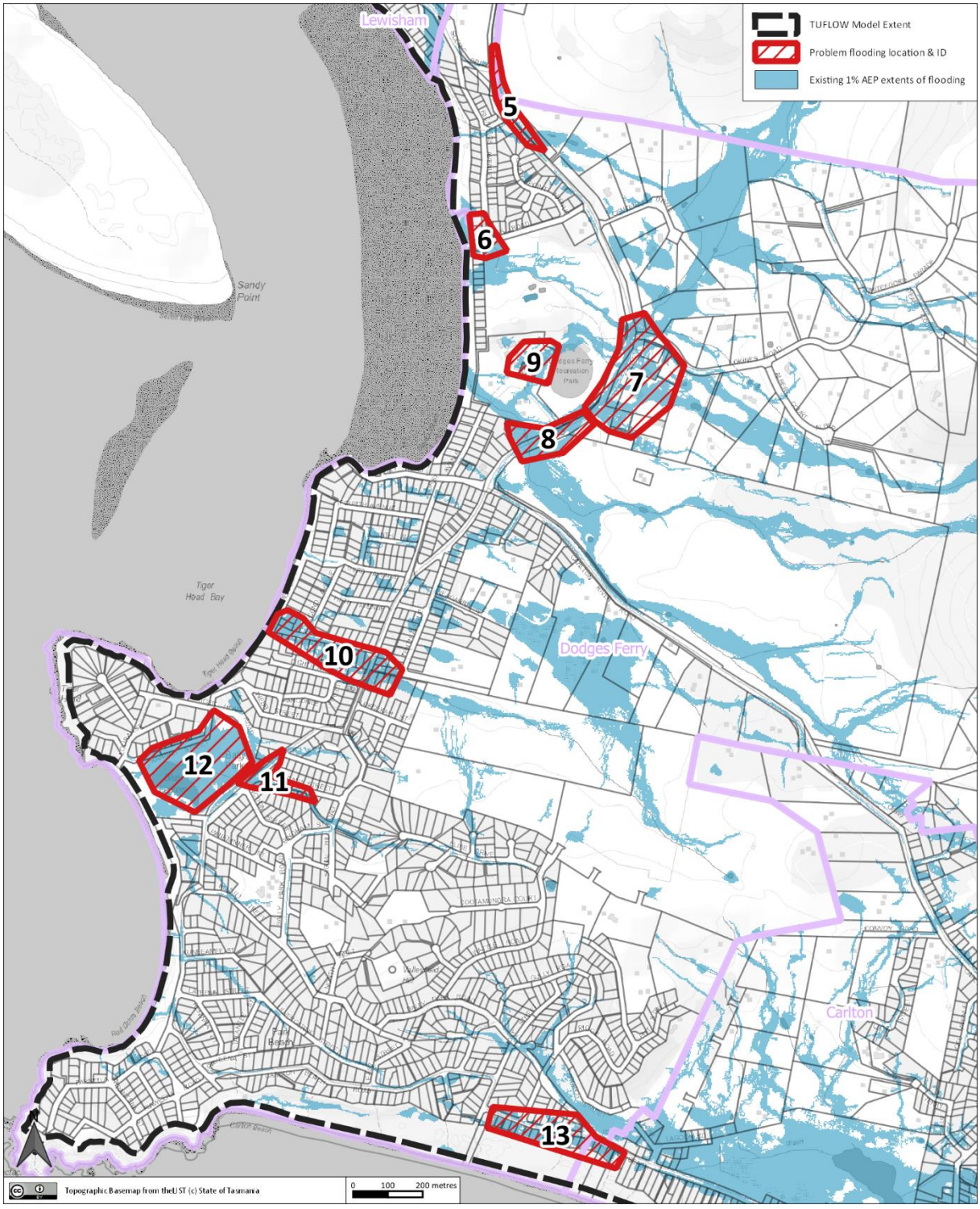

Figure 3.4: Potential flooding problem locations – Dodges Ferry (Southern Beaches area of interest)

3.2.3.3 Carlton

Table 3.5: Southern Beaches area of interest – potential flooding problem locations – Carlton

ID	Location	Potential flooding problem	Associated management measure
14	Carlton Beach Road near Lagoon Road	Runoff draining eastwards from Dodges Ferry and towards Carlton floods the lower areas (where some are trapped sag points) adjacent to Carlton Beach Road and Lagoon Road. Maximum on-road flood hazard category of H2, and H3 affecting existing property.	(refer to Appendix A.3)
15	Moomere Street	Water flowing eastwards from the ephemeral lagoon at 248 Carlton Beach Road passes through property on both sides of Moomere Street, ultimately draining towards the Carlton River via the open channel running east from Moomere Street. Maximum on-road flood hazard category of H2, and H3 affecting existing property.	(refer to Appendix A.3)
16	Carlton Beach Road south of Carlton River Road	At the eastern end of Carlton Beach Road (i.e. south of Carlton River Road), runoff flows in a southerly direction via existing longitudinal draining ditch system. Adjacent to Freedom Close, water spills across Carlton Beach Road, resulting in flooding of the road and within some of the properties in the vicinity. Maximum on-road flood hazard category of H5, and H1 affecting existing property.	FM-SBS-10

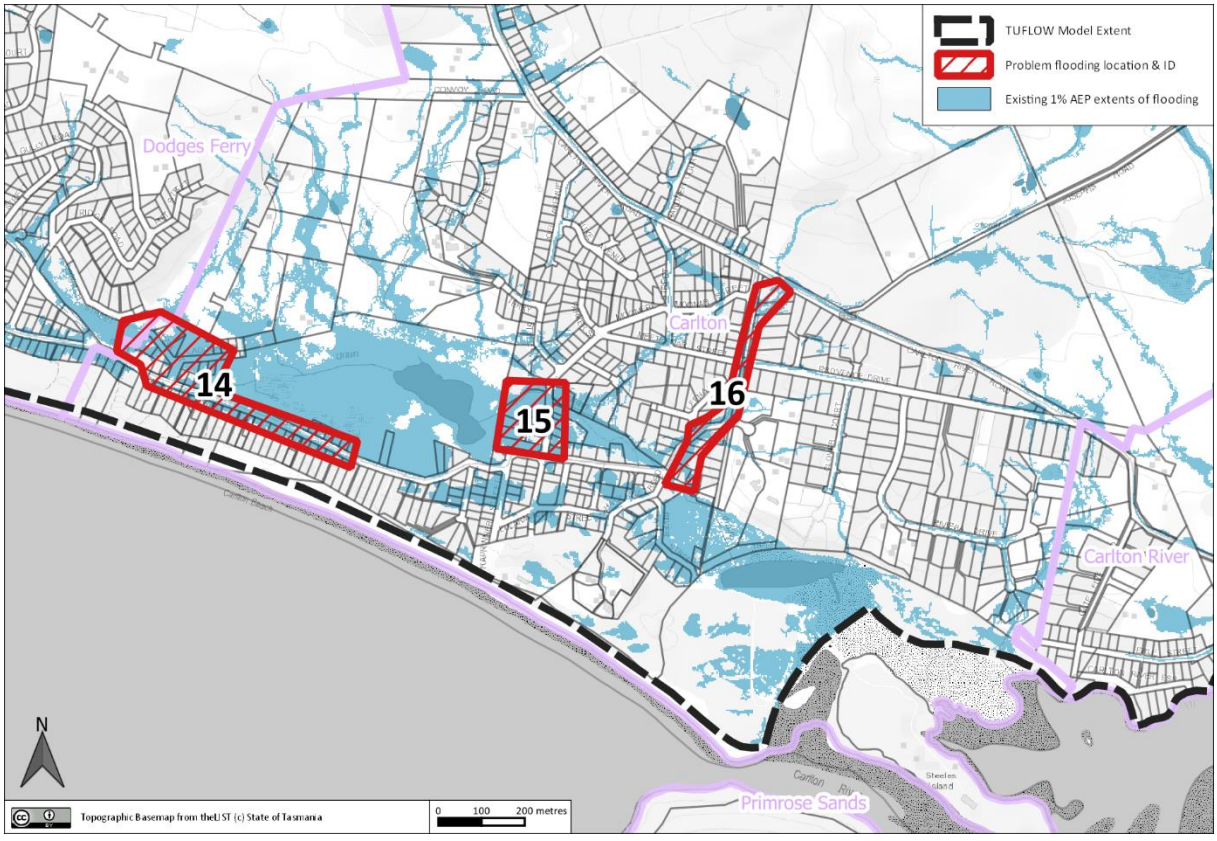

Figure 3.5: Potential flooding problem locations – Carlton (Southern Beaches area of interest)

3.2.3.4 Primrose Sands

Table 3.6: Southern Beaches area of interest – potential flooding problem locations – Primrose Sands

ID	Location	Potential flooding problem	Associated management measure
17	Area south of Tamarix Road	Flooding occurs within properties south of Tamarix Road, where the source of runoff is from a combination of local runoff, runoff originating from east of Primrose Sands Road and flowing across Esplanade, and water ponding in the ephemeral lagoon located on the northern side of Tamarix Road. Maximum flood hazard category of H3 affecting the roads and existing property.	FM-SBS-11 FM-SBS-12 FM-SBS-13 (also refer to Section 5.9)
18	Primrose Sands Road	Catchments on the eastern side of Primrose Sands Road near the Primrose Sands RSL drain to an existing culvert conveying water westwards to the ephemeral lagoon located on the northern side of Tamarix Road. Runoff from these catchments exceeds the capacity of the existing cross-drainage culvert, resulting in flooding of the road with a maximum flood hazard category of H1.	FM-SBS-14

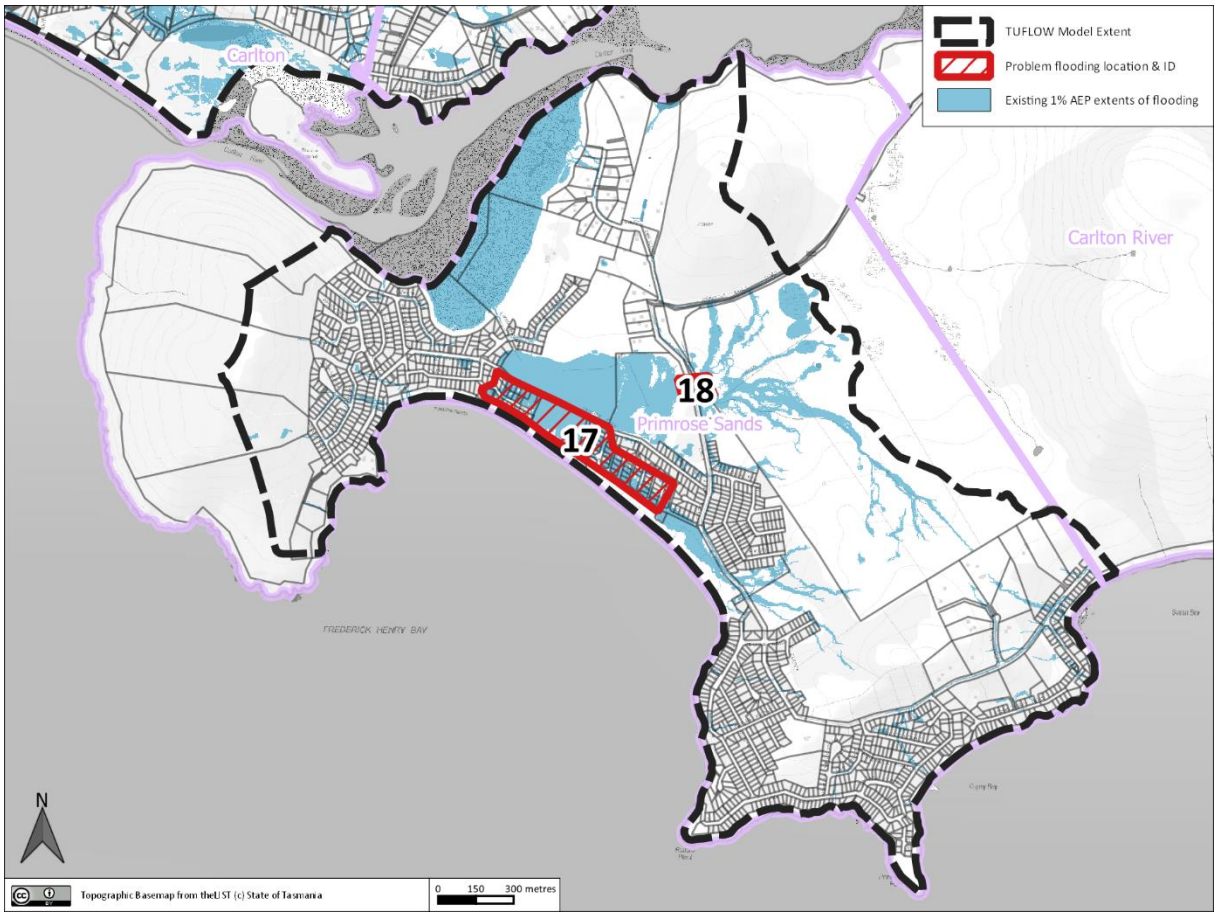

Figure 3.6: Potential flooding problem locations – Primrose Sands (Southern Beaches area of interest)

3.2.3.5 Connellys Marsh

Table 3.7: Southern Beaches area of interest – potential flooding problem locations – Connellys Marsh

ID	Location	Potential flooding problem	Associated management measure
19	Knights Road and Beach Road area	The low lying area along Knights Road and Beach Road is flooded from a combination of local runoff and water backing up from Connellys Bay via Connellys Creek, where the only free-draining outlet is via Connellys Creek. Maximum flood hazard category of H3 affecting the Knights Road area and H4 affecting the Beach Road area.	(refer to Appendix A.3)

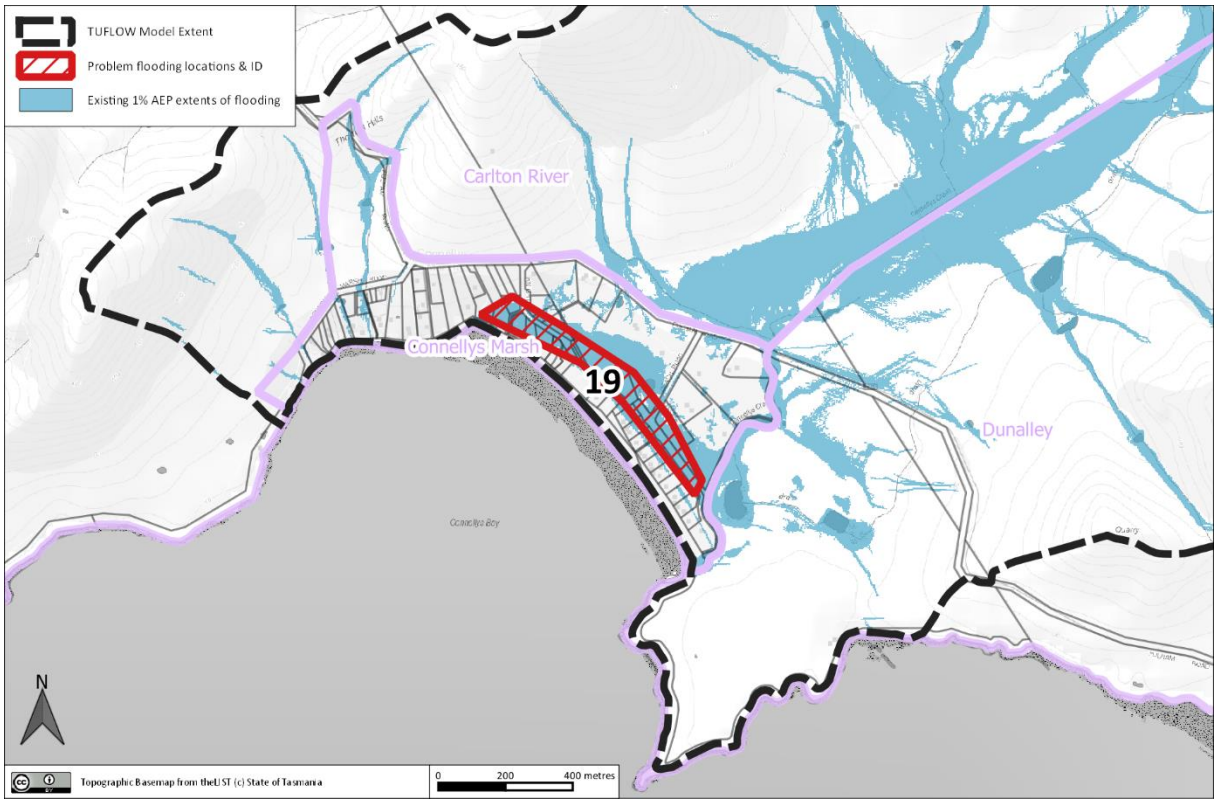

Figure 3.7: Potential flooding problem locations – Connellys Marsh (Southern Beaches area of interest)

3.2.3.6 Dunalley

Table 3.8: Southern Beaches area of interest – potential flooding problem locations – Dunalley

ID	Location	Potential flooding problem	Associated management measure
20	Fulham Road area	The south-western portion of the Dunalley locality and catchments west of Gellibrand Street drain southwards in the direction of Fulham Road. Water ponds in the low-lying area on the northern side of Fulham Road, resulting in flooding of Fulham Road and the southern end of Gellibrand Street. Maximum on-road flood hazard category of H3.	FM-SBS-15
21	Gilpins Creek at Church Street West	Runoff in Gilpins Creek exceeds the capacity of the existing cross-drainage culvert at Church Street West resulting in flooding over the road with high flood hazard (category H5).	FM-SBS-16
22	139 Arthur Highway	Runoff from catchments on the north-western side of the Arthur Highway ponds on the upstream side of the highway then floods the highway before flowing through to the Denison Canal. Maximum on-road flood hazard category of H1.	(refer to Appendix A.3)
23	Arthur Highway at intersection with Imlay Street	Runoff from catchments on the north-western side of the Arthur Highway exceeds the capacity of the existing cross-drainage culvert near the intersection with Imlay Street, resulting in water flowing across the highway and ultimately flowing through to Blackman Bay via East Bay. Maximum on-road flood hazard category of H1.	(refer to Appendix A.3)
24	59-69 Arthur Highway	Runoff from catchments on the north-western side of the Arthur Highway exceeds the capacity of the existing cross-drainage culvert, resulting in water flowing across the highway and ultimately flowing through to Blackman Bay. Maximum on-road flood hazard category of H1.	(refer to Appendix A.3)
25	47 Arthur Highway	Runoff from catchments on the north-western side of the Arthur Highway exceeds the capacity of the existing cross-drainage culvert, resulting in water flowing across the highway and ultimately flowing through to Blackman Bay. Maximum on-road flood hazard category of H1.	(refer to Appendix A.3)
26	Arthur Highway north-east of Dunalley township	Runoff from catchments on the north-western side of the Arthur Highway exceeds the capacity of the existing cross-drainage culverts, resulting in water flowing across the highway and ultimately flowing through to Blackman Bay. Maximum on-road flood hazard category of H1.	(refer to Appendix A.3)

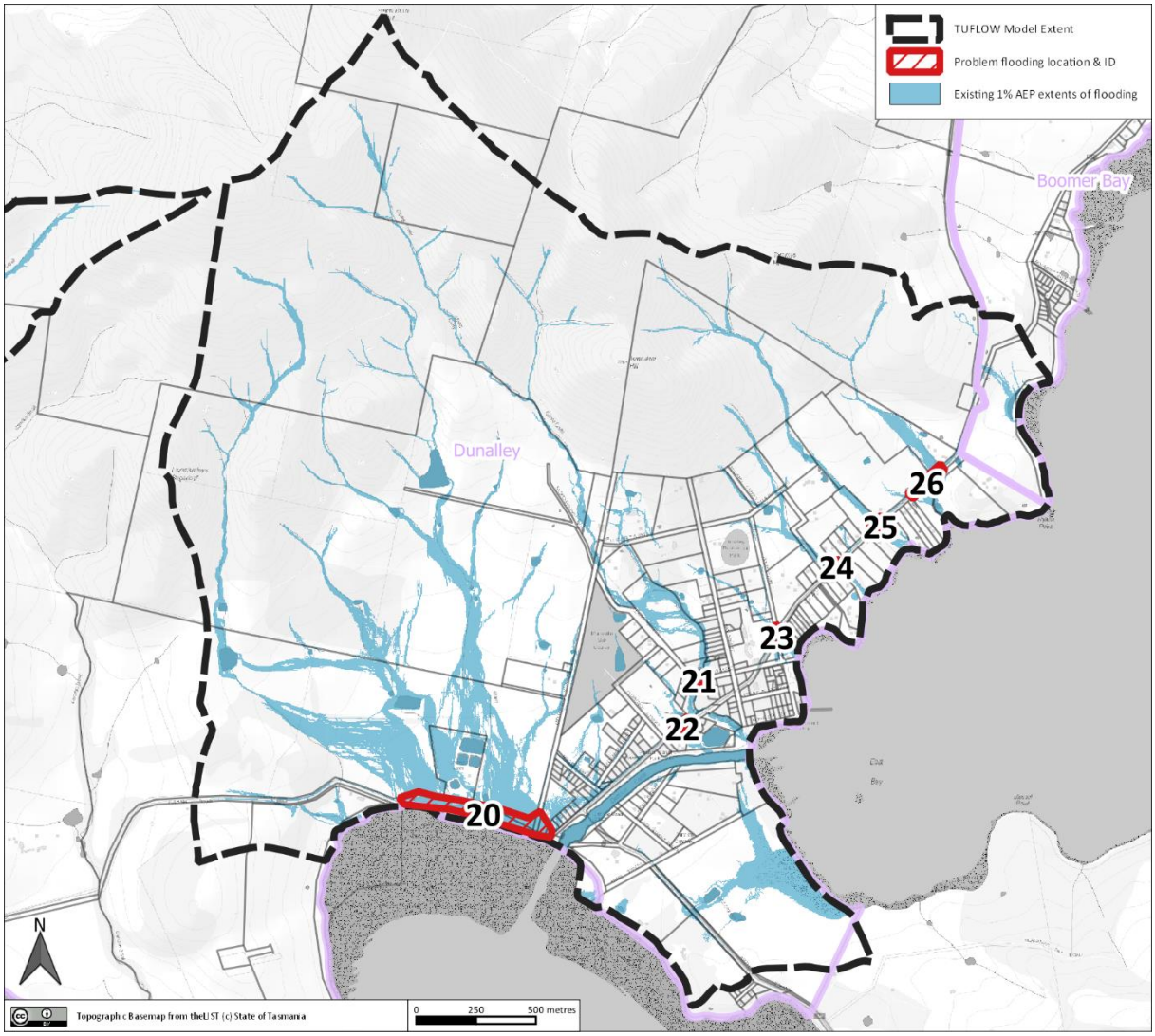

Figure 3.8: Potential flooding problem locations – Dunalley (Southern Beaches area of interest)

4. Existing stormwater management for flood risk

4.1 Overview

Sorell Council's current stormwater management activities that are considered to be applicable to the study area can be separated into the following categories:

- Council's capital works program as related to stormwater management;
- Policies, strategies, planning controls;
- Community awareness and alerts; and
- Emergency planning and response.

4.2 Capital works program

Council undertakes specific and targeted stormwater management projects as part of its existing Capital Works program, which may include drainage network upgrades and flood mitigation works. Summaries of these activities are provided in the following report sections.

4.2.1 Stormwater network maintenance

Sorell Council has an established maintenance program aimed at preventative cleaning and maintenance of the stormwater drainage network. Council also responds during and following storm and flood events to undertake cleaning operations where required. Specific tasks included in Council's current maintenance regime include the following:

- All GPT's are vacuum-trucked once per year;
- All GPT's are monitored after rain events to assess whether they require extra cleaning;
- All trash baskets are checked prior to rain events and cleaned after rain event;
- Known problem sites (e.g. Montagu Street drain, Lewisham Scenic Drive) are checked pre and post rain events on top of general monitoring;
- Outfalls are monitored pre and post rain events in addition to general monitoring and cleaning;
- Swales are monitored for silt and vegetation build up, and when required, they are cleaned/slashed or large regrowth is removed;
- A large number of pits and pipes have been cleaned ("vacuum-trucked") over the past couple of years to improve their standard in addition to ongoing monitoring of their condition;
- Numerous pipes are inspected via camera to ensure they are clear or require clearing;
- Grated pits are monitored to ensure grates are clear of vegetation/rubbish build up particularly pre and post rain events;
- Grated pit lid replacement program is in place for 2019/20; and

- Some rain gardens and retarding basins are cleared and relined to allow for improved ongoing maintenance and ability to work to their design capacity.

4.2.2 Stormwater quality

Existing stormwater quality management activities are discussed in Section 8.2.

4.3 Policies, strategies and planning controls

4.3.1 Overview of policies, strategies and planning controls

LGAT (2016) describes that the primary aim of an urban stormwater management system is to minimise economic, environmental, and social impacts of flooding and water quality degradation caused by stormwater runoff. The specific stormwater management measures discussed in Section 5 and included in the final Sorell Stormwater System Management Plan (Section 9), have been conceived to manage the impacts and risks caused by stormwater runoff.

In addition to these management measures, future impacts and risks caused by stormwater are managed by Council through the application of land use planning and development controls. These controls are part of the planning framework, which is comprised of several pieces of legislation, policy and regulations that are relevant to stormwater system management in Tasmania. This section provides a review of stormwater controls and planning provisions in the relevant policy, strategy and planning documents.

4.3.1.1 State Stormwater Strategy

The State Stormwater Strategy (DPIPWE, 2010) is an important tool to help manage and protect Tasmania's waterways from potentially adverse effects of stormwater runoff. The Strategy provides practical guidance to assist local government and other organisations with responsibilities for stormwater management across Tasmania.

The Strategy helps to address recommendations of the Tasmanian State Policy on Water Quality Management 1997 (SPWQM) which emphasises the need to manage stormwater at source and highlights the importance of managing stormwater in new developments at both the construction and operational stages (LGAT, 2016). The strategy addresses a range of Water Sensitive Urban Design (WSUD) principles, discussing a range of treatment methods for the management of stormwater runoff.

4.3.1.2 Urban Drainage Act 2013

The Urban Drainage Act of 2013 (the Act) replaces the Drains Act of 1954 and provides for the management of urban drainage, stormwater systems and infrastructure in Tasmania. It expands on the traditional view of stormwater management, as solely concerned with the collection and removal of runoff to minimise urban flooding, to also be sustainable and environmentally responsible. This means that stormwater will be considered in the context of catchment management, ecosystem health, safety, and social amenity.

The main objectives of the Urban Drainage Act are:

- To protect people and property by ensuring that stormwater services, infrastructure and planning are provided so as to minimise the risk of urban flooding due to stormwater flows; and
- To provide for the safe, environmentally responsible, efficient and sustainable provision of stormwater services in accordance with the objectives of the resource management and planning system of Tasmania.

To achieve this, the Act clearly establishes that the responsibility of urban drainage lies with the relevant council. They are required to develop a stormwater system management plan (SSMP) which gives a clear strategy for the delivery of stormwater services, flood risk identification, asset management and other matters.

4.3.1.3 Tasmanian Planning Scheme

The Tasmanian Government passed a bill in November 2015 to provide for the development of the Tasmanian Planning Scheme (TPS) which sets out the requirements for use or development of land in accordance with the Land Use Planning and Approvals Act 1993. The TPS comprises the State Planning Provisions (SPPs) and Local Provisions Schedule (LPSs) which will apply to each municipal area, and together form all the planning provisions that apply to a municipal area, i.e. local application of the TPS. Whilst the SPPs came into effect in March 2017 as part of the TPS, they have no practical effect until the LPS is in place for the Municipality of Sorell. Therefore, discussion herein regarding planning controls relates to the applicable planning legislation at the time of preparation of this report.

4.3.2 Sorell Interim Planning Scheme 2015

The primary local planning control for the Municipality of Sorell is the Sorell Interim Planning Scheme 2015. The planning scheme sets out the requirements for use or development of land in accordance with the Land Use Planning and Approvals Act 1993. The planning scheme incorporates:

- Overall planning scheme objectives
- Zones
    - The planning scheme area is divided into zones in respect of which the primary controls for the use or development of land are set out;
    - Development standards apply to each zone;
- Codes
    - These identify areas or planning issues which require compliance with additional provisions set out in the codes.

The provisions of the Sorell Interim Planning Scheme 2015 incorporate general considerations with respect to the management of stormwater and development within inundation prone areas. The stated objectives of the planning scheme and codes to achieve these objectives, as related to stormwater management and the preparation of the Sorell Stormwater System Management Plan, are summarised in the following report sections.

4.3.2.1 Natural environment regional objectives

The stated objective of Section 3.0.6 (Natural Environment) of the Sorell Interim Planning Scheme 2015 is "to increase responsiveness to the region's natural environment". The desired outcomes relating to stormwater management are as follows:

- Significant biodiversity, landscape, scenic and cultural values of the region's coast are recognised and protected;
- Use and development in coastal areas is responsive to effects of climate change including sea level rise, coastal inundation and shoreline recession; and
- The risk of loss of life and property from flooding is minimised.

The planning scheme provides that these outcomes are to be achieved by:

- Protecting significant environmental values through codes dealing with biodiversity, landscape, wetlands & waterways and water quality & stormwater;
- Avoiding zoning any new areas identified as at unacceptable risk from bushfire, flooding, land instability, dispersive and/or acid sulphate soils for urban development;
- Recognising areas at risk from flooding and managing use and development accordingly through a flood prone areas code.

4.3.2.2 Water resources regional objectives

The stated objective of Section 3.0.7 (Water Resources) of the Sorell Interim Planning Scheme 2015 is "to improve management of the region's water resources". The desired outcomes relating to stormwater management are as follows:

- The ecological health, environmental values and water quality of surface and groundwater, including waterways, drinking water catchments, wetlands and estuaries are protected and managed;
- Wetlands and waterways are managed for their water quality, scenic, biodiversity, tourism and recreational values; and
- The sustainable use of water is encouraged to decrease pressure on water supplies and reduce long-term cost of infrastructure provision.

The planning scheme provides that these outcomes are to be achieved by:

- Protecting environmental values of waterways generally through a number of codes;
- Requiring total water cycle management and water sensitive urban design principles to be applied to relevant development;
- Facilitating the use of rainwater tanks in residential areas.

4.3.2.3 Planning scheme codes

The purpose of the planning scheme codes is to provide more detailed provisions to guide development with the aim of achieving the planning scheme objectives. The codes within the Sorell Interim Planning Scheme 2015 applicable to stormwater management are:

- Stormwater Management Code, where the purpose of this Code is to ensure that stormwater disposal is managed in a way that furthers the objectives of the State Stormwater Strategy;
- Waterway and Coastal Protection Code, where the purpose of the Code is to manage vegetation and soil disturbance in the vicinity of wetlands, watercourses and the coastline in order to:
    - Minimise impact on water quality, natural values including native riparian vegetation, river condition and the natural ecological function of watercourses, wetlands and lakes;
    - Minimise impact on coastal and foreshore values, native littoral vegetation, natural coastal processes and the natural ecological function of the coast;
    - Protect vulnerable coastal areas to enable natural processes to continue to occur, including the landward transgression of sand dunes, wetlands, saltmarshes and other sensitive coastal habitats due to sea-level rise; and
    - Minimise impact on water quality in potable water supply catchment area.
- Inundation Prone Areas Code, where the purpose of this Code is to:
    - identify areas which are at risk of periodic or permanent inundation from one or more of the following:
        - riverine, watercourse and inland flooding;
        - storm tide;
        - sea level rise
    - manage development in areas at risk from periodic or permanent inundation so that:
        - people, property and infrastructure are not exposed to an unacceptable level of risk;
        - future costs associated with options for adaptation, protection, retreat or abandonment of property and infrastructure are minimised;
        - marine-infrastructure on coastal landforms is undertaken in a way that protects coastal features, processes and ecological systems from adverse impacts;
    - facilitate sustainable development of the coast in response to the impacts of climate change;
    - manage development on the coast so that:
        - people, property and infrastructure are not exposed to an unacceptable level of risk,
        - adverse effects on the stability and functioning of the coastal environment are minimised,
        - future options for adaptation, protection, retreat or abandonment of property and infrastructure are maintained and associated future costs are minimised,
        - marine-infrastructure on coastal landforms is undertaken in a way that protects coastal features, processes and ecological systems from adverse impacts;
    - preclude development that will affect flood flow or be affected by flood water, or change coastal dynamics in a way detrimental to development sites or other property; and

- provide for appropriate development dependent on a coastal location.

Each of these Codes provides for requirements of how the Code is to be applied and specific development standards associated with that Code, including acceptable stormwater quality and quantity targets.

4.3.3 Other relevant Sorell council strategies and policies

4.3.3.1 Sorell Land Supply Strategy

In response to the current and projected population growth rate in the Municipality of Sorell, in 2017 Council finalised a Land Supply Strategy for the Municipality[2]. The strategy addresses the following elements:

- Land supply and demand analysis for residential, industrial and commercial land;
- Assessment of expansion options for residential, industrial and commercial land;
- Preparation of masterplans for expansion options for residential, industrial and commercial land.

The outcomes of the strategy will be used by Council in its development of local planning provisions (LPPs) for inclusion in the Tasmanian Planning Scheme.

4.3.3.2 Onsite wastewater disposal

Much of the Sorell Municipality is not connected to the reticulated sewerage system. Where this is the case, all wastewater must be treated and disposed of within the confines of the property boundaries. There are a number of different options available that can be utilised such as aerated wastewater treatment, septic tanks, wastewater treatment plants and composting toilets.

Council has prepared a number of informative publications to assist property owners with the management of onsite wastewater disposal[3].

4.4 Community awareness and alerts

4.4.1 Tasmania SES

The Tasmania SES provides a range of targeted information and advice via their website[4] to assist the community better understand emergency events, including flood and storm events. The information provided addresses the following three actions to be taken in relation to a given event:

- Plan and Prepare
- Respond (during event); and

[2] https://www.sorell.tas.gov.au/planning-building/sorell-land-supply-strategy/

[3] https://www.sorell.tas.gov.au/planning-building/onsite-wastewater-disposal/

[4] https://www.ses.tas.gov.au/

- Recover.

4.4.2 TasALERT

The TasALERT website[5] administered by the Tasmanian Government Department of Premier and Cabinet provides a single source of clear and consistent emergency and resilience information for use both during emergency response periods and in preparedness for such emergencies. Information on the TasALERT platform has been provided for both flood and storm emergencies.

4.5 Emergency planning and response

4.5.1 Sorell Emergency Management Plan

The Sorell Municipal Emergency Management Plan (Sorell Municipal Emergency Management Committee, 2018) aims to describe the emergency management arrangements for the Municipal Area of Sorell. The plan records:

- Roles and responsibilities related to identified hazards and emergency management functions; and
- Current arrangements for prevention and mitigation, preparedness, response, and recovery.

4.5.2 Emergency services

Responsibility for emergency management operations in response to flooding lies with the Tasmania State Emergency Service (SES). Assistance is also provided by other organisations including Tasmania Police, Tasmania Fire Service, Ambulance Tasmania, Bureau of Meteorology and Sorell Council.

The stormwater catchments across the areas of interest for this study have no formal flood warning service, and flooding is generally characterised by a rapid catchment response following intense rainfall resulting in overland flooding and flooding along existing drainage paths. For flooding conditions of this nature, the emergency management role and response of the SES is generally limited to responding to calls for assistance with recovery following the event.

4.5.3 Storm warnings and flood forecasting

In Tasmania, severe weather warnings and flood warnings are issued to the community by the Bureau of Meteorology (BoM). The BoM also provides services that issue a range of forecasts, watches, alerts and other products to the community that can assist in responding to natural hazards. These warnings are typically prepared through cooperation with relevant state and local government agencies (including the SES) and other stakeholders. The warnings are typically communicated via local radio and relevant websites, including TasALERT which is an online emergency warning and information system administered by the Tasmanian Government Department of Premier and Cabinet.

There is presently no formal flood warning service for stormwater or overland flooding within the Municipality of Sorell. Warning services currently provided by the BoM and SES that are relevant to the Sorell Municipality and the subject stormwater catchments include:

[5] http://alert.tas.gov.au/Pages/Home.aspx

- Detailed Severe Thunderstorm Warnings – A detailed severe thunderstorm warning is a highly detailed warning that graphically identifies where severe thunderstorms are currently located, where they will be over the next hour and what locations will be affected. Storms are classified as severe if they have the potential to generate extreme wind gusts, large hail, heavy rainfall that could lead to flooding, or tornadoes. An example of the warning provided with this service is shown in Figure 4.1.
- Severe Weather Warnings – A severe weather warning is provided for potentially hazardous or dangerous weather that is not solely related to severe thunderstorms, tropical cyclones or bushfires. They are issued whenever severe weather is occurring in an area or is expected to develop or move into an area. An example of the warning provided with this service is shown in Figure 4.2.

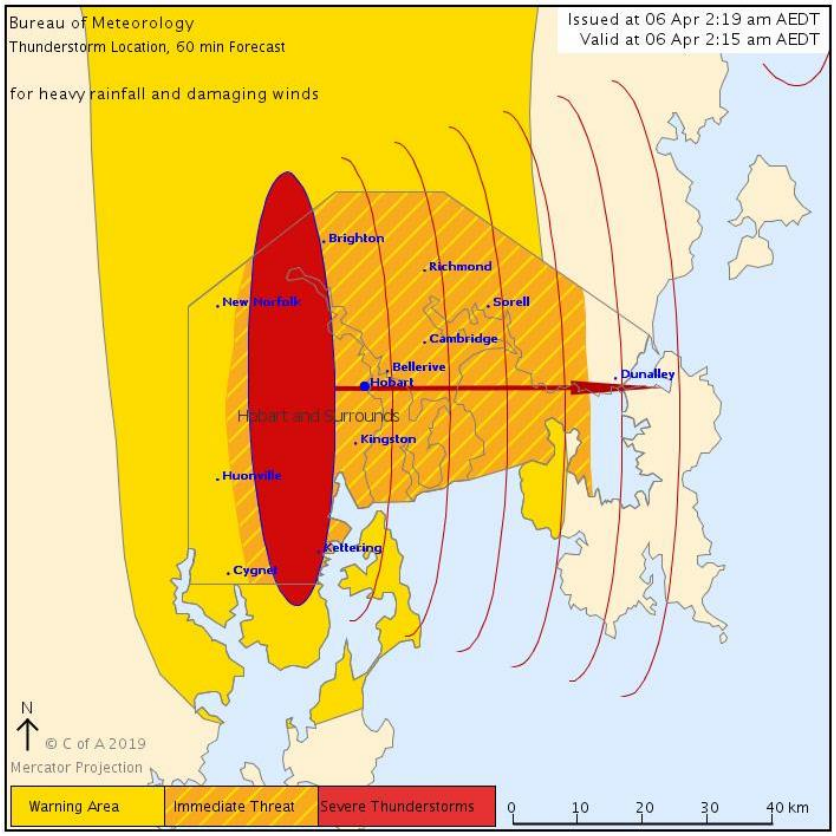

Figure 4.1: Example Detailed Severe Thunderstorm Warning for Hobart and Surrounds

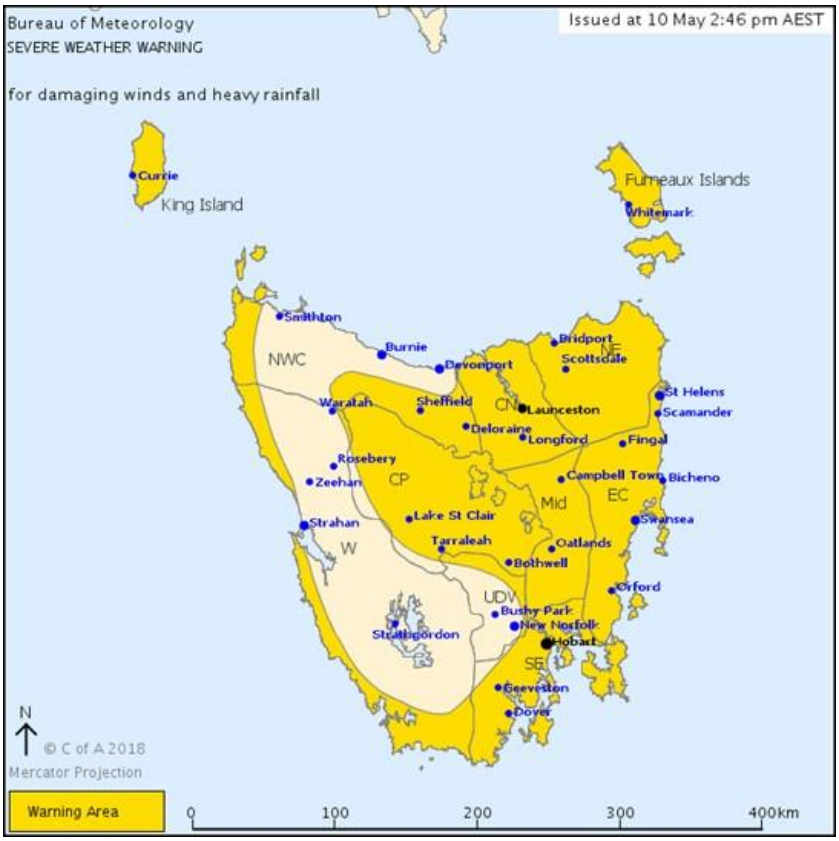

Figure 4.2: Example Severe Weather Warning for Tasmania

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5. Potential measures for management of flood risk

5.1 Stormwater management measures overview

A range of potential management measures have been considered for the study area. These measures have the potential to reduce economic impacts of flooding, whilst consideration has also been given to reduction of social impacts (i.e. community) and to improving safety through reducing flood hazard.

The Australian Disaster Resilience Handbook 7 Managing the Floodplain: A Guide to Best Practice in Flood Risk Management (AIDR, 2017a) outlines a general range of potential measures suitable for managing flood risk to existing and future development, as reproduced respectively in Table 5.1 and Table 5.2.

Table 5.1: Potential flood risk management measures for existing development (from AIDR, 2017a; Table 7.1)

Development Scale	Type of flood risk	Potential Management Measures (example)
Community, or a specific area	Existing	Flood mitigation dams Retarding and detention basins Permanent levees Flow conveyance improvements Flood gates Temporary barriers Change in property zoning
	Residual	Flood prediction and warning Community-scale emergency response plans Evacuation arrangements Evacuation route upgrade Community flood readiness Community recovery plans
Property	Existing	House raising House purchase/buyback Relocation of development Flood proofing of buildings Temporary measures
	Residual	Residual risk management options listed above augmented by appropriate property-based emergency management plans

Table 5.2: Potential flood risk management measures for future development (from AIDR, 2017a; Table 7.2)

Development Scale	Type of flood risk	Potential Management Measures (example)
New development and redevelopment areas	Existing	Zoning Development Controls Building Controls
	Residual	Flood prediction and warning Flood access and evacuation routes Emergency response arrangement for new areas Update of community-scale emergency response plans Development-scale flood awareness and readiness
Infill development within existing zoned areas	Future	Development controls Building controls
	Residual	Residual risk management options listed above augmented by appropriate property-based emergency management plans

An effective flood risk management strategy typically comprises a suite of interdependent management measures designed to address existing and residual flood risk. These measures can be developed to address these risks at a community-wide/regional scale or on an individual property basis.

Whilst specific management measures are designed and assessed in isolation for their effectiveness at mitigating or reducing the impacts of flooding, the development of the final stormwater system management plan for the study area has considered a range of management measures such as those listed above. This has ensured that the suite of management measures advocated herein is appropriate for the characteristics of the stormwater catchments across the study area. Where possible, these measures have considered the dual functions of mitigating or reducing flood risk and enhancing the natural environment.

5.1.1 Managing flood risk for existing development

As discussed in AIDR (2017a), mitigating flood risk to existing development involves reducing flood impacts retrospectively by reducing the frequency and/or the consequences of flooding by:

- Modifying flood behaviour;
- Improving flood warning and emergency response;
- Altering the community's behaviour during floods (e.g. changing attitudes to entering or driving through flood waters) or their response to floods;
- Reducing the effects of flooding on vulnerable sectors of the community; and
- Reducing the vulnerability of the built environment to flooding.

5.1.2 Managing flood risk for future development

There are areas of the subject stormwater catchments that are zoned for future development (typically residential), and instances may arise in the future where redevelopment or infill development may be proposed. Whilst it is not considered appropriate to investigate specific flood mitigation measures as part of this study to address these areas of future development, it is important to address flood risk for future development as part of the stormwater system management plan.

As discussed in AIDR (2017a), mitigating flood risk for future development can be achieved most effectively through strategic and development-scale land-use planning cognisant of the need to maintain flood function, consider flood hazard and develop sustainable emergency response arrangements. Best practice encourages the setting of 'flood risk' informed strategic land-use planning directions, and supporting zonings and development and building controls that:

- limit the impacts of new development and the intensification of development on the flood risk of the existing community;
- limit the exposure of the new community to flood hazard;
- limit damage to new property and infrastructure to acceptable levels; and
- consider public safety and the associated needs of emergency response management.

5.2 Management measures assessment methodology

Assessment of management measures for the study area stormwater catchments has been undertaken by adopting a multi-objective approach to the management of stormwater from urban areas, as described in LGAT (2016), in which:

- Flood risk to existing and future development is minimised;
- Stormwater harvesting and re-use opportunities are maximised;
- Adverse impacts on watercourses and receiving waters are reduced; and
- Desirable development planning outcomes associated with urban landscape, open space, recreation, and amenity are achieved.

This approach has been applied to identify a range of potential stormwater management measures across the study area. Where applicable, more detailed assessments have been undertaken using the TUFLOW model to quantify the changes in flooding behaviour attributable to a given management measure. Outputs from the modelling of specific structural measures have been used to calculate the reduction in flood damages.

It should be noted that whilst specific management measures have been identified and investigated as part of a suite of management measures, it is not feasible to eliminate all flooding risks across the study area. The suite of management measures presented herein also includes a number of catchment-wide/regional management measures to address situations where localised management measures are not feasible (e.g. modifications to emergency management procedures and land-use planning controls).

5.2.1 Design standards

The following definitions are provided in the Sorell Interim Planning Scheme 2015 for minor and major stormwater system:

- A minor stormwater drainage system means the stormwater reticulation infrastructure designed to accommodate more frequent rainfall events (in comparison to major stormwater drainage systems) having regard to convenience, safety and cost; and
- A major stormwater drainage system means the combination of overland flow paths (including roads and watercourses) and the underground reticulation system designed to provide safe conveyance of stormwater runoff and a specific level of flood mitigation.

Table E7.7.1 of the Sorell Interim Planning Scheme 2015 gives the following objectives for the design of stormwater drainage:

- A minor stormwater drainage system must be able to accommodate a storm with an ARI of 20 years (5% AEP) in the case of non-industrial zoned land and an ARI of 50 years (2% AEP) in the case of industrial zoned land, when the land serviced by the system is fully developed; and
- A major stormwater drainage system must be designed to accommodate a storm with an ARI of 100 years (1% AEP).

Where practicable, the concept design of the potential structural management measures has sought to uphold these design objectives. Given the extent of existing development across the study area, there are some physical limits to the size of new infrastructure that can be feasibly implemented whilst considering other design criteria (e.g. minimum cover requirements). It follows that it may not be possible to fully achieve the design objectives stated above. However, the reductions in flood affectation and flood risk achieved by the management measures represent improvements compared with the existing situation and are therefore considered appropriate for this study.

5.3 Identification of potential management measures

In accordance with the discussion in AIDR (2017b), the identification and selection of specific management measures for the area of interest has been influenced by:

- the physical characteristics of the location;
- economic, social and environmental benefits and costs;
- the technical feasibility; and
- local factors, including community attitudes, support and affordability.

The potential management measures assessed for the study area can be grouped into the categories presented in Table 5.3.

Table 5.3: Categories of Potential Management Measures

Prefix	Category	Description	Report Section
FM	Flood modification / structural management measures	Structural management measures are generally used to modify a flood's behaviour in order to reduce the flood risk. These measures may include drainage network upgrades, detention basins, channel improvements.	Section 5.4 Section 5.5 Section 5.6
PS	Property-scale management measures	Property-scale management measures aim to reduce the flood risk at existing property. These measures include house raising, house buyback and individual house flood proofing, and planning and development controls.	Section 5.7
CS	Community/catchment-scale management measures	Community and/or catchment-scale management measures aim to reduce flood risk at a community scale, rather than at specific locations. These measures include flood warning, emergency response, community preparedness and recovery.	Section 5.8

5.4 Sorell area of interest - flood modification/structural management measures

The potential flood modification or structural management measures considered for the Sorell area of interest are summarised in Table 5.4.

Table 5.4: Potential structural management measures – Sorell area of interest

Measure ID*	Description
FM-SOR-01	Drainage upgrade – Tasman Highway at Stores Lane
FM-SOR-02	Drainage upgrade – Tasman Highway cross-drainage at Stores Lane
FM-SOR-03	Detention basin – NW of Tasman Highway at Stores Lane
FM-SOR-04	Drainage upgrade – upstream of Devenish Drive to Montagu Street outfall
FM-SOR-05	Detention basin and drainage upgrade – upstream of Gatehouse Drive development
FM-SOR-06	Drainage upgrade – Weston Hill Road near Valley View Close

*"FM" denotes flood modification measure; "SOR" identifies measures for the Sorell area of interest

5.4.1 FM-SOR-01 – Drainage upgrade – Tasman Highway at Stores Lane

5.4.1.1 Existing flood risk

This management measure addresses existing flood risk at location 7 identified in Table 3.1 and Figure 3.1.

Runoff from the sub-catchment bounded by the ridge of high ground running through Department of Education land (South-East Trade Training Centre) and the Tasman Highway to the south and east drains to the sag point on the Tasman highway opposite the intersection with Stores Lane. The elevation of the road at this location results in most of the runoff ponding on the north-western side of the intersection, resulting in flooding of properties at this location.

The capacity of the existing stormwater drainage at this location is limited by:

- Insufficient pit inlet capacity to capture excess/ponded water; and
- Insufficient pipe capacity south of the Tasman Highway

Results from the modelling of the existing catchment conditions indicates this area has a flood hazard category of H3, which is defined as "*unsafe for vehicles, children and the elderly*".

5.4.1.2 Details of the proposed management measure

The aim of this management measure is to minimise the flood risk at properties and within the roadway. The concept design has taken into account the highway upgrade planned by the Department of State Growth and comprises the following elements:

- Removal of the existing 0.525m diameter pipe south of the highway; and
- Replacement of the pipe with open channel/ditch
    - The new open channel reach connects with the existing channel running along the western side of Stores Lane.

The layout of the proposed works associated with the management measure is presented in Figure 5.1.

Whilst not explicitly modelled, the opportunity exists for the creation of a water quality treatment device upstream of the outfall to Pitt Water (e.g. vegetated filter swale or bio-retention basin).

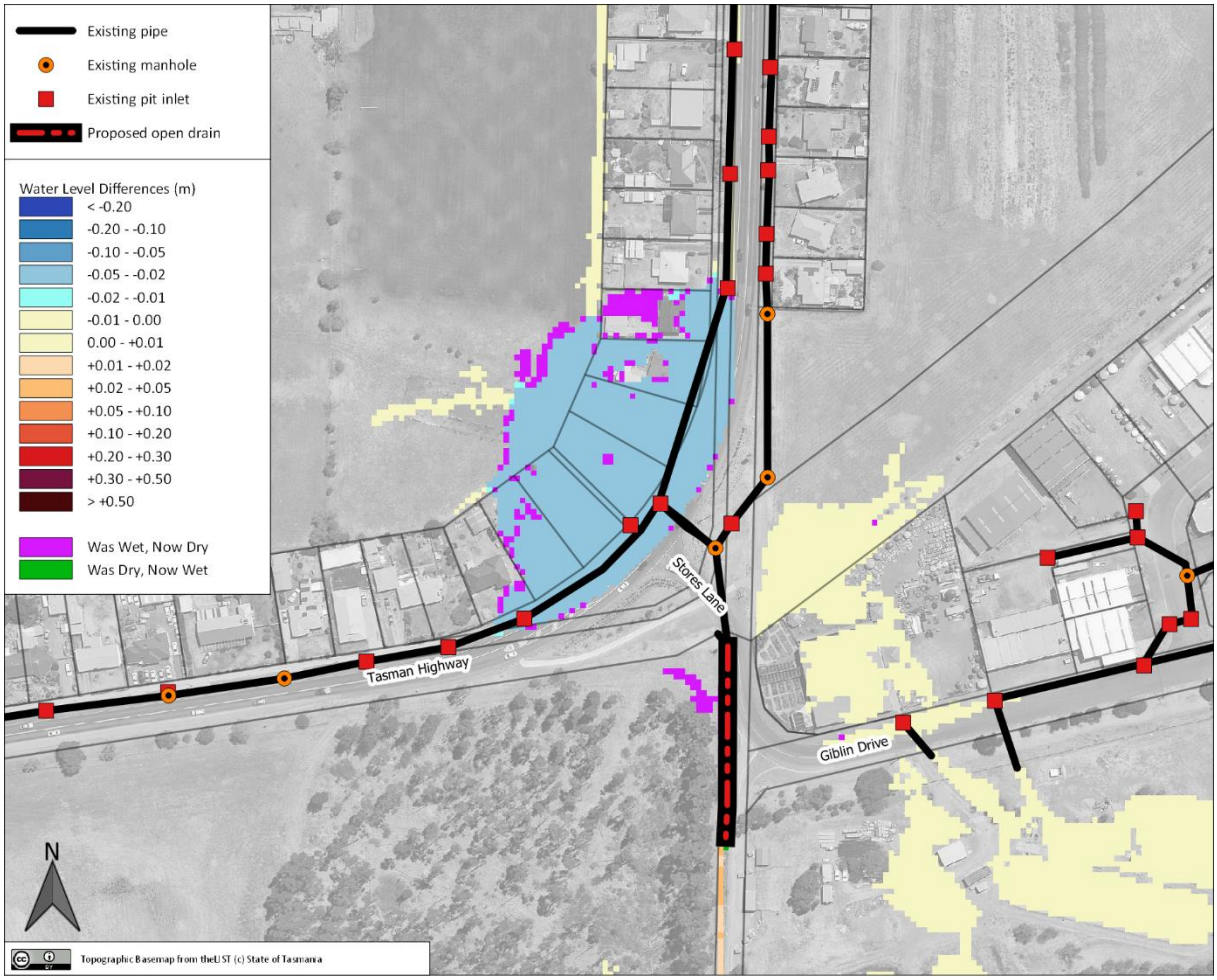

Figure 5.1: Management measure FM-SOR-01 – proposed works and peak water level differences (1% AEP event)

5.4.1.3 Hydraulic modelling of the proposed works

The TUFLOW hydraulic model has been used to assess the changes in flooding behaviour with the inclusion of the proposed works. The resulting peak water level differences for the 1% AEP event are shown in Figure 5.1, where these differences represent the change in peak water level compared with the existing case modelling. The model results indicate there is a reduction in flood risk on the north-western side of the Tasman Highway with the following changes in flooding behaviour:

- Lower peak flood levels on the Tasman Highway and at flood-affected properties
  - Up to 0.04m lower for a 1% AEP event;
  - Up to 0.03m lower for a 5% AEP event;
- Minor reduction in the extents of flooding on the north-western side of the Tasman Highway for both 1% AEP and 5% AEP events;
- Minor increase in peak flood levels within the open channel running along the western side of Stores Lane;
- Minor increase in the extents of flooding along the existing drainage path to the south of the TasWater site;

- Minor increases in peak flood velocity within the existing open channel and outfall drainage path for both 1% AEP and 5% AEP events;
- Reduction in the extent of flood hazard category H3, noting that the proposed works do not eliminate this flood hazard category.

The predicted reduction in flood damages, implementation cost and benefit-cost ratio are provided in Table 5.5. This indicates that there is a relatively small reduction in flood damages, resulting in a benefit-cost ratio less than 1. It must be noted that the economic assessment does not explicitly account for the reduction in flood risk on roads as it only accounts for tangible damages (i.e. property damage).

Further details of the economic assessment of the management measures, including details of the cost estimates, are provided in Section 6, whilst the multi-criteria assessment of the management measures (including assessment of intangible damages such as reduced flood risk on roads) is detailed in Section 7.

Table 5.5: Damages, cost and benefit-cost ratio for management measure FM-SOR-01

Measure ID	Reduction in Average Annual Damage (AAD)	Reduction in NPV Damages	Cost Estimate of Implementation (NPV)	Benefit-Cost Ratio relative to Baseline
FM-SOR-01	$2,000	$30,000	$84,000	0.36

5.4.1.4 Summary

Management measure FM-SOR-01 achieves minor reductions in flood affectation for properties and within the roadway at the existing sag point on the north-western side of the Tasman Highway opposite Stores Lane.

Environmental impacts are minimised through the use of the existing drainage path, noting that there is potential for a water quality treatment device to be constructed upstream of the outfall to Pitt Water.

5.4.2 FM-SOR-02 – Drainage upgrade – Tasman Highway cross-drainage at Stores Lane

5.4.2.1 Existing flood risk

This management measure addresses existing flood risk at location 7 identified in Table 3.1 and Figure 3.1, and represents an alternative solution to that presented in Section 5.4.1 for management measure FM-SOR-01. Refer to Section 5.4.1 for discussion on the existing flood risk at this location.

5.4.2.2 Details of the proposed management measure

The aim of this management measure is to minimise the flood risk at properties and within the roadway. The concept design has taken into account the highway upgrade planned by the Department of State Growth and comprises the following elements:

- Removal of the existing 0.525m diameter pipe south of the highway (as for measure FM-SOR-01); and

- Replacement of the pipe with open channel/ditch (as for measure FM-SOR-01)
    - The new open channel reach connects with the existing channel running along the western side of Stores Lane.
- Increased cross-drainage capacity via a single 0.675m diameter pipe and a single 750mm diameter pipe; and
- Increased pit inlet capacity with three new pit inlets.

The layout of the proposed works associated with the management measure is presented in Figure 5.2.

Whilst not explicitly modelled, the opportunity exists for the creation of a water quality treatment device upstream of the outfall to Pitt Water (e.g. vegetated filter swale or bio-retention basin).

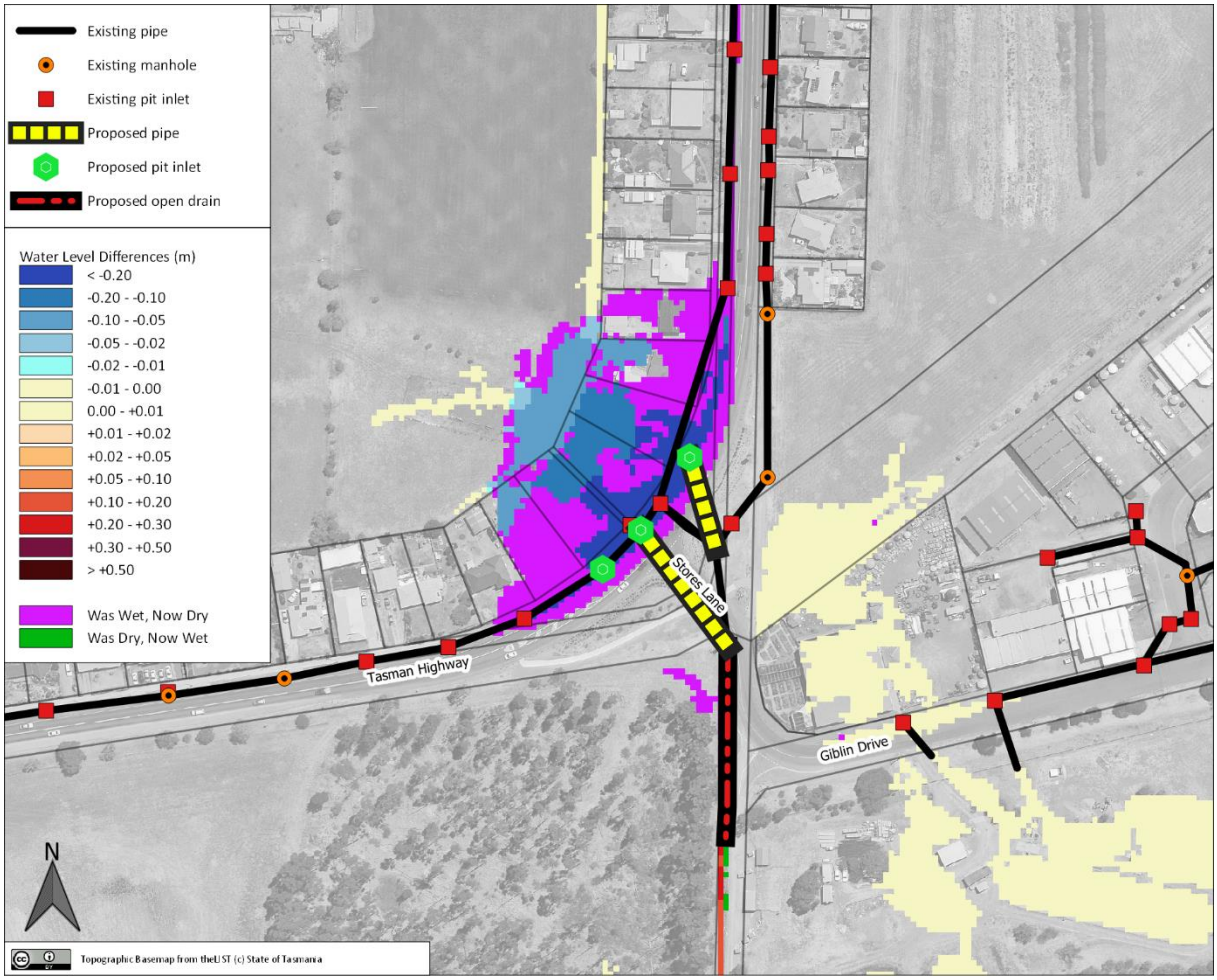

Figure 5.2: Management measure FM-SOR-02 – proposed works and peak water level differences (1% AEP event)

5.4.2.3 Hydraulic modelling of the proposed works

The TUFLOW hydraulic model has been used to assess the changes in flooding behaviour with the inclusion of the proposed works. The resulting peak water level differences for the 1% AEP event are shown in Figure 5.2, where these differences represent the change in peak water level compared with the existing case modelling. The model results indicate there is a significant reduction in flood

risk on the north-western side of the Tasman Highway with the following changes in flooding behaviour:

- Lower peak flood levels on the Tasman Highway and at flood-affected properties
  - Up to 0.47m lower for a 1% AEP event;
  - Up to 0.41m lower for a 5% AEP event;
- Significant reduction in the extents of flooding on the north-western side of the Tasman Highway for both 1% AEP and 5% AEP events;
- Increases peak flood levels within the open channel running along the western side of Stores Lane;
- Minor increase in the extents of flooding along the existing drainage path to the south of the TasWater site;
- Minor increases in peak flood velocity within the existing open channel and outfall drainage path for both 1% AEP and 5% AEP events;
- Elimination of flood hazard category H3 on the north-western side of the Tasman Highway, retaining a localised area of category of H2 within the road reserve; and
- Increased flood hazard downstream of the Tasman Highway along the existing drainage path to outfall to Pitt Water.

The predicted reduction in flood damages, implementation cost and benefit-cost ratio are provided in Table 5.6. This indicates that there is a modest reduction in flood damages, resulting in a benefit-cost ratio less than 1. It must be noted that the economic assessment does not explicitly account for the reduction in flood risk on roads as it only accounts for tangible damages (i.e. property damage).

Further details of the economic assessment of the management measures, including details of the cost estimates, are provided in Section 6, whilst the multi-criteria assessment of the management measures (including assessment of intangible damages such as reduced flood risk on roads) is detailed in Section 7.

Table 5.6: Damages, cost and benefit-cost ratio for Management Measure FM-SOR-02

Measure ID	Reduction in Average Annual Damage (AAD)	Reduction in NPV Damages	Cost Estimate of Implementation (NPV)	Benefit-Cost Ratio relative to Baseline
FM-SOR-02	$10,000	$148,000	$331,000	0.45

5.4.2.4 Summary

Management measure FM-SOR-02 achieves significant reductions in flood affectation for properties and within the roadway at the existing sag point on the north-western side of the Tasman Highway opposite Stores Lane.

Environmental impacts are minimised through the use of the existing drainage path, noting that there is potential for a water quality treatment device to be constructed upstream of the outfall to Pitt Water.

5.4.3 FM-SOR-03 – Detention basin – NW of Tasman Highway at Stores Lane

5.4.3.1 Existing flood risk

This management measure addresses existing flood risk at location 7 identified in Table 3.1 and Figure 3.1, and represents an alternative solution to those presented in Section 5.4.1 for management measure FM-SOR-01 and Section 5.4.2 for management measure FM-SOR-02. Refer to Section 5.4.1 for discussion on the existing flood risk at this location.

5.4.3.2 Details of the proposed management measure

The aim of this management measure is to minimise the flood risk at properties and within the roadway. The concept design has taken into account the highway upgrade planned by the Department of State Growth and comprises the following elements:

- Attenuation of runoff through the creation of a detention basin within the Department of Education land upstream of the flood affected properties
    - Construction of a wall/barrier along the property boundaries to contain flooding to the detention basin area
    - Inlet pit and 300mm diameter outlet pipe form the basin, connecting to the existing stormwater drainage network.

The layout of the proposed works associated with the management measure is presented in Figure 5.3.

Whilst not explicitly modelled, the opportunity exists for the basin to be designed to have a dual function as a water quality treatment device. Alternatively, a water quality treatment device could be constructed upstream of the outfall to Pitt Water (e.g. vegetated filter swale or bio-retention basin).

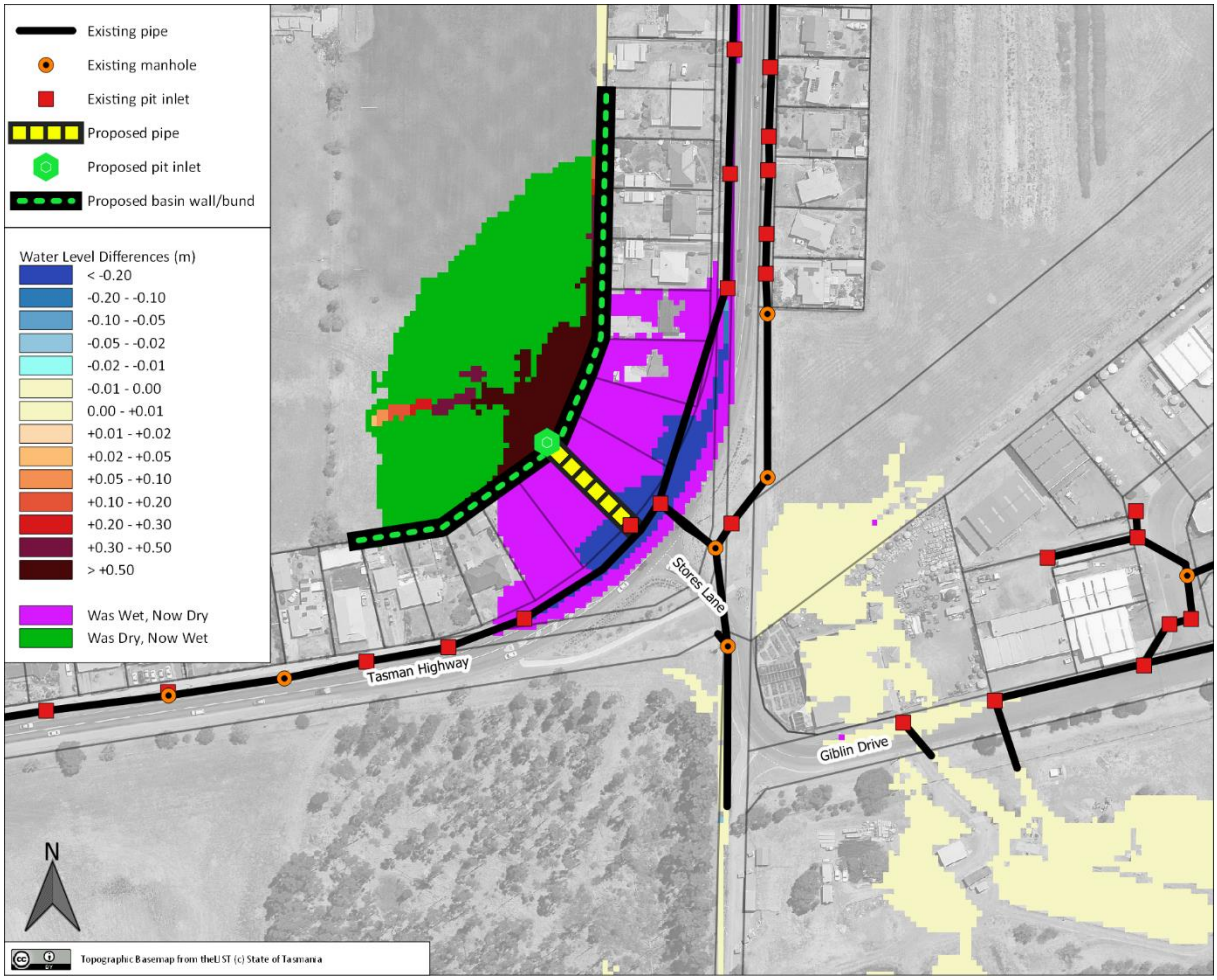

Figure 5.3: Management measure FM-SOR-03 – proposed works and peak water level differences (1% AEP event)

5.4.3.3 Hydraulic modelling of the proposed works

The TUFLOW hydraulic model has been used to assess the changes in flooding behaviour with the inclusion of the proposed works. The resulting peak water level differences for the 1% AEP event are shown in Figure 5.3, where these differences represent the change in peak water level compared with the existing case modelling. The model results indicate there is a significant reduction in flood risk on the north-western side of the Tasman Highway with the following changes in flooding behaviour:

- Lower peak flood levels on the Tasman Highway and at flood-affected properties
  - Up to 0.43m lower for a 1% AEP event;
  - Elimination of flooding for a 5% AEP event;
- Significant reduction in the extents of flooding on the north-western side of the Tasman Highway for both 1% AEP and 5% AEP events;
- Negligible change in flooding behaviour downstream of the Tasman Highway;
- Negligible change in peak flood velocity;

- Elimination of flood hazard category H3 on the north-western side of the Tasman Highway, retaining a localised area of category of H2 within the road reserve; and
- Increased flood hazard within the detention basin area, commensurate with the function of the basin.

The predicted reduction in flood damages, implementation cost and benefit-cost ratio are provided in Table 5.7. This indicates that there is a significant reduction in flood damages, resulting in a relatively high benefit-cost ratio.

Whilst the 1% AEP event peak flood level reduction for this management measure (0.43m) is less than the value calculated for measure FM-SOR-02 (0.47m), this management measure results in a significantly greater reduction in flood extents. This effect translates into a greater reduction in flood damages given the fewer number of properties that are flood affected compared with measure FM-SOR-02. It must be noted that the economic assessment does not explicitly account for the reduction in flood risk on roads as it only accounts for tangible damages (i.e. property damage).

Further details of the economic assessment of the management measures, including details of the cost estimates, are provided in Section 6, whilst the multi-criteria assessment of the management measures (including assessment of intangible damages such as reduced flood risk on roads) is detailed in Section 7.

Table 5.7: Damages, cost and benefit-cost ratio for Management Measure FM-SOR-03

Measure ID	Reduction in Average Annual Damage (AAD)	Reduction in NPV Damages	Cost Estimate of Implementation (NPV)	Benefit-Cost Ratio relative to Baseline
FM-SOR-03	$40,000	$592,000	$292,000	2.03

5.4.3.4 Summary

Management measure FM-SOR-03 achieves significant reductions in flood affectation for properties and within the roadway at the existing sag point on the north-western side of the Tasman Highway opposite Stores Lane. The nature of this management measure is such that there is an increase in flooding within the detention basin area and use of this land would require negotiation with the Department of Education. Furthermore, the design of the detention basin would need to consider safety issues such as wall/embankment failure.

Environmental impacts are minimised through the use of the existing drainage path, noting that there is potential for a water quality treatment device to be constructed upstream of the outfall to Pitt Water.

5.4.4 FM-SOR-04 – Drainage upgrade – Devenish Drive to Montagu Street outfall

5.4.4.1 Existing flood risk

This management measure addresses existing flood risk at locations 3 and 4 identified in Table 3.1 and Figure 3.1, whilst addressing flood risk for parts of locations 2 and 5.

The proposed works associated with this management measure have been designed to address existing flood risk from water flowing via a number of existing flow paths. These sub-catchments and flow paths can be described as follows:

- Catchment draining to the Tasman Highway from north of the intersection with Shark Point Road and disused railway
    - Excess overland flow crosses the Tasman Highway and flows generally along Peppe Drive in the direction of Attunga Drive
- Catchment draining to the existing open drain south of Leitram Avenue and to the headwall of the existing stormwater drainage network located west of Devenish Drive
    - Excess flow continues to Devenish Drive where the flow continues generally southwards, including flow along Devenish Drive where there is flood hazard category of H5 defined as "*Unsafe for all people and vehicles. Buildings require special engineering design and construction*";
    - Overland flow crosses the Tasman Highway in multiple locations where there is hazard category of H2 (defined as "*unsafe for small vehicles*") and passes through residential property, ultimately draining to the western end of Attunga Drive;
    - Flood hazard category of H2 (defined as "*unsafe for small vehicles*") along Attunga Drive, with a category of H3 (defined as "*unsafe for all vehicles, children and the elderly*") affecting some residential properties
- Catchment draining to land owned by Sorell Council north of the intersection of the Tasman Highway and Arthur Street
    - This catchment drains land to the north of Pennington Drive and westwards from Dubs and Co Drive

The capacity of the existing stormwater drainage at this location is limited by:

- Insufficient major drainage system capacity to capture excess flow (e.g. at headwall west of Devenish Drive); and
- Absence of piped drainage network addressing runoff from some of the contributing sub-catchments.

5.4.4.2 Details of the proposed management measure

This management measure embodies a significant change to the existing major stormwater drainage infrastructure with the aim of minimising the flood risk and flood hazard at existing property and along roads. The concept design has sought to maximise the use of Council-controlled easements and land and comprises the following major elements:

- Construction of a new channel running from the Tasman Highway at the intersection of Shark Point Road eastwards towards Devenish Drive
    - Utilises the existing easement formed by the disused railway corridor
    - Requires pipe culverts to maintain the existing access to private property and a TasNetworks facility;
    - Requires wall/embankment to ensure flow is contained within the channel and does not spill southwards towards the Tasman Highway;

- Construction of a new open channel running from upstream of the existing headwall west of Devenish Drive running eastwards along the easement formed by the disused railway corridor to Council's land north of the intersection of the Tasman Highway;
    - Requires the removal of part of the existing major piped drainage network in the vicinity of Devenish Drive (i.e. replaced with open channel);
    - Culvert crossing at Devenish Drive (1/3.60mx1.20m RCBC);
    - Existing piped drainage will discharge to the open channel via new headwalls;
    - Requires various sections of wall/embankment to ensure flow is contained within the channel and does not spill southwards;
- Continuation of the large open channel in a southerly direction to the Tasman Highway, replacing the existing piped drainage infrastructure;
    - Existing piped drainage will discharge to the open channel via new headwalls;
    - Requires various sections of wall/embankment to ensure flow is contained within the channel and does not spill westwards;
- New headwall and box culvert crossing of the Tasman Highway heading south-westerly to Pembroke Park
    - Utilises 1/3.60mx1.20m RCBC, reducing to 1/3.60mx0.90m RCBC within Pembroke Park to ensure the offtake for the existing stormwater harvesting system is preserved;
- Construction of new open channel heading southwards through Pembroke Park to connect with existing open channel
    - Receives discharge from the new Tasman Highway box culvert;
    - Culvert crossing at the Pembroke Park access road (1/3.60mx1.20m RCBC), where the downstream headwall will combine an outfall from the existing piped drainage;
- Widening and deepening of the existing open channel that continues westwards following the alignment of Montagu Street
    - Requires new box culverts (typically, 1/2.70mx0.90m RCBC) to preserve existing access across the channel.
    - Noting that there are known tunnel erosion issues with drainage through Pembroke Park and Miena Park, the design of the reaches of open channel will need to account for this, potentially requiring lining or armouring.

The layout of the proposed works associated with the management measure is presented in Figure 5.4.

Whilst not explicitly modelled, the opportunity exists for the creation of a water quality treatment device upstream of the outfall to Orielton Lagoon. Given the size of the contributing catchment and ownership of land at this location, it is likely that a bio-retention basin/system would be appropriate.

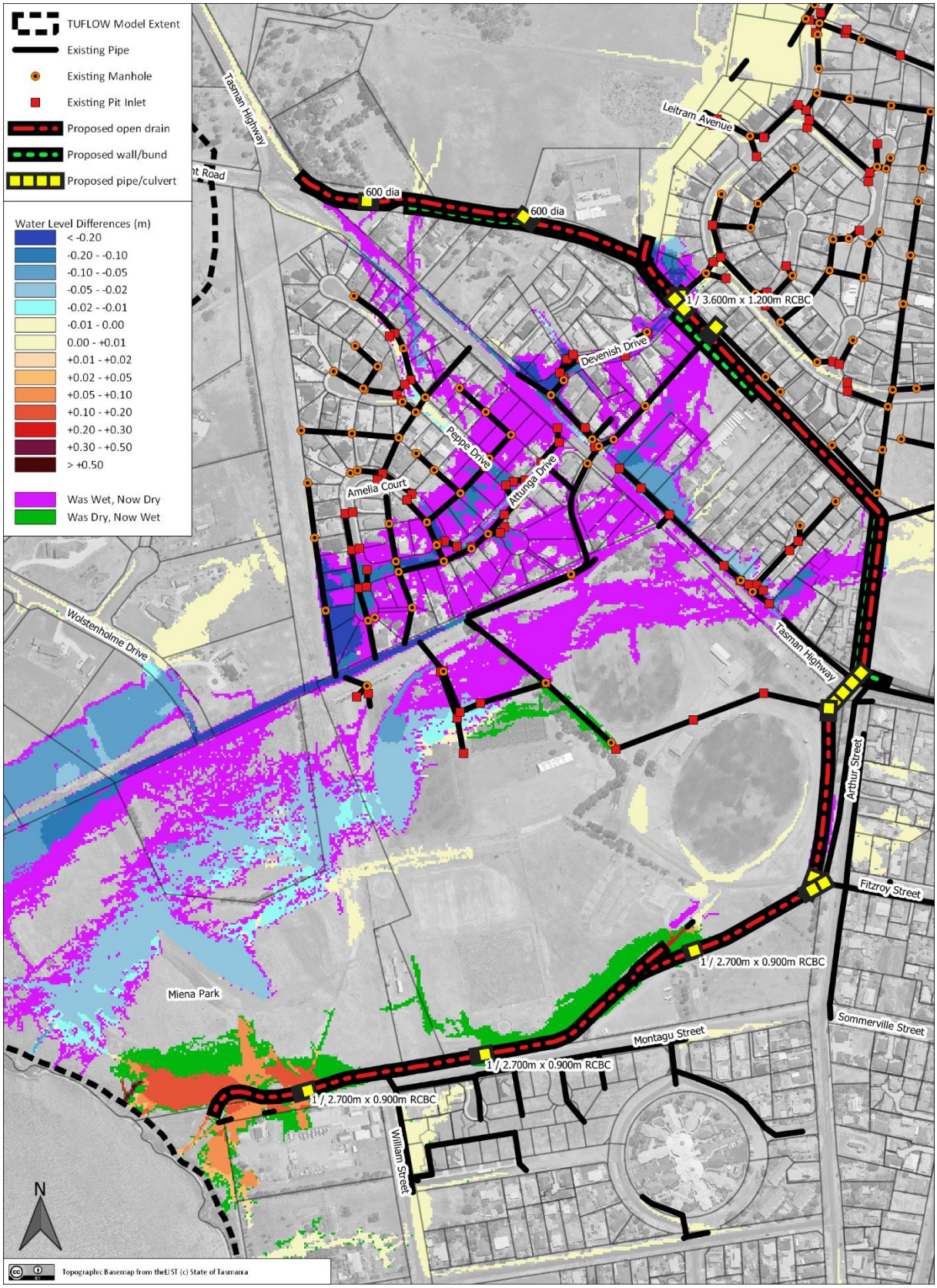

Figure 5.4: Management measure FM-SOR-04 – proposed works and peak water level differences (1% AEP event)

5.4.4.3 Hydraulic modelling of the proposed works

The TUFLOW hydraulic model has been used to assess the changes in flooding behaviour with the inclusion of the proposed works. The resulting peak water level differences for the 1% AEP event are shown in Figure 5.4, where these differences represent the change in peak water level compared with the existing case modelling. The model results indicate there is a reduction in flood risk for the areas described in Section 5.4.4.1, with the following changes in flooding behaviour:

- Capture of runoff from north of the intersection of the Tasman Highway and Shark Point Road, resulting in:
    - Lower peak flood levels through residential property along Peppe Drive of up to 0.10m for a 1% AEP event
    - Reduced extents of flooding;
    - Reduction of peak flood velocity along Peppe Drive;
- Capture of excess flow originating from north of Leitram Avenue, resulting in:
    - Significant reductions of flow passing south along Devenish Drive with lower peak flood levels of up to 0.35m for a 1% AEP event and of up to 0.28m for a 5% AEP event;
    - Significant reduction of peak flood velocity and flood hazard category along Devenish Drive;
    - Significantly reduced extent of flooding through property between Devenish Drive and the Tasman Highway;
- Capture of overland flow originating from Pennington Drive and Dubs and Co Drive;
- Elimination of flow crossing the Tasman Highway, where under existing conditions this occurs in multiple locations from multiple flow paths;
- Reduced flood risk along Attunga Drive with:
    - Significant reductions of peak flood levels of up to 0.28m in both 1% AEP and 5% AEP events;
    - Reduction of peak flood velocity and flood hazard category;
- Increased flood risk along the widened channel through Pembroke Park and Miena Park (i.e. running parallel to Montagu Street) with:
    - Increased flood levels and extents of flooding;
    - Increased peak flood velocity and flood hazard category.

The predicted reduction in flood damages, implementation cost and benefit-cost ratio are provided in Table 5.8. This indicates that there is a significant reduction in flood damages, resulting in a benefit-cost ratio greater than 1. It must be noted that the economic assessment does not explicitly account for the reduction in flood risk on roads as it only accounts for tangible damages (i.e. property damage).

Further details of the economic assessment of the management measures, including details of the cost estimates, are provided in Section 6, whilst the multi-criteria assessment of the management measures (including assessment of intangible damages such as reduced flood risk on roads) is detailed in Section 7.

Table 5.8: Damages, cost and benefit-cost ratio for Management Measure FM-SOR-04

Measure ID	Reduction in Average Annual Damage (AAD)	Reduction in NPV Damages	Cost Estimate of Implementation (NPV)	Benefit-Cost Ratio relative to Baseline
FM-SOR-04	$524,000	$7,756,000	$4,523,000	1.71

5.4.4.4 Summary

Management measure FM-SOR-04 achieves significant reductions in flood affectation for numerous properties and roads through the western part of the Sorell stormwater catchment. Despite attracting a very high capital cost for implementation, the reduced flood risk is shown to translate into a benefit-cost ratio greater than 1.

Environmental impacts are generally minimised through the use of the existing drainage path. The opportunity exists for the creation of a water quality treatment device upstream of the outfall to Orielton Lagoon. Given the size of the contributing catchment and ownership of land at this location, it is likely that a bio-retention basin/system would be appropriate.

5.4.5 FM-SOR-05 – Detention basin and drainage upgrade – upstream of Gatehouse Drive development

5.4.5.1 Existing flood risk

This management measure addresses existing flood risk at location 1 identified in Table 3.1 and Figure 3.1.

Runoff from the catchment draining the area north of Valley View Road can be described as follows:

- Runoff flows across Valley View Road and continues generally in a south-westerly direction through the new subdivision north of the intersection of Gatehouse Drive and Pennington Drive;
    - There is a 0.90m diameter pipe running through the subdivision forming the trunk stormwater drainage. Following the construction of the subdivision there is no inlet headwall to facilitate the capture of runoff into this pipe, resulting in an under-utilisation of its flow-carrying capacity;
- Flow continues along Pennington Drive and through residential property before entering the existing detention basin located on the western side of Pennington Drive
    - The predicted flood hazard category along Pennington Drive is H5 which is defined as "*Unsafe for all people and vehicles. Buildings require special engineering design and construction"*; and
- Water spilling from the detention basin continues along the alignment of the existing open drain south of Leitram Avenue to the existing headwall west of Devenish Drive.

5.4.5.2 Details of the proposed management measure

The aim of this management measure is to minimise the flood risk within the new subdivision (particularly along Pennington Drive) by maximising the flow-carrying capacity of the existing trunk

stormwater drainage whilst attenuating runoff from the upstream catchment. The key elements of this management measure are as follows:

- Construction of a new detention basin within the property at 5 Valley View Close. This is privately owned land and whilst there are well-defined existing flow paths, use of the land for the purpose of this management measure will require either acquisition of the land or a long-term lease;
- Construction of a reach of piped drainage, taking flow from the outlet of the new detention basin and connecting with the upstream extent of the existing 900mm diameter trunk drainage.

The layout of the proposed works associated with the management measure is presented in Figure 5.5.

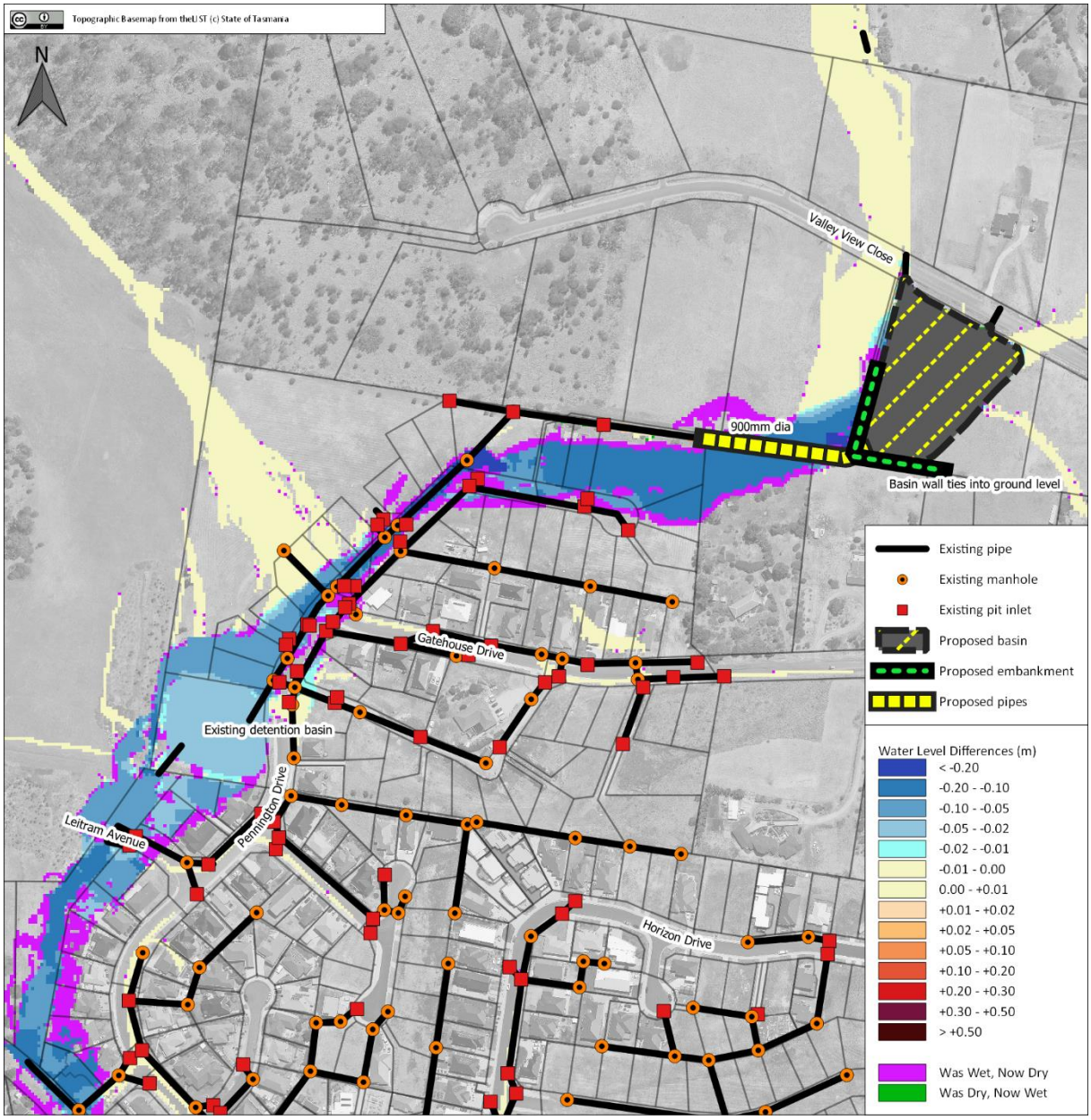

Figure 5.5: Management measure FM-SOR-05 – proposed works and peak water level differences (1% AEP event)

5.4.5.3 Hydraulic modelling of the proposed works

The TUFLOW hydraulic model has been used to assess the changes in flooding behaviour with the inclusion of the proposed works. The resulting peak water level differences for the 1% AEP event are shown in Figure 5.5, where these differences represent the change in peak water level compared with the existing case modelling. The model results indicate there is a reduction in flood risk through the subdivision and along Pennington Drive with the following changes in flooding behaviour:

- Through the north-eastern portion of the new subdivision:
  - Peak flood levels up to 0.14m lower for a 1% AEP event and up to 0.13m lower for a 5% AEP event;
  - Peak flood velocities up to 0.4 m/s lower;
  - Reduced extent of flooding for all events modelled;
  - Reduced flood hazard category through the future residential parcels, from H2 to H1
- Along the northern extension of Pennington Drive in the new subdivision:
  - Peak flood levels up to 0.22m lower for both a 1% AEP event and 5% AEP event;
  - Peak flood velocities up to 1.0 m/s lower;
  - Reduced extent of flooding for all events modelled
  - Reduced peak flood hazard category, with a flood hazard category of H2 along Pennington Drive in both a 1% AEP event and 5% AEP event (H5 for existing conditions);
- Along the open drain south of Leitram Drive
  - Peak flood levels up to 0.16m lower for a 1% AEP event and up to 0.10m lower for a 5% AEP event;
  - Peak flood velocities of up to 0.6 m/s lower for a 1% AEP event and up to 0.2 m/s lower for a 5% AEP event;
  - Minor reductions in peak flood hazard along the existing open drain.

The predicted reduction in flood damages, implementation cost and benefit-cost ratio are provided in Table 5.9. This indicates that there is a significant reduction in flood damages, resulting in a benefit-cost ratio greater than 1. It must be noted that the economic assessment does not explicitly account for the reduction in flood risk on roads as it only accounts for tangible damages (i.e. property damage).

Further details of the economic assessment of the management measures, including details of the cost estimates, are provided in Section 6, whilst the multi-criteria assessment of the management measures (including assessment of intangible damages such as reduced flood risk on roads) is detailed in Section 7.

Table 5.9: Damages, cost and benefit-cost ratio for Management Measure FM-SOR-05

Measure ID	Reduction in Average Annual Damage (AAD)	Reduction in NPV Damages	Cost Estimate of Implementation (NPV)	Benefit-Cost Ratio relative to Baseline
FM-SOR-05	$147,000	$2,176,000	$912,000	2.39

5.4.5.4 Summary

Management measure FM-SOR-05 achieves significant reductions in flood affectation for numerous properties, including the new subdivision. Despite attracting a high capital cost for implementation, the reduced flood risk is shown to translate into a benefit-cost ratio greater than 1.

The modelling results indicate that implementation of the works associated with this management measure would reduce the scope of works for management measure FM-SOR-04. However, due to the sensitive nature of these works, specifically the use of privately owned land as the key feature, a combination of the works in this management measure (FM-SOR-05) and those identified further downstream (FM-SOR-04) has not been undertaken as part of this study.

5.4.6 FM-SOR-06 – Drainage upgrade – Weston Hill Road near Valley View Close

5.4.6.1 Existing flood risk

This management measure addresses existing flood risk at location 10 identified in Table 3.1 and Figure 3.1.

Runoff from the western side of Weston Hill Road drains to the sag point at the inlet to the existing cross-drainage pipe culvert under Weston Hill Road, where this sag point is located near the intersection with Valley View Close. Runoff ponds behind the road embankment, affecting property immediately to the west. The capacity of the existing cross-drainage at this location is limited by the capacity of the existing pipe culvert.

Results from the modelling of the existing catchment conditions indicates this area has a flood hazard category of H4, which is defined as "*unsafe for all people and vehicles*".

5.4.6.2 Details of the proposed management measure

The aim of this management measure is to minimise the flood risk within property upstream of the culvert inlet. The concept design comprises the replacement of the existing 0.450m diameter pipe with a 0.900m diameter pipe.

The layout of the proposed works associated with the management measure is presented in Figure 5.6.

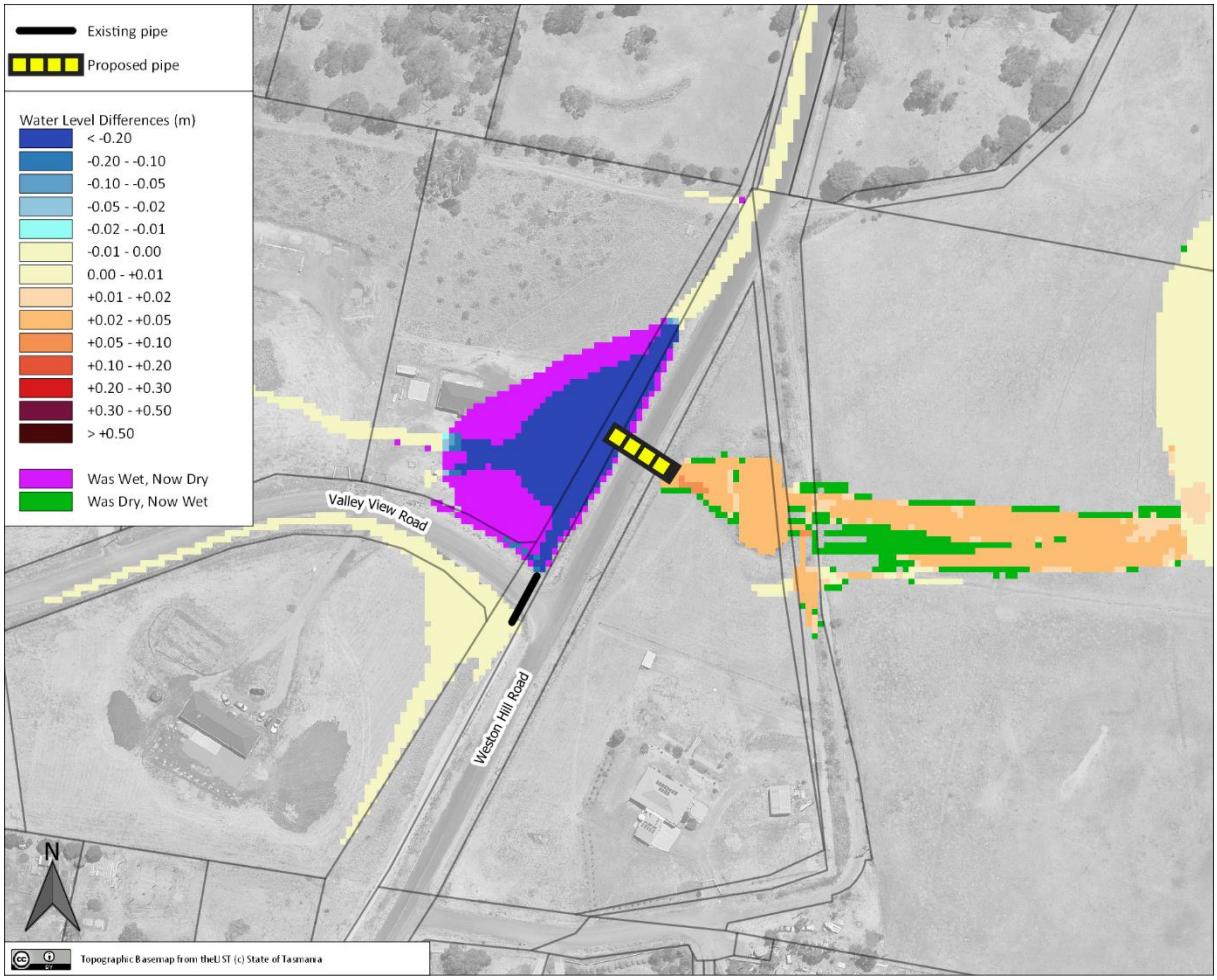

Figure 5.6: Management measure FM-SOR-06 – proposed works and peak water level differences (1% AEP event)

5.4.6.3 Hydraulic modelling of the proposed works

The TUFLOW hydraulic model has been used to assess the changes in flooding behaviour with the inclusion of the proposed works. The resulting peak water level differences for the 1% AEP event are shown in Figure 5.6, where these differences represent the change in peak water level compared with the existing case modelling. The model results indicate a reduction in flood risk on the western side Weston Hill Road with the following changes in flooding behaviour:

- Upstream of the culvert:
  - Lower peak flood levels of up to 0.73m lower for a 1% AEP event and up to 0.58m lower for a 5% AEP event;
  - Reduced extent of flooding, with the existing house no longer flood affected in a 1% AEP event;
  - Reduced flood hazard category, from H4 to H3
- Downstream of the culvert (through open space / pasture):
  - Increased flood levels of up to 0.05m in a 1% AEP event
  - Increased peak flood velocity

- No change to the peak flood hazard category

The predicted reduction in flood damages, implementation cost and benefit-cost ratio are provided in Table 5.10. Due to the limited number of properties benefiting from this measure and low-density nature of the development, the proposed works have been assessed to result in a very small reduction in flood damages, with a benefit-cost ratio less than 1.

Further details of the economic assessment of the management measures, including details of the cost estimates, are provided in Section 6, whilst the multi-criteria assessment of the management measures (including assessment of intangible damages such as reduced flood risk on roads) is detailed in Section 7.

Table 5.10: Damages, cost and benefit-cost ratio for Management Measure FM-SOR-06

Measure ID	Reduction in Average Annual Damage (AAD)	Reduction in NPV Damages	Cost Estimate of Implementation (NPV)	Benefit-Cost Ratio relative to Baseline
FM-SOR-06	$0	$0	$65,000	0.00

5.4.6.4 Summary

Management measure FM-SOR-06 achieves significant reductions in flood affectation immediately west of Weston Hill Road. However, this does not necessarily translate into a corresponding reduction in flood damages which may be attributed to assumptions regarding the floor level at the existing house on the affected property.

5.5 Midway area of interest - flood modification/structural management measures

Following review of the predicted flooding behaviour across the Midway area of interest, there are no location-specific structural management measures identified for inclusion in this stormwater system management plan.

Flooding problem location 1 identified in Table 3.2 and Figure 3.2 details the existing flooding problem at the intersection of the Tasman Highway and Penna Road. Flooding at this location mainly affects the highway and is therefore the responsibility of the Department of State Growth (DSG). It is therefore recommended that output from this study be used by DSG to inform future maintenance and upgrade works at this location.

5.6 Southern Beaches area of interest - flood modification/structural management measures

The potential flood modification or structural management measures considered for the Southern Beaches area of interest are summarised in Table 5.11.

Table 5.11: Potential structural management measures – Southern Beaches area of interest

Measure ID*	Description
FM-SBS-01	Drainage upgrade: Old Forcett Road near Lewisham Scenic Drive
FM-SBS-02	Drainage upgrade: Intersection of Okines Road and Old Forcett Road to outlet
FM-SBS-03	Drainage upgrade: Cross-drainage adjacent to 542 Old Forcett Road
FM-SBS-04	Drainage upgrade: Combination of FM-SBS-02 and FM-SBS-03
FM-SBS-05	Drainage upgrade: Western side of Old Forcett Road at Dodges Ferry Recreation Park
FM-SBS-06	Drainage upgrade: Carlton Beach Road and Seventh Avenue to outfall
FM-SBS-07	Drainage upgrade: Mongana Street to Blue Lagoon, crossing Carlton Beach Road
FM-SBS-08	Fence removal: flow path west of Signal Hill Rd
FM-SBS-09	Fence removal: western side of Moomere St
FM-SBS-10	Drainage upgrade: Freedom Close to estuary via new overland flow path
FM-SBS-11	Defences: Terrain raising to prevent water spilling across Esplanade to Tamarix Road area
FM-SBS-12	Drainage upgrade: Increased capacity for Carlton Bluff Rd drainage
FM-SBS-13	Combination of FM-SBS-12 and FM-SBS-13
FM-SBS-14	Drainage upgrade: Primrose Sands Road cross-drainage adjacent to the RSL
FM-SBS-15	Warning signage: Fulham Road
FM-SBS-16	Drainage upgrade: Gilpins Creek cross-drainage culvert at Church Street West

*"FM" denotes flood modification measure; "SBS" identifies measures for the Southern Beaches area of interest

5.6.1 FM-SBS-01 – Drainage upgrade – Old Forcett Road near Lewisham Scenic Drive

5.6.1.1 Existing flood risk

This management measure addresses existing flood risk at location 5 identified in Table 3.4 and Figure 3.4.

Runoff from the eastern side of Old Forcett Road drains to the eastern side of the Road where it initially ponds then later resulting in flooding of the road. There is a peak flood hazard category of H1 affecting Old Forcett Road, which is defined as "*Generally safe for vehicles, people and buildings*". Whilst the peak flood hazard category is low, Old Forcett Road is a major traffic route and it is considered desirable to maintain such routes as flood-free.

5.6.1.2 Details of the proposed management measure

This management measure aims to minimise the flood risk on Old Forcett Road and comprises the following elements:

- Widening of the existing longitudinal drainage on the eastern side of Old Forcett Road for a length of approximately 130m with a nominal base width of 7.0m;
- New cross-drainage pipe culvert (600mm dia) under Old Forcett Road, aligned to connect to the upstream extent of the existing stormwater drainage network on Short Street; and
- Upgrade of the existing stormwater drainage network along Short Street to the existing manhole at the intersection with Richards Avenue, with all upgraded pipes having diameter of 600mm.

The layout of the proposed works associated with the management measure is presented in Figure 5.7.

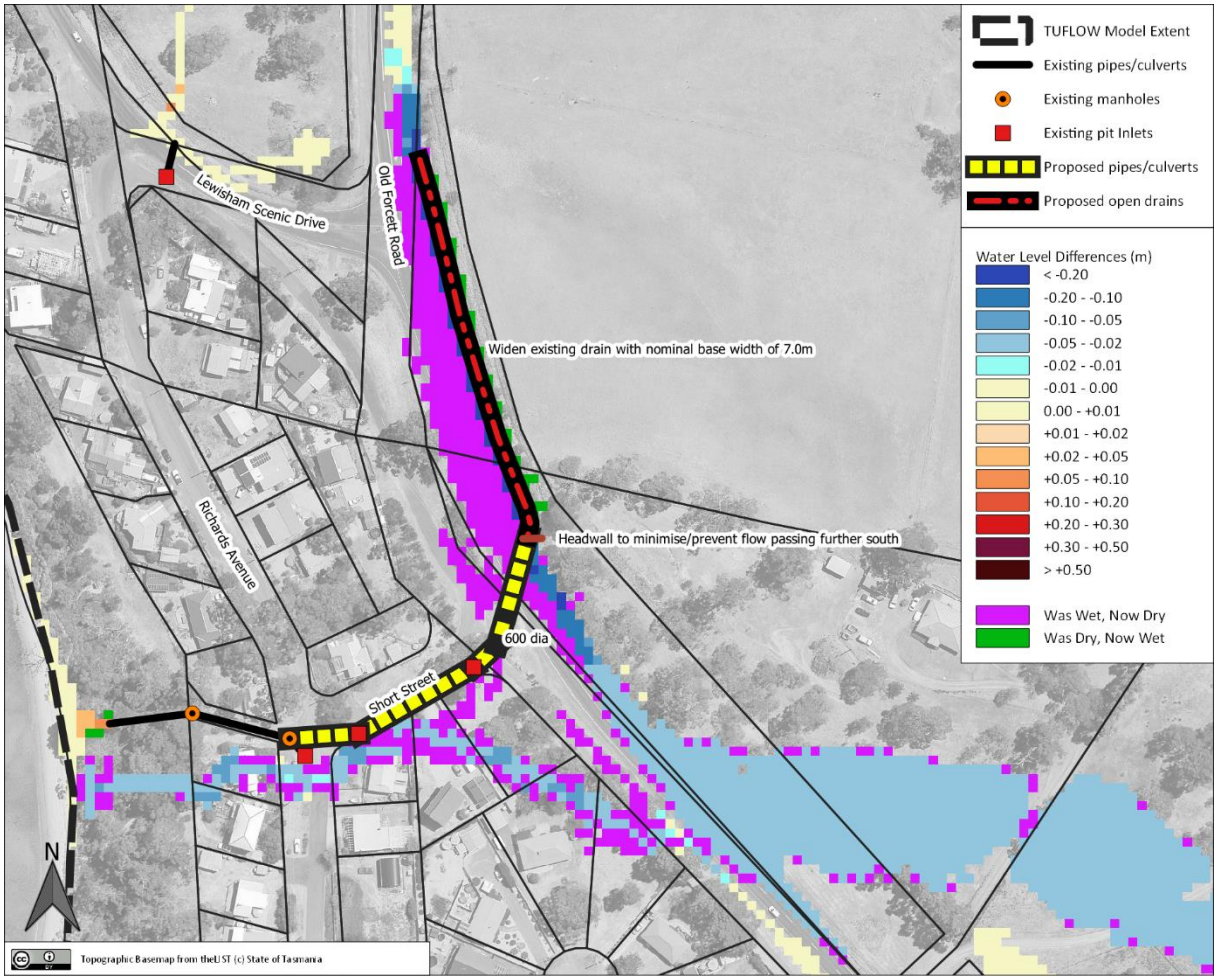

Figure 5.7: Management measure FM-SBS-01 – proposed works and peak water level differences (1% AEP event)

5.6.1.3 Hydraulic modelling of the proposed works

The TUFLOW hydraulic model has been used to assess the changes in flooding behaviour with the inclusion of the proposed works. The resulting peak water level differences for the 1% AEP event are shown in Figure 5.7, where these differences represent the change in peak water level compared with the existing case modelling. The model results indicate the following changes in flooding behaviour for a 1% AEP event:

- Significant reduction of flooding along Old Forcett Road, with most of this section of road now predicted to be free from inundation in a 1% AEP event; and
- Reduction in flooding east of Old Forcett Road resulting from increased flow along the upgraded stormwater line along Short Street.

The predicted reduction in flood damages, implementation cost and benefit-cost ratio are provided in Table 5.12. This indicates that there is a small reduction in flood damages, resulting in a very low benefit-cost ratio. It must be noted that the economic assessment does not explicitly account for the reduction in flood risk to Old Forcett Road as it only accounts for tangible damages (i.e. property damage).

Further details of the economic assessment of the management measures, including details of the cost estimates, are provided in Section 6, whilst the multi-criteria assessment of the management measures (including assessment of intangible damages such as reduced flood risk to Old Forcett Road) is detailed in Section 7.

Table 5.12: Damages, cost and benefit-cost ratio for Management Measure FM-SBS-01

Measure ID	Reduction in Average Annual Damage (AAD)	Reduction in NPV Damages	Cost Estimate of Implementation (NPV)	Benefit-Cost Ratio relative to Baseline
FM-SBS-01	$1,000	$10,000	$360,000	0.03

5.6.1.4 Summary

Management measure FM-SBS-01 achieves a significant reduction in flood risk to Old Forcett Road, with minor reductions in flood levels along the overland flow path running parallel to Short Street. Environmental impacts are minimised through the use of the existing drainage network and overland flow path.

5.6.2 FM-SBS-02 – Drainage upgrade – Intersection of Okines Road and Old Forcett Road to outlet

5.6.2.1 Existing flood risk

This management measure addresses existing flood risk at locations 6, 7, 8 and 9 identified in Table 3.4 and Figure 3.4.

Multiple flow paths from catchments east of Old Forcett Road drain to the intersection of Okines Road and Old Forcett Road via a series of minor drainage ditches and culverts. Existing cross-drainage structures have insufficient capacity which results in flooding of existing commercial property and Old Forcett Road in this area. The peak flood hazard category on Old Forcett Road is H2 (defined as "*Unsafe for small vehicles*"), with H1 predicted for existing property (defined as "*Generally safe for vehicles, people and buildings*").

Runoff crosses Old Forcett Road in a number of locations, as follows:

- Runoff flows north-westerly through a Council Reserve to Rantons Road via a minor watercourse. The passage of water to the outfall in Pitt Water appears to be impeded by filling on private property on Richards Avenue on the northern side of Rantons Road in combination with the limited conveyance of the existing cross-drainage culvert and downstream channel. The peak flood hazard category on Rantons Road is H2 (defined as "*Unsafe for small vehicles*"), with H4 predicted for existing property (defined as "*Unsafe for vehicles and people*");
- Runoff flows due west in the direction of the Dodges Ferry Recreation Park, ultimately draining through the Dodges Ferry Primary School. The peak flood hazard predicted for the school is H1 (defined as "*Generally safe for vehicles, people and buildings*"); and
- Runoff continues in a south-westerly direction, flooding most of the Old Forcett Road carriageway before continuing in a westerly direction towards Okines Beach via the drainage path around the southern side of Okines Community House or via the overland flow path through 542 Old Forcett Road. The peak flood hazard category on Old Forcett Road is H5

(defined as "*Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure*"), with H3 predicted for existing property (defined as "*Unsafe for vehicles, children and the elderly*").

These flooding characteristics indicate that the majority of flood risk at this location affects Old Forcett Road, with the existing drainage infrastructure predicted to be under-capacity to convey flow from the multiple flow paths that converge in this area.

5.6.2.2 Details of the proposed management measure

The primary aim of this management measure is to minimise the flood risk on Old Forcett Road, where under existing conditions a length of approximately 550m is predicted to be flooded in a 1% AEP event. The concept design comprises the following elements:

- Replacement of the existing cross-drainage culvert under Old Forcett Road immediately north of the intersection with Okines Road with 3/2700x600mm RCBC;
- Widened longitudinal drain along the eastern side of Old Forcett Road;
- Access road cross-drainage culvert (3/2100x600mm RCBC);
- Cross-drainage culvert under Old Forcett Road opposite intersection with thee Dodges Ferry Primary School access road (3/2100x600mm RCBC); and
- Widened open drain south of the Okines Community House.

The proposed works results in an increased flow heading in a north-westerly direction through the existing Council reserve towards Rantons Road. Flooding in the vicinity of Rantons Road is currently exacerbated by historical filling on the northern side of Rantons Road (43-47 Richards Avenue). At the time of preparation of this study and the analysis of this concept design, Council was investigating partial removal of this fill to remove some of this obstruction. On this basis, modelling of this management option has included some of these works which are required to minimise the flooding impacts on properties south of Rantons Road. The proposed works in this area comprise the following elements:

- Replacement of the existing cross-drainage culvert under Rantons Road with 3/2100x600mm RCBC;
- Partial removal of the fill on 45-47 Richards Avenue; and
- Widening of the existing drain flowing northwards from Rantons Road.

The layout of the proposed works associated with this management measure is presented in Figure 5.8.

Whilst not explicitly modelled, the opportunity exists for the creation of a water quality treatment trains within the Council reserve (west of Old Forcett Road and south of Rantons Road) or within Lagoon Park (south of the Dodges Ferry Primary School).

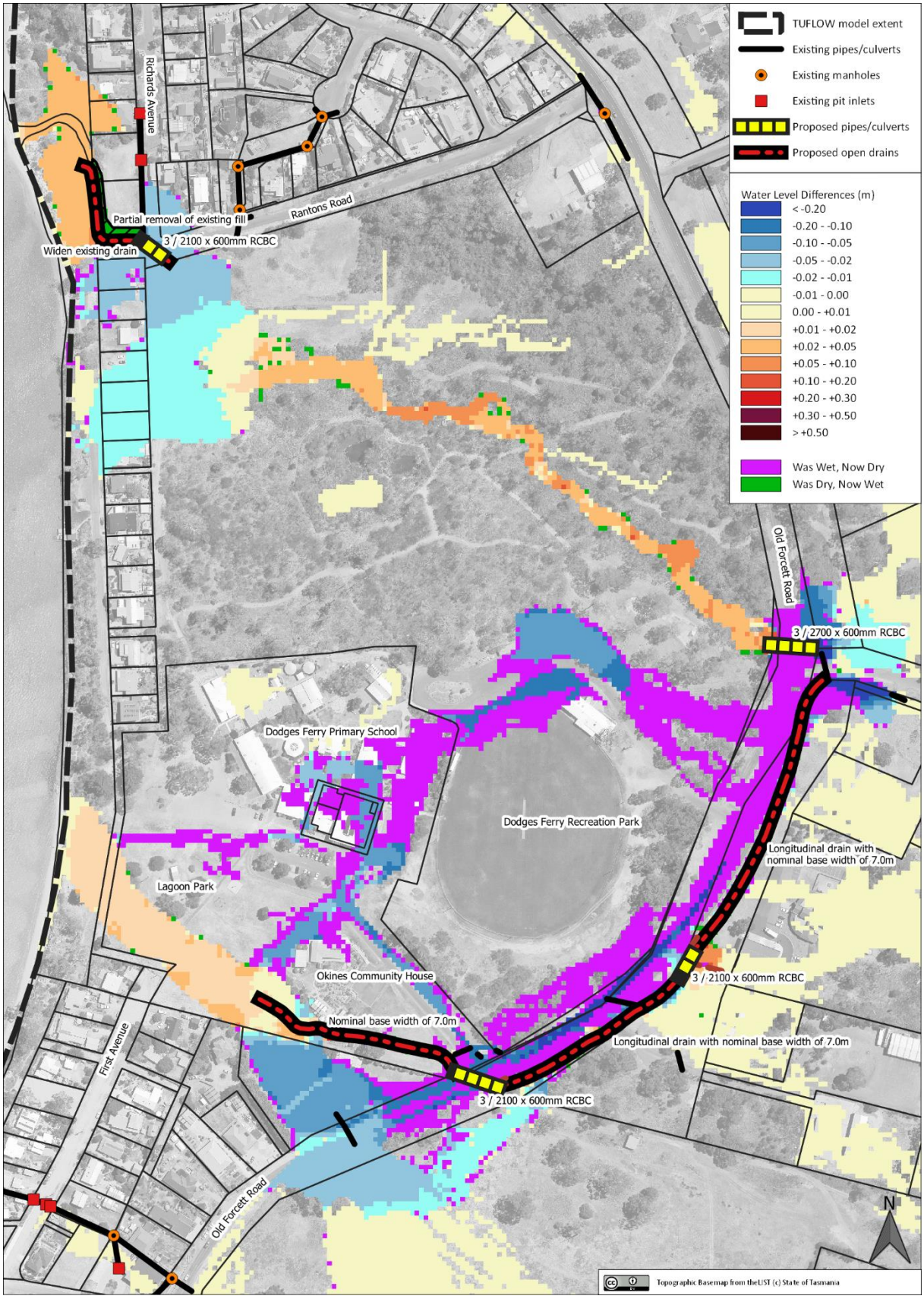

Figure 5.8: Management measure FM-SBS-02 – proposed works and peak water level differences (1% AEP event)

5.6.2.3 Hydraulic modelling of the proposed works

The TUFLOW hydraulic model has been used to assess the changes in flooding behaviour with the inclusion of the proposed works. The resulting peak water level differences for the 1% AEP event are shown in Figure 5.8, where these differences represent the change in peak water level compared with the existing case modelling. The model results indicate the following changes in flooding behaviour for a 1% AEP event:

- Significant reduction of flooding along Old Forcett Road, with most of this section of road now predicted to be free from inundation in a 1% AEP event;
    - The sag point opposite 542 Old Forcett Road is still predicted to be flooded, albeit with a reduction in peak water level of up to 0.04m;
- Reduction in overland flow passing westwards towards the Dodges Ferry Primary School, resulting in a reduction in peak flood levels and extent of flooding;
- Increased flood levels along the existing overland flow path through Lagoon Park of up to 0.02m, with negligible change in the extent of flooding at this location;
- Increased flow through the Council reserve west of Old Forcett Road; and
- Reduction in peak water levels of up to 0.04m in the vicinity of the Rantons Road crossing, with minor increases in the outfall reach of the drain.
- Minor increases in peak flood velocity within the existing open channel and outfall drainage path in the Rantons Road area for both 1% AEP and 5% AEP events; and
- Negligible change in the peak flood hazard category for the flooded extent (i.e. disregarding areas that are now dry due to the proposed works).

The predicted reduction in flood damages, implementation cost and benefit-cost ratio are provided in Table 5.13. This indicates that the proposed works results in a small reduction in flood damages and very low benefit-cost ratio. It must be noted that the economic assessment does not explicitly account for the reduction in flood risk to Old Forcett Road as it only accounts for tangible damages (i.e. property damage).

Further details of the economic assessment of the management measures, including details of the cost estimates, are provided in Section 6, whilst the multi-criteria assessment of the management measures (including assessment of intangible damages such as reduced flood risk to Old Forcett Road) is detailed in Section 7.

Table 5.13: Damages, cost and benefit-cost ratio for Management Measure FM-SBS-02

Measure ID	Reduction in Average Annual Damage (AAD)	Reduction in NPV Damages	Cost Estimate of Implementation (NPV)	Benefit-Cost Ratio relative to Baseline
FM-SBS-02	$14,000	$141,000	$2,291,000	0.06

5.6.2.4 Summary

Management measure FM-SBS-02 achieves significant reductions in flood affectation for Old Forcett Road and within a selected number of properties currently affected by flooding. Environmental impacts are minimised through the use of the existing drainage paths, noting that there is potential

for water quality treatment trains to be provided within the Council reserve (west of Old Forcett Road and south of Rantons Road) or within Lagoon Park (south of the Dodges Ferry Primary School).

5.6.3 FM-SBS-03 – Drainage upgrade – Cross-drainage adjacent to 542 Old Forcett Road

5.6.3.1 Existing flood risk

This management measure addresses existing flood risk at location 8 and identified in Table 3.4 and Figure 3.4.

Flooding in the vicinity of 542 Old Forcett Road results from runoff from multiple catchments draining to the eastern side of Old Forcett Road (refer to discussion in Section 5.6.2.1), with most of the runoff originating from the catchment that drains along the northern side of Carlton River Road. The road and property at this location lie in a sag point in the middle of an existing overland flow path. Water flows across Old Forcett Road at this location resulting in flooding of number 542.

Flooding is exacerbated by the limited capacity of the existing cross-drainage infrastructure at this location (single 375mm diameter pipe).

Results from the modelling of the existing catchment conditions indicates the road has a maximum flood hazard category of H2 (defined as "*unsafe for small vehicles*"), whilst 542 Old Forcett Road has a maximum flood hazard category of H3 (which is defined as "*unsafe for vehicles, children and the elderly*") affecting the main building.

5.6.3.2 Details of the proposed management measure

The aim of this management measure is to reduce the flood risk on Old Forcett Road and at 542 Old Forcett Road. The concept design has been prepared by utilising the road reserve and driveway within the subject property and comprises the following elements:

- Formation of a new open drain on the southern side of Old Forcett Road to capture flow from the sag point upstream of the road;
- Culvert running from upstream (south) of Old Forcett Road along the alignment of the driveway at 542 Old Forcett Road, discharging to the existing open drain on the northern side of the property
    - The culvert comprises four segments, all as a single 3600x600mm RCBC; and
- Widening of the existing drain on the northern side of the property.

The sizing and therefore capacity of the proposed culvert is limited by the alignment and width of the corridor along the driveway, and available fall in elevation from upstream of the road to the drain on the northern side of the property. The concept design has been prepared on the basis of achieving the best possible reduction in flood risk with these limitations in place.

The layout of the proposed works associated with the management measure is presented in Figure 5.9.

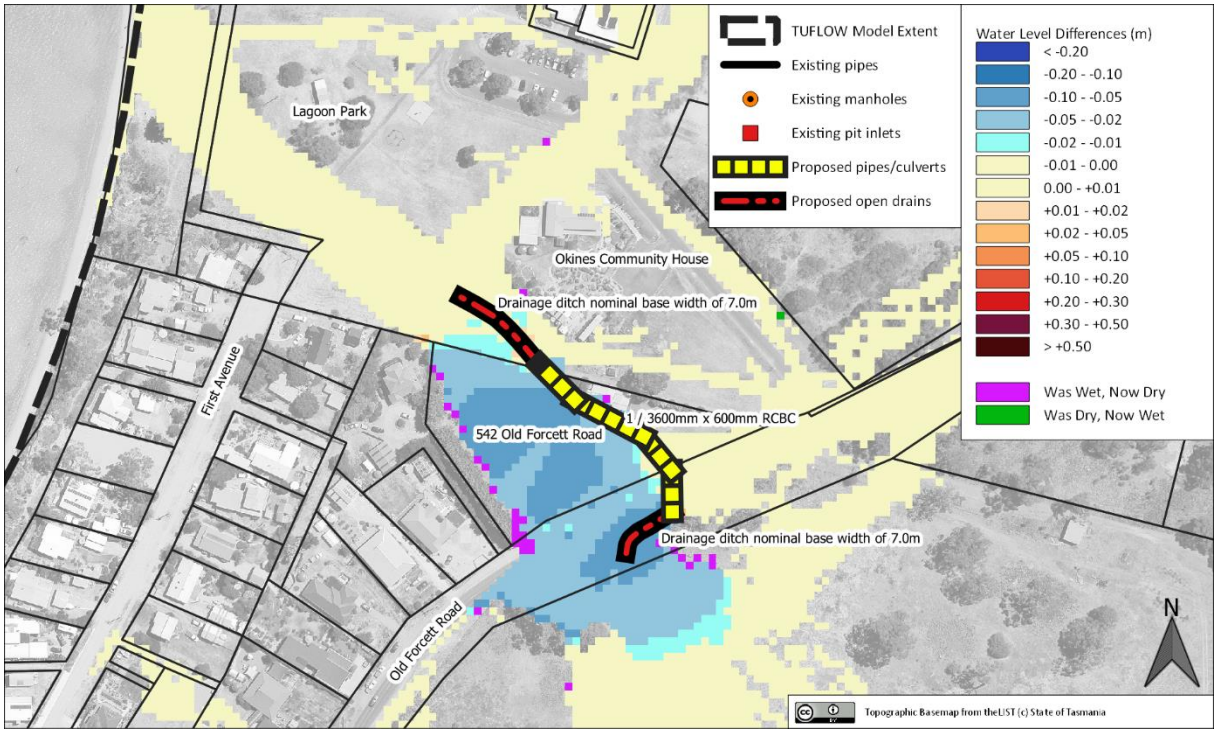

Figure 5.9: Management measure FM-SBS-03 – proposed works and peak water level differences (1% AEP event)

5.6.3.3 Hydraulic modelling of the proposed works

The TUFLOW hydraulic model has been used to assess the changes in flooding behaviour with the inclusion of the proposed works. The resulting peak water level differences for the 1% AEP event are shown in Figure 5.9, where these differences represent the change in peak water level compared with the existing case modelling. The model results indicate the following changes in flooding behaviour for a 1% AEP event:

- Reduction of flooding on Old Forcett Road of up to 0.09m in a 1% AEP event and up to 0.10m in a 5% AEP event; and
- Reduction in flooding at the main building at 542 Old Forcett Road of up to 0.06m in a 1% AEP event and up to 0.07m in a 5% AEP event;
- Reduction in peak flood velocity across Old Forcett Road of up to 0.30 m/s; and
- Negligible change in peak flood hazard category.

It would be possible to eliminate flooding of Old Forcett Road at this location in a 1% AEP event by raising the road elevation, albeit this would increase flood levels and the extent of flooding within the property south of Old Forcett Road. These impacts would generally be deemed unacceptable and on this basis, raising the road profile has not been considered as part of this study. However, the opportunity to explore raising the road elevation may arise in the future through negotiation with the land owner as part of a future development application.

The predicted reduction in flood damages, implementation cost and benefit-cost ratio are provided in Table 5.14. This indicates that there is a small reduction in flood damages, resulting in a very low benefit-cost ratio. It must be noted that the economic assessment does not explicitly account for the

reduction in flood risk to Old Forcett Road as it only accounts for tangible damages (i.e. property damage).

Further details of the economic assessment of the management measures, including details of the cost estimates, are provided in Section 6, whilst the multi-criteria assessment of the management measures (including assessment of intangible damages such as reduced flood risk to Old Forcett Road) is detailed in Section 7.

Table 5.14: Damages, cost and benefit-cost ratio for Management Measure FM-SBS-03

Measure ID	Reduction in Average Annual Damage (AAD)	Reduction in NPV Damages	Cost Estimate of Implementation (NPV)	Benefit-Cost Ratio relative to Baseline
FM-SBS-03	$10,000	$100,000	$826,000	0.12

5.6.3.4 Summary

Management measure FM-SBS-03 achieves a minor reduction in flood risk on Old Forcett Road with a minor reduction in flood risk at 542 Old Forcett Road. Environmental impacts are minimised through the use of the existing drainage path north of the subject property.

5.6.4 FM-SBS-04 – Drainage upgrade – Combination of FM-SBS-02 and FM-SBS-03

5.6.4.1 Existing flood risk

This management measure addresses existing flood risk at locations 6, 7, 8 and 9 identified in Table 3.4 and Figure 3.4. Details of the flood risk are summarised in Section 5.6.2.1 and Section 5.6.3.1.

5.6.4.2 Details of the proposed management measure

This management measure is a combination of FM-SBS-02 and FM-SBS-03, where both of these measures aim to minimise the flood risk on Old Forcett Road, Rantons Road and at a selected number of properties (refer to Section 5.6.2.2 and Section 5.6.3.2).

The layout of the proposed works associated with the management measure is presented in Figure 5.10.

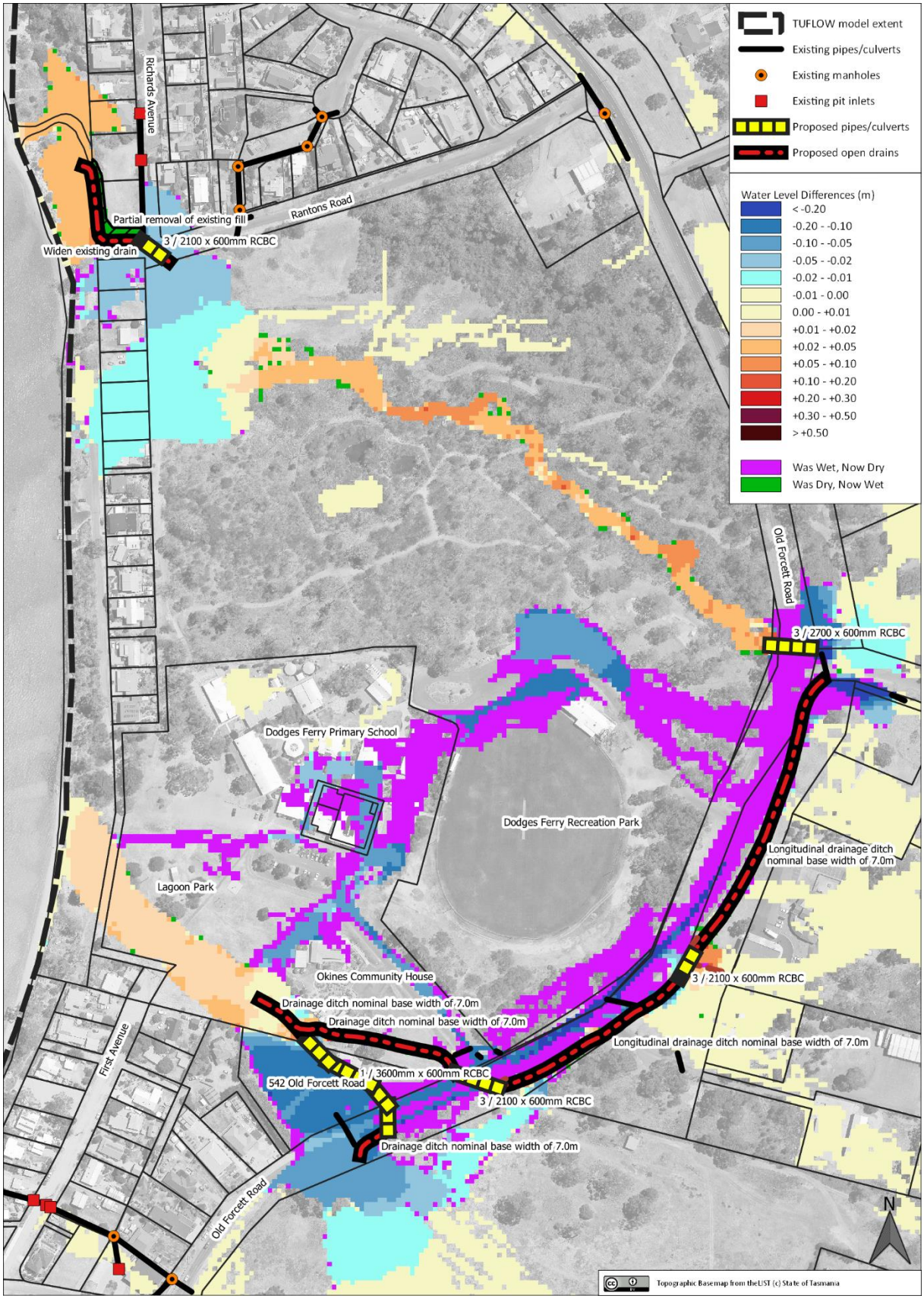

Figure 5.10: Management measure FM-SBS-04 – proposed works and peak water level differences (1% AEP event)

5.6.4.3 Hydraulic modelling of the proposed works

The TUFLOW hydraulic model has been used to assess the changes in flooding behaviour with the inclusion of the proposed works. The resulting peak water level differences for the 1% AEP event are shown in Figure 5.8, where these differences represent the change in peak water level compared with the existing case modelling. The model results indicate the following changes in flooding behaviour for a 1% AEP event that are very similar to those for management measures FM-SBS-02 and FM-SBS-03:

- Significant reduction of flooding along Old Forcett Road, with most of this section of road now predicted to be free from inundation in a 1% AEP event;
    - The sag point opposite 542 Old Forcett Road is still predicted to be flooded, albeit with a reduction in peak water level of up to 0.10m;
- Reduction in overland flow passing westwards towards the Dodges Ferry Primary School, resulting in a reduction in peak flood levels and extent of flooding;
- Increased flood levels along the existing overland flow path through Lagoon Park of up to 0.02m, with negligible change in the extent of flooding at this location;
- Increased flow through the Council reserve west of Old Forcett Road;
- Reduction in peak water levels of up to 0.04m in the vicinity of the Rantons Road crossing, with minor increases in the outfall reach of the drain;
- Minor increases in peak flood velocity within the existing open channel and outfall drainage path in the Rantons Road area for both 1% AEP and 5% AEP events; and
- Negligible change in the peak flood hazard category for the flooded extent (i.e. disregarding areas that are now dry due to the proposed works).

It would be possible to eliminate flooding of Old Forcett Road at this location in a 1% AEP event by raising the road elevation, albeit this would increase flood levels and the extent of flooding within the property south of Old Forcett Road. These impacts would generally be deemed unacceptable and on this basis, raising the road profile has not been considered as part of this study. However, the opportunity to explore raising the road elevation may arise in the future through negotiation with the land owner as part of a future development application.

The predicted reduction in flood damages, implementation cost and benefit-cost ratio are provided in Table 5.13. This indicates that the proposed works results in a small reduction in flood damages and very low benefit-cost ratio. It must be noted that the economic assessment does not explicitly account for the reduction in flood risk to Old Forcett Road as it only accounts for tangible damages (i.e. property damage).

Further details of the economic assessment of the management measures, including details of the cost estimates, are provided in Section 6, whilst the multi-criteria assessment of the management measures (including assessment of intangible damages such as reduced flood risk to Old Forcett Road) is detailed in Section 7.

Table 5.15: Damages, cost and benefit-cost ratio for Management Measure FM-SBS-04

Measure ID	Reduction in Average Annual Damage (AAD)	Reduction in NPV Damages	Cost Estimate of Implementation (NPV)	Benefit-Cost Ratio relative to Baseline
FM-SBS-04	$26,000	$261,000	$3,116,000	0.08

5.6.4.4 Summary

As per FM-SBS-02 and FM-SBS-03, management measure FM-SBS-04 achieves significant reductions in flood affectation for Old Forcett Road and within a selected number of properties currently affected by flooding.

Environmental impacts are minimised through the use of the existing drainage paths, noting that there is potential for water quality treatment trains to be provided within the Council reserve (west of Old Forcett Road and south of Rantons Road) or within Lagoon Park (south of the Dodges Ferry Primary School)

5.6.5 FM-SBS-05 – Drainage upgrade – Western side of Old Forcett Road at Dodges Ferry Recreation Park

5.6.5.1 Existing flood risk

This management measure addresses existing flood risk at location 9 identified in Table 3.4 and Figure 3.4. Details of the flood risk are summarised in Section 5.6.2.1.

5.6.5.2 Details of the proposed management measure

This management measure aims to reduce the flood risk at the Dodges Ferry Primary School and comprises the following elements:

- Widening of the existing longitudinal open drain on the western side of Old Forcett Road to increase the flow draining northwards;
- Proposed bund/wall to prevent water from spilling westwards to the Dodges Ferry Recreation Park and Dodges Ferry Primary School; and
- Works at the western end of Rantons Road in line with management option FM-SBS-02 (refer to Section 5.6.2.2).

The layout of the proposed works associated with the management measure is presented in Figure 5.11.

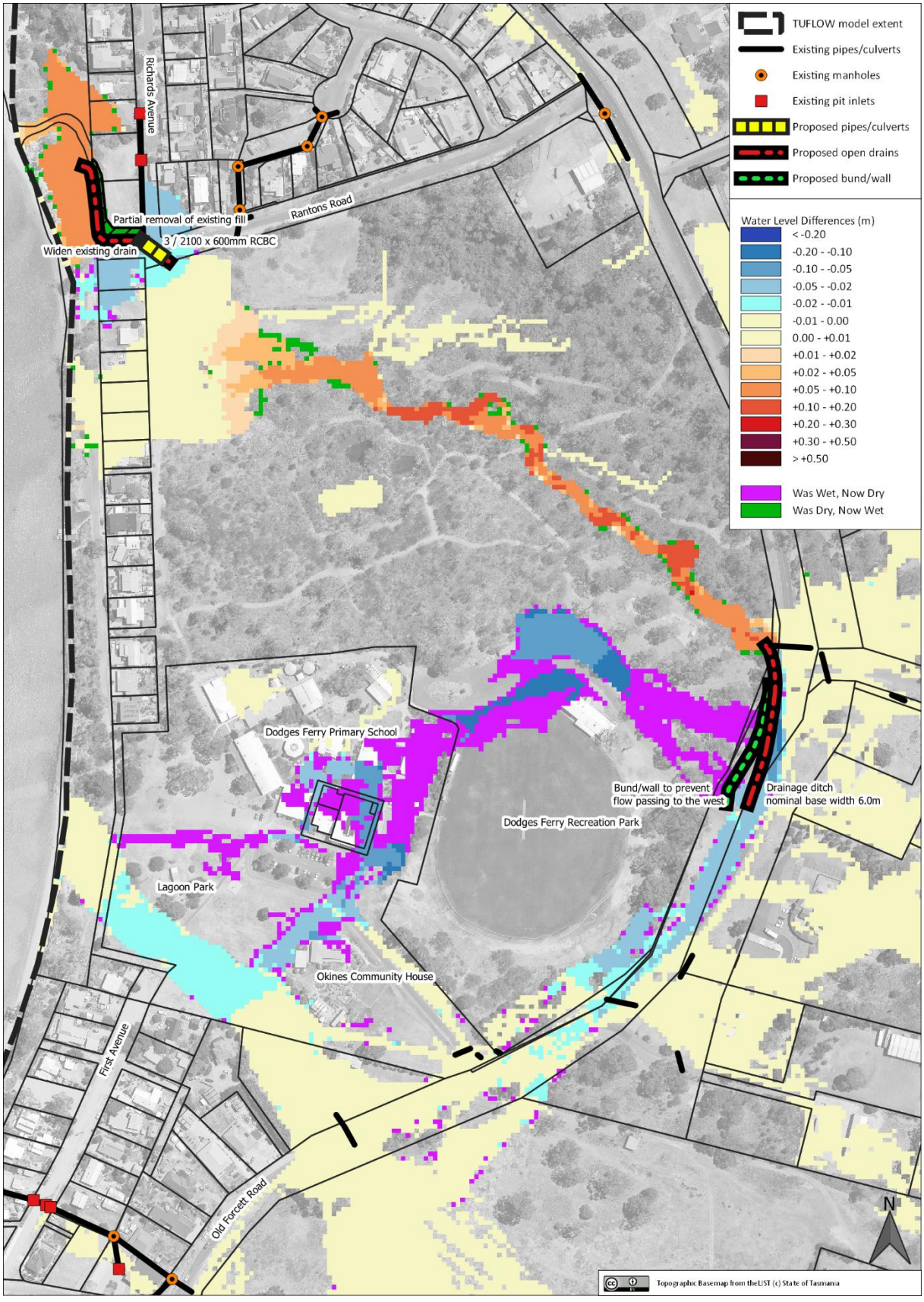

Figure 5.11: Management measure FM-SBS-05 – proposed works and peak water level differences (1% AEP event)

5.6.5.3 Hydraulic modelling of the proposed works

The TUFLOW hydraulic model has been used to assess the changes in flooding behaviour with the inclusion of the proposed works. The resulting peak water level differences for the 1% AEP event are shown in Figure 5.8, where these differences represent the change in peak water level compared with the existing case modelling. The model results indicate the following changes in flooding behaviour for a 1% AEP event:

- Significant reduction of flooding along Old Forcett Road, with most of this section of road now predicted to be free from inundation in a 1% AEP event;
    - The sag point opposite 542 Old Forcett Road is still predicted to be flooded, albeit with a reduction in peak water level of up to 0.04m;
- Reduction in overland flow passing westwards towards the Dodges Ferry Primary School, resulting in a reduction in peak flood levels and extent of flooding;
- Increased flood levels along the existing overland flow path through Lagoon Park of up to 0.02m, with negligible change in the extent of flooding at this location;
- Increased flow through the Council reserve west of Old Forcett Road; and
- Reduction in peak water levels of up to 0.04m in the vicinity of the Rantons Road crossing, with minor increases in the outfall reach of the drain.
- Minor increases in peak flood velocity within the existing open channel and outfall drainage path in the Rantons Road area for both 1% AEP and 5% AEP events; and
- Negligible change in the peak flood hazard category for the flooded extent (i.e. disregarding areas that are now dry due to the proposed works).

The predicted reduction in flood damages, implementation cost and benefit-cost ratio are provided in Table 5.16. This indicates that the proposed works results in a small reduction in flood damages and very low benefit-cost ratio. It must be noted that the economic assessment does not explicitly account for the reduction in flood risk on roads as it only accounts for tangible damages (i.e. property damage).

Further details of the economic assessment of the management measures, including details of the cost estimates, are provided in Section 6, whilst the multi-criteria assessment of the management measures (including assessment of intangible damages such as reduced flood risk on roads) is detailed in Section 7.

Table 5.16: Damages, cost and benefit-cost ratio for Management Measure FM-SBS-05

Measure ID	Reduction in Average Annual Damage (AAD)	Reduction in NPV Damages	Cost Estimate of Implementation (NPV)	Benefit-Cost Ratio relative to Baseline
FM-SBS-05	$4,000	$40,000	$473,000	0.08

5.6.5.4 Summary

Management measure FM-SBS-05 achieves minor reductions in flood risk at the Dodges Ferry Primary School and for properties in the Rantons Road area. Environmental impacts are minimised through the use of the existing drainage paths.

5.6.6 FM-SBS-06 – Drainage upgrade – Carlton Beach Road and Seventh Avenue to outfall

5.6.6.1 Existing flood risk

This management measure addresses existing flood risk at location 10 identified in Table 3.4 and Figure 3.4.

Runoff draining to Carlton Beach Road near Seventh Avenue ponds on the eastern side of Carlton Beach Road. The existing stormwater drainage network has insufficient inlet and conveyance capacity to address this runoff, leading to water spilling across Carlton Beach Road and flowing through residential property to Seventh Avenue.

There is a trapped low point toward the western end of Seventh Avenue where flow currently surcharges from the stormwater network to the ground surface.

The peak flood hazard category affecting Carlton Beach Road and properties in this area is H1 (defined as "*Generally safe for vehicles, people and buildings*"), whilst there are isolated locations where the peak flood hazard category is up to H2 (defined as "*Unsafe for small vehicles* ").

5.6.6.2 Details of the proposed management measure

This management measure aims to minimise the flood risk at Carlton Beach Road and to minimise the flooding through residential property and comprises the following elements:

- Five new pit inlets on the eastern side of Carlton Beach Road;
- Proposed culvert (single 1500x600mm RCBC) heading north along Carlton Beach Road then turning westwards along Seventh Avenue
    - At the mid-point of Seventh Avenue, the proposed culvert follows the alignment of the existing stormwater network; and
- New outfall for the proposed box culvert replacing the existing pipe outfall.

The layout of the proposed works associated with the management measure is presented in Figure 5.12.

Whilst not explicitly modelled, the opportunity exists for the provision of a GPT near the outlet to provide some water quality treatment for runoff from this catchment.

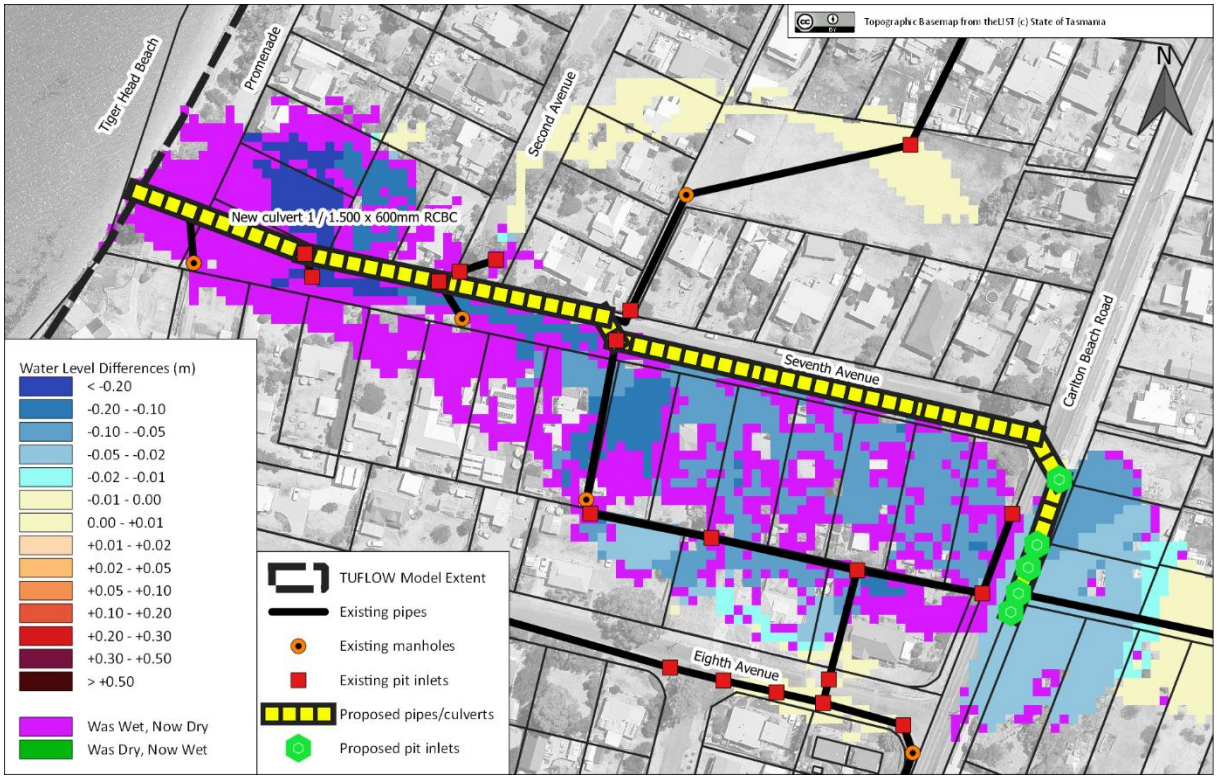

Figure 5.12: Management measure FM-SBS-06 – proposed works and peak water level differences (1% AEP event)

5.6.6.3 Hydraulic modelling of the proposed works

The TUFLOW hydraulic model has been used to assess the changes in flooding behaviour with the inclusion of the proposed works. The resulting peak water level differences for the 1% AEP event are shown in Figure 5.12, where these differences represent the change in peak water level compared with the existing case modelling. The model results indicate the following changes in flooding behaviour for a 1% AEP event:

- Reduced peak flood levels on the eastern side of Carlton Beach Road of up to 0.05m in the 1% AEP event;
    - Flooding is not eliminated in this area as it effectively sits in a trapped sag point;
- Elimination of flow crossing over Carlton Beach Road in the 1% AEP event;
- Reduced peak flood levels through the residential property west of Carlton Beach Road, including a reduction in the extent of flooding; and
- Localised reductions in peak flood hazard in the trapped sag points on the eastern side of Carlton Beach Road and at the western end of Seventh Avenue.

The predicted reduction in flood damages, implementation cost and benefit-cost ratio are provided in Table 5.17. This indicates that there is a relatively small reduction in flood damages, resulting in a very low benefit-cost ratio. It must be noted that the economic assessment does not explicitly account for the reduction in flood risk on roads as it only accounts for tangible damages (i.e. property damage).

Further details of the economic assessment of the management measures, including details of the cost estimates, are provided in Section 6, whilst the multi-criteria assessment of the management measures (including assessment of intangible damages such as reduced flood risk on roads) is detailed in Section 7.

Table 5.17: Damages, cost and benefit-cost ratio for Management Measure FM-SBS-06

Measure ID	Reduction in Average Annual Damage (AAD)	Reduction in NPV Damages	Cost Estimate of Implementation (NPV)	Benefit-Cost Ratio relative to Baseline
FM-SBS-06	$25,000	$251,000	$1,385,000	0.18

5.6.6.4 Summary

Management measure FM-SBS-06 achieves minor reductions in flood risk on Carlton Beach Road, Seventh Avenue, and residential properties west of Carlton Beach Road.

Environmental impacts are minimised through the use of the existing stormwater outfall location, thereby minimising impacts on the shoreline. There is potential for a GPT to be provided before the outfall.

5.6.7 FM-SBS-07 – Drainage upgrade – Mongana Street to Blue Lagoon, crossing Carlton Beach Road

5.6.7.1 Existing flood risk

This management measure addresses existing flood risk at location 11 identified in Table 3.4 and Figure 3.4.

Runoff draining to the Blue Lagoon originating from the eastern side of Carlton Beach Road flows via three main overland flow routes and four stormwater drainage lines. Overland flow from the catchment east of Signal Hill Road flows via an existing flow path to Mongana Street, before flowing westwards towards Blue Lagoon. Overland flow also drains from both the north and south along Carlton Beach Road in the direction of the intersection with Mongana Street. Overland flow from these sources meet at the intersection of Carlton Beach Road and Mongana Street, resulting in flooding of the intersection. The maximum flood hazard category affecting the roadway on Mongana Street and Carlton beach Road is H1 (defined as "*Generally safe for vehicles, people and buildings*").

The flood risk at this intersection can be attributed to insufficient capacity to capture the overland flow then convey that via the drainage infrastructure to Blue Lagoon.

5.6.7.2 Details of the proposed management measure

The aim of this management measure is to minimise the flood risk on Mongana Street and Carlton Beach Road and comprises the following elements:

- Proposed new culvert running along Mongana Street starting at the overland flow path;

  - The sizing of the proposed culvert increases from east to west to accommodate the required flows and reducing slope nearer to Blue Lagoon (i.e. a flatter slope results in reduced pipe/culvert capacity).
  - The proposed culvert starts as a single 1500 x 600m mm RCBC, transitioning to a single 1800 x 600mm RCBC then single 3600 x 600mm RCBC
- Proposed pit inlets on Mongana Street to increase the capture of excess overland flow, where these connect to both the existing and proposed stormwater drainage on Mongana Street;
- Proposed outfall to Blue Lagoon, located adjacent to the existing pipe outfall;
- Connection of the stormwater drainage network on the northern approach of Carlton Beach Road to the proposed box culvert
- Break and seal the existing pipe drainage on the southern approach of Carlton Beach Road approximately 50m north if the intersection with Paneminner Street with a proposed 450mm diameter pipe crossing Carlton Beach Road with new outfall to the Blue Lagoon area

The layout of the proposed works associated with the management measure is presented in Figure 5.13.

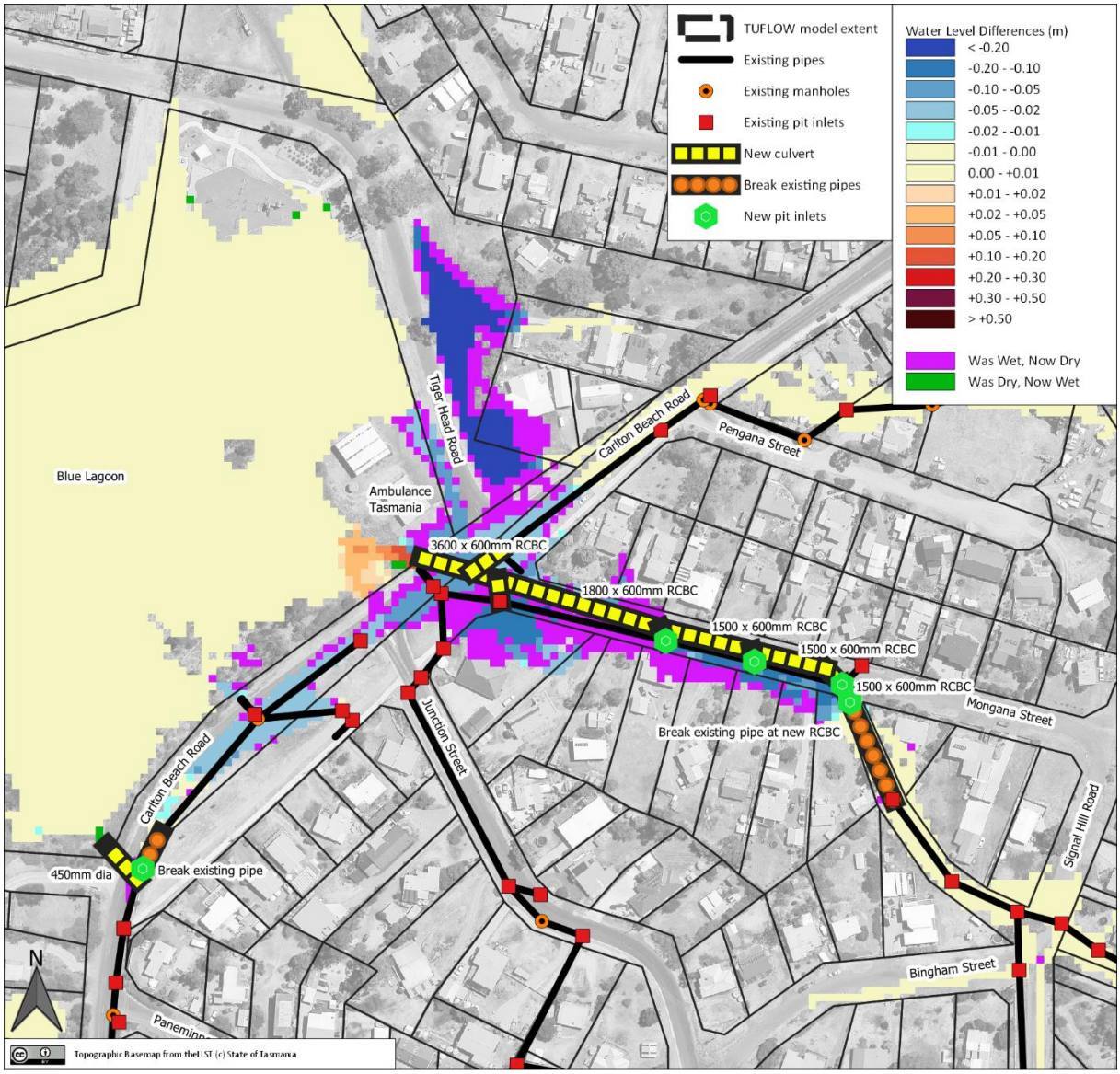

Figure 5.13: Management measure FM-SBS-07 – proposed works and peak water level differences (1% AEP event)

5.6.7.3 Hydraulic modelling of the proposed works

The TUFLOW hydraulic model has been used to assess the changes in flooding behaviour with the inclusion of the proposed works. The resulting peak water level differences for the 1% AEP event are shown in Figure 5.13, where these differences represent the change in peak water level compared with the existing case modelling. The model results indicate the following changes in flooding behaviour for a 1% AEP event:

- Reduced peak flood levels along Mongana Street of up to 0.16m in a 1% AEP event with a reduction in the extent of flooding on the road and within properties currently affected by flooding;
- Reduced peak flood levels on Carlton Beach Road of up to 0.09m in a 1% AEP event;
    - Flooding across Carlton Beach Road still occurs in a 1% AEP event but has been eliminated for a 5% AEP event;

- Localised reduction in peak flood hazard category along Mongana Street and on the eastern side of Tiger Head Road.

The predicted reduction in flood damages, implementation cost and benefit-cost ratio are provided in Table 5.18. This indicates that there is a relatively small reduction in flood damages, resulting in a very low benefit-cost ratio. It must be noted that the economic assessment does not explicitly account for the reduction in flood risk on roads as it only accounts for tangible damages (i.e. property damage).

Further details of the economic assessment of the management measures, including details of the cost estimates, are provided in Section 6, whilst the multi-criteria assessment of the management measures (including assessment of intangible damages such as reduced flood risk on roads) is detailed in Section 7.

Table 5.18: Damages, cost and benefit-cost ratio for Management Measure FM-SBS-07

Measure ID	Reduction in Average Annual Damage (AAD)	Reduction in NPV Damages	Cost Estimate of Implementation (NPV)	Benefit-Cost Ratio relative to Baseline
FM-SBS-07	$1,000	$10,000	$1,200,000	0.01

5.6.7.4 Summary

Management measure FM-SBS-07 achieves minor reductions in flood risk for Mongana Street and Carlton Beach Road and a selected number of residential properties.

Environmental impacts are minimised through the use of the existing drainage path and outfall location to Blue Lagoon for the major element of the proposed works.

5.6.8 FM-SBS-08 – Fence removal – flow path west of Signal Hill Road

5.6.8.1 Existing flood risk

Runoff from the catchment east of Signal Hill Road flows via a defined overland flow path to Mongana Street, before flowing westwards towards Blue Lagoon. Observations made during a site inspection undertaken as part of this study indicated that a fence has been constructed across the overland flow path. This obstruction may lead to diversion of flow or failure of the fence under high runoff conditions which could send a wave of water passing downstream, ultimately affecting flood risk on Mongana Street and Carlton Beach Road.

5.6.8.2 Details of the proposed management measure

This management measure comprises the removal of this fence to ensure the overland flow path remains operational and free from obstructions.

The location of the subject fence is presented in Figure 5.14.

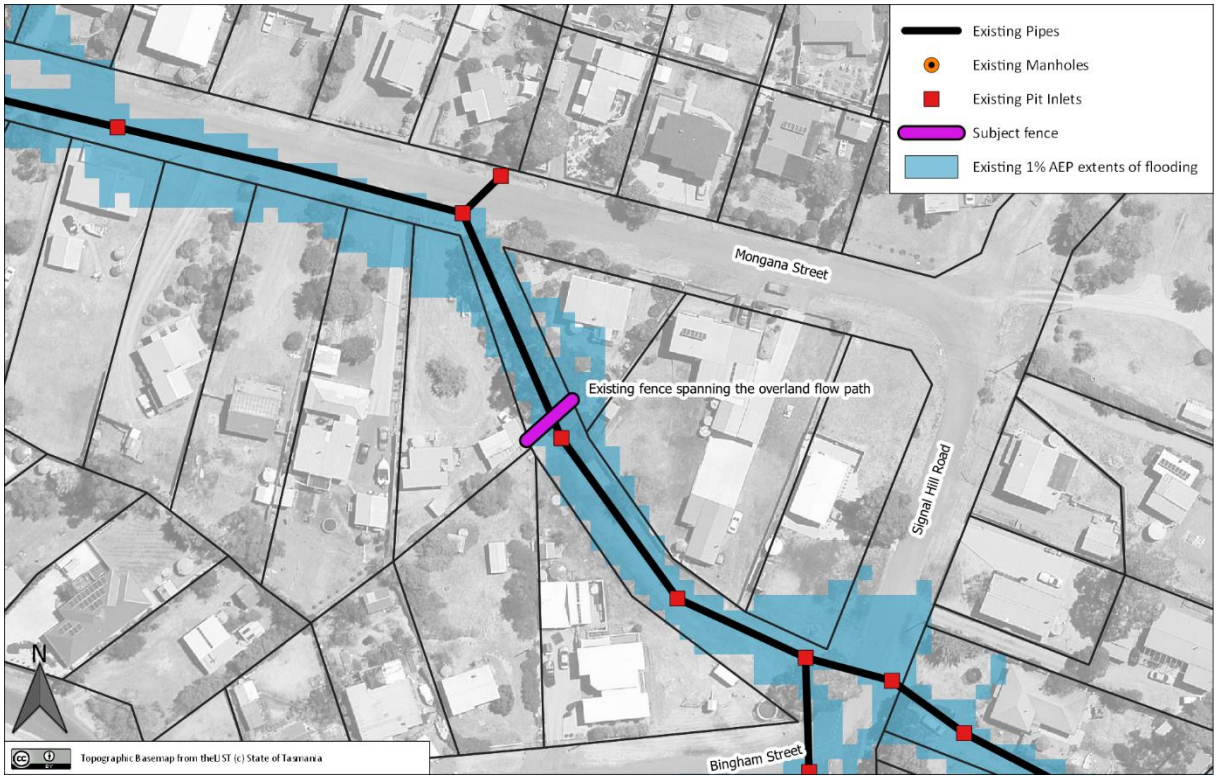

Figure 5.14: Management measure FM-SBS-08 – proposed works

5.6.8.3 Hydraulic modelling of the proposed works

This management measure has not been assessed with the hydraulic model on the basis that the fence is not a permanent feature. As such there are no changes in flood damages to be calculated for this management measure, as summarised in Table 5.19.

Further details of the economic assessment of the management measures, including details of the cost estimates, are provided in Section 6, whilst the multi-criteria assessment of the management measures is detailed in Section 7.

Table 5.19: Damages, cost and benefit-cost ratio for Management Measure FM-SBS-08

Measure ID	Reduction in Average Annual Damage (AAD)	Reduction in NPV Damages	Cost Estimate of Implementation (NPV)	Benefit-Cost Ratio relative to Baseline
FM-SBS-08	$0	$0	$0	0.00

5.6.8.4 Summary

Management measure FM-SBS-08 provides for the maintenance of an existing overland flow path as free from obstructions to ensure there are no unintended flow patterns or flooding consequences during runoff events. It is recommended that Council liaise with the affected property owner(s) to implement this measure.

5.6.9 FM-SBS-09 – Fence removal – western side of Moomere Street

5.6.9.1 Existing flood risk

The floodplain west of Moomere Street drains towards the Carlton River via the open drain/channel running eastwards from Moomere Street. Observations made during a site inspection undertaken as part of this study indicated that a fence has been constructed across the drainage path on the upstream (western) side of Moomere Street, effectively blocking the drain. This obstruction may lead to diversion of flow or failure of the fence under high runoff conditions which could send a wave of water passing downstream.

5.6.9.2 Details of the proposed management measure

This management measure comprises the removal of this fence to ensure the drainage path remains operational and free from obstructions.

The location of the subject fence is presented in Figure 5.15.

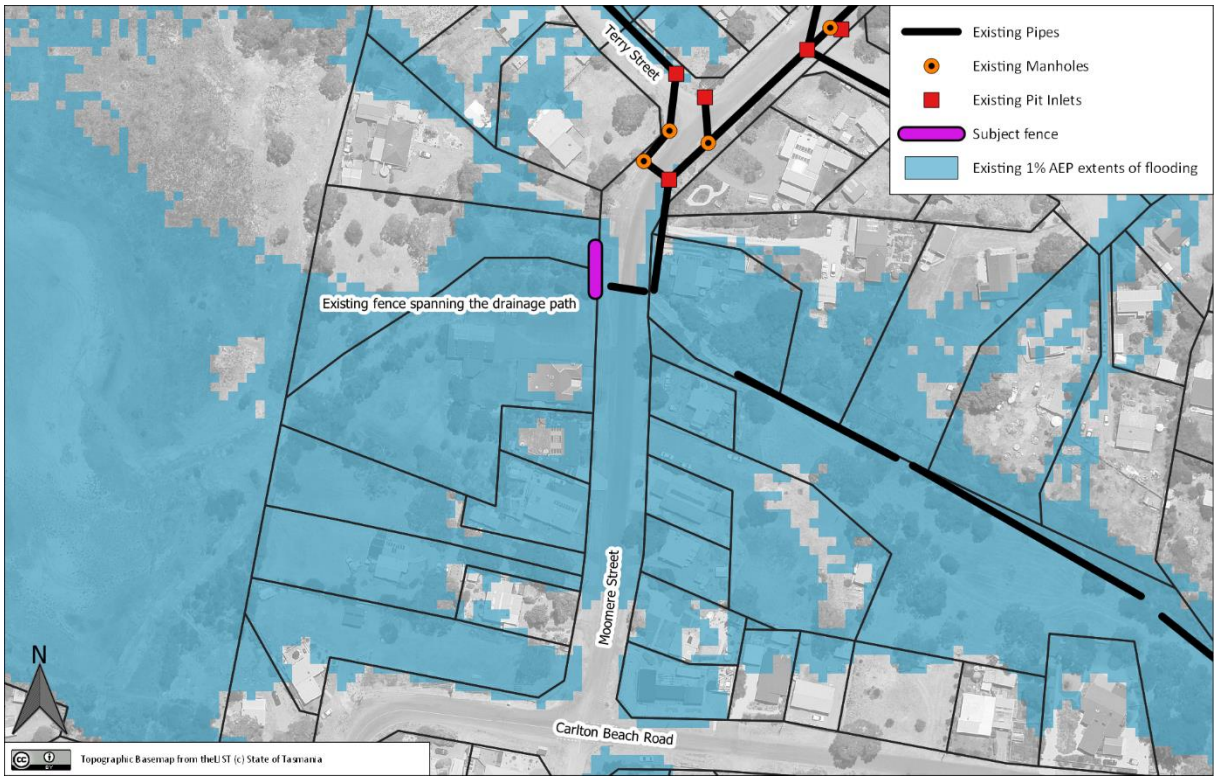

Figure 5.15: Management measure FM-SBS-09 – proposed works

5.6.9.3 Hydraulic modelling of the proposed works

This management measure has not been assessed with the hydraulic model on the basis that the fence is not a permanent feature. As such there are no changes in flood damages to be calculated for this management measure, as summarised in Table 5.20.

Further details of the economic assessment of the management measures, including details of the cost estimates, are provided in Section 6, whilst the multi-criteria assessment of the management measures is detailed in Section 7.

Table 5.20: Damages, cost and benefit-cost ratio for Management Measure FM-SBS-09

Measure ID	Reduction in Average Annual Damage (AAD)	Reduction in NPV Damages	Cost Estimate of Implementation (NPV)	Benefit-Cost Ratio relative to Baseline
FM-SBS-09	$0	$0	$0	0.00

5.6.9.4 Summary

Management measure FM-SBS-08 provides for the maintenance of an existing overland flow path as free from obstructions to ensure there are no unintended flow patterns or flooding consequences during runoff events. It is recommended that Council liaise with the affected property owner(s) to implement this measure.

5.6.10 FM-SBS-10 – Drainage upgrade – Freedom Close to estuary via new overland flow path

5.6.10.1 Existing flood risk

This management measure addresses existing flood risk at location 16 identified in Table 3.5 and Figure 3.5.

Runoff from the catchment draining to the eastern side of Carlton Beach Road and south of Provence Drive flows along the existing open drain in the direction of Freedom Close, where the modelling indicates water spills across Carlton Beach Road. The flooding on the road is predicted to have a maximum flood hazard category of H5 in a 1% AEP event (defined as "*Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure*").

5.6.10.2 Details of the proposed management measure

The aim of this management measure is to minimise the flood risk on Carlton Beach Road where the concept design comprises the following elements:

- Widening of the existing open drain on the eastern side of Carlton Beach Road between Provence Drive and Freedom Close
- Proposed new 1200mm diameter pipe culvert under Freedom Close;
- Formation of a new open drain heading due south from Freedom Close, utilising an existing easement than runs through to the Carlton River estuary;
- Minor road reprofiling on the northern side of Freedom Close to direct flow into the culvert inlet; and
- Proposed bunding to direct flow along the proposed open drain and prevent flow passing westwards through residential property.

The layout of the proposed works associated with the management measure is presented in Figure 5.16.

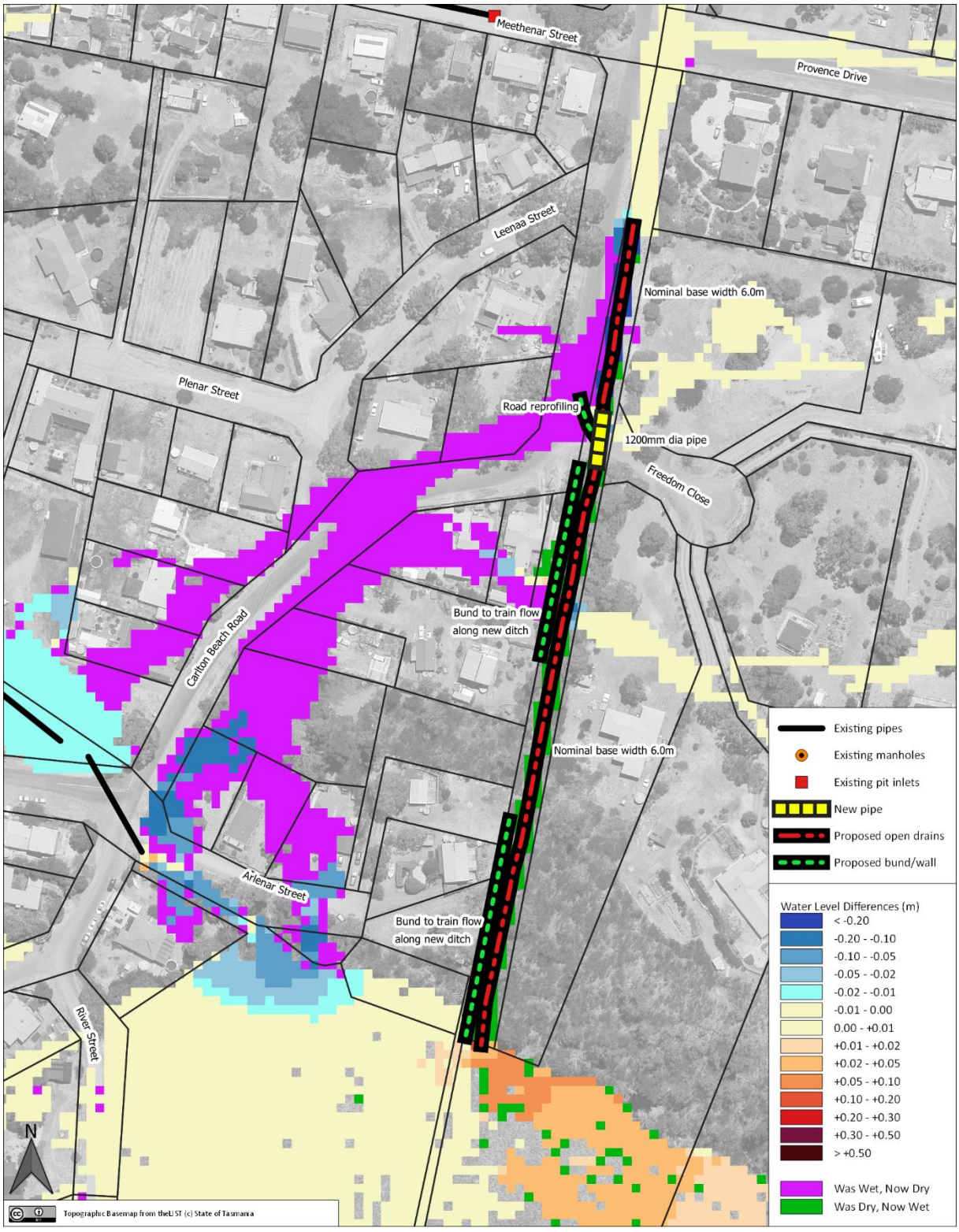

Figure 5.16: Management measure FM-SBS-10 – proposed works and peak water level differences (1% AEP event)

5.6.10.3 Hydraulic modelling of the proposed works

The TUFLOW hydraulic model has been used to assess the changes in flooding behaviour with the inclusion of the proposed works. The resulting peak water level differences for the 1% AEP event are shown in Figure 5.16, where these differences represent the change in peak water level compared with the existing case modelling. The model results indicate the following changes in flooding behaviour for a 1% AEP event:

- Significant reduction of flooding on Carlton Beach Road and currently flood-affected properties, with elimination of flooding for a 1% AEP event
- Minor reduction in peak flood levels in the Arlenar Street area; and
- Localised increases in peak flood levels within the estuary which does not affect any property.

The predicted reduction in flood damages, implementation cost and benefit-cost ratio are provided in Table 5.21. This indicates that the proposed works results in a small reduction in flood damages and very low benefit-cost ratio. It must be noted that the economic assessment does not explicitly account for the reduction in flood risk on roads as it only accounts for tangible damages (i.e. property damage).

Further details of the economic assessment of the management measures, including details of the cost estimates, are provided in Section 6, whilst the multi-criteria assessment of the management measures (including assessment of intangible damages such as reduced flood risk on roads) is detailed in Section 7.

Table 5.21: Damages, cost and benefit-cost ratio for Management Measure FM-SBS-10

Measure ID	Reduction in Average Annual Damage (AAD)	Reduction in NPV Damages	Cost Estimate of Implementation (NPV)	Benefit-Cost Ratio relative to Baseline
FM-SBS-10	$2,000	$20,000	$551,000	0.04

5.6.10.4 Summary

Management measure FM-SBS-10 achieves significant reductions in flood risk to Carlton Beach Road with the roadway in the Freedom Close vicinity predicted to be flood-free for a 1% AEP event.

Environmental impacts along the proposed open drain will need to be managed, noting that there may be a need for some removal of vegetation along the easement.

5.6.11 FM-SBS-11 – Defences – Terrain raising to prevent water spilling across Esplanade to Tamarix Road area

5.6.11.1 Existing flood risk

This management measure addresses existing flood risk at location 17 identified in Table 3.6 and Figure 3.6.

The residential area south of Tamarix Road is affected by runoff originating from the catchment east of Primrose Sands Road that drains in a north-westerly direction across the Esplanade and ultimately in the direction of the ephemeral lake on the northern side of Tamarix Road. This area has poorly defined natural flow paths and stormwater drainage network with no currently known outlet, and drainage of the area typically relies on infiltration.

The predicted peak flood hazard category in a 1% AEP event at some of the residential properties in this area is H3 (defined as "*unsafe for vehicles, children and the elderly*").

5.6.11.2 Details of the proposed management measure

The aim of this management measure is to minimise the flood risk at properties in the area south of Tamarix Road. The proposed works comprises the raising of ground elevations along the Esplanade to minimise/prevent water spilling northwards in the direction of Tamarix Road.

The layout of the proposed works associated with the management measure is presented in Figure 5.17.

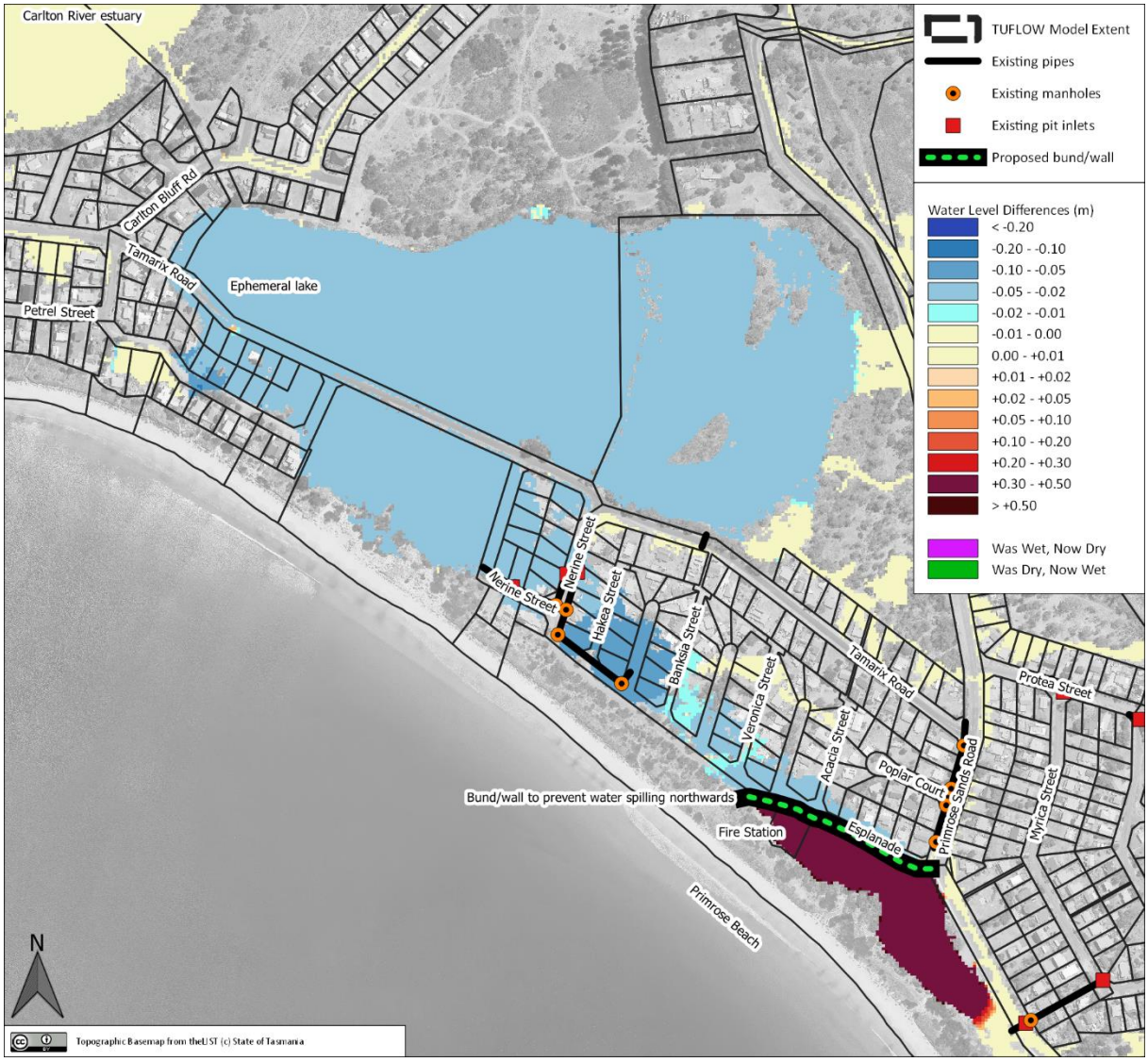

Figure 5.17: Management measure FM-SBS-11 – proposed works and peak water level differences (1% AEP event)

5.6.11.3 Hydraulic modelling of the proposed works

The TUFLOW hydraulic model has been used to assess the changes in flooding behaviour with the inclusion of the proposed works. The resulting peak water level differences for the 1% AEP event are shown in Figure 5.17, where these differences represent the change in peak water level compared with the existing case modelling. The model results indicate the following changes in flooding behaviour for a 1% AEP event:

- Reduction in peak flood levels north of the Esplanade of up to 0.06m in a 1% AEP event and up to 0.12m in a 5% AEP event;
- Minor reductions in the extent of flooding; and
- Increased water levels south of the Esplanade and west of Primrose Sands Road of up to 0.49m in a 1% AEP event and up to 0.19m in a 5% AEP event.

The predicted reduction in flood damages, implementation cost and benefit-cost ratio are provided in Table 5.22. This indicates that the proposed works results in a small reduction in flood damages and low benefit-cost ratio. This indicates that flooding of the properties south of Tamarix Road is as much affected by rainfall on the local catchment as is from flow crossing the Esplanade. It should be noted that the alignment of the raised ground levels did not consider the location of the fire station and this would need to be taken into account should this management measure be progressed further.

Further details of the economic assessment of the management measures, including details of the cost estimates, are provided in Section 6, whilst the multi-criteria assessment of the management measures (including assessment of intangible damages such as reduced flood risk to Old Forcett Road) is detailed in Section 7.

Table 5.22: Damages, cost and benefit-cost ratio for Management Measure FM-SBS-11

Measure ID	Reduction in Average Annual Damage (AAD)	Reduction in NPV Damages	Cost Estimate of Implementation (NPV)	Benefit-Cost Ratio relative to Baseline
FM-SBS-11	$8,000	$80,000	$478,000	0.17

5.6.11.4 Summary

Management measure FM-SBS-11 achieves reductions in peak flood levels in the Tamarix Road area, with minor reductions in the extent of flooding. However, the proposed works do not eliminate flooding in the areas at risk of flooding.

This management measure has been prepared on the basis of the modelling prepared for this study, where the flooding characteristics are influenced by a number of factors at this location. What is not well understood are what roles the ephemeral lake and connectivity with the estuary play with respect to existing flood risk, including effects of tide, antecedent conditions and losses via infiltration. As given in the Section 5.9, it is recommended that further assessment be undertaken to understand these interactions and effects on flooding before progressing this management measure.

5.6.12 FM-SBS-12 – Drainage upgrade – Increased capacity for Carlton Bluff Road drainage

5.6.12.1 Existing flood risk

This management measure addresses existing flood risk at location 17 identified in Table 3.6 and Figure 3.6.

The existing flood risk associated with this management is described in Section 5.6.11.1, further noting that flood levels in the ephemeral lake and Tamarix Road area are affected by water flowing via the stormwater infrastructure that connects the lake and the Carlton River estuary (i.e. crossing Carlton Bluff Road). The existing infrastructure comprises two pipes at both the lake and estuary outfalls, with single pipes limiting the capacity the convey flow from the lake to estuary.

5.6.12.2 Details of the proposed management measure

The aim of this management measure is to minimise the flood risk at properties in the area south of Tamarix Road and comprises the following elements:

- Duplication of the existing single 900mm diameter pipes; and
- Installation of flapped outlet on both outfall pipes to the Carlton River estuary.

The layout of the proposed works associated with the management measure is presented in Figure 5.18.

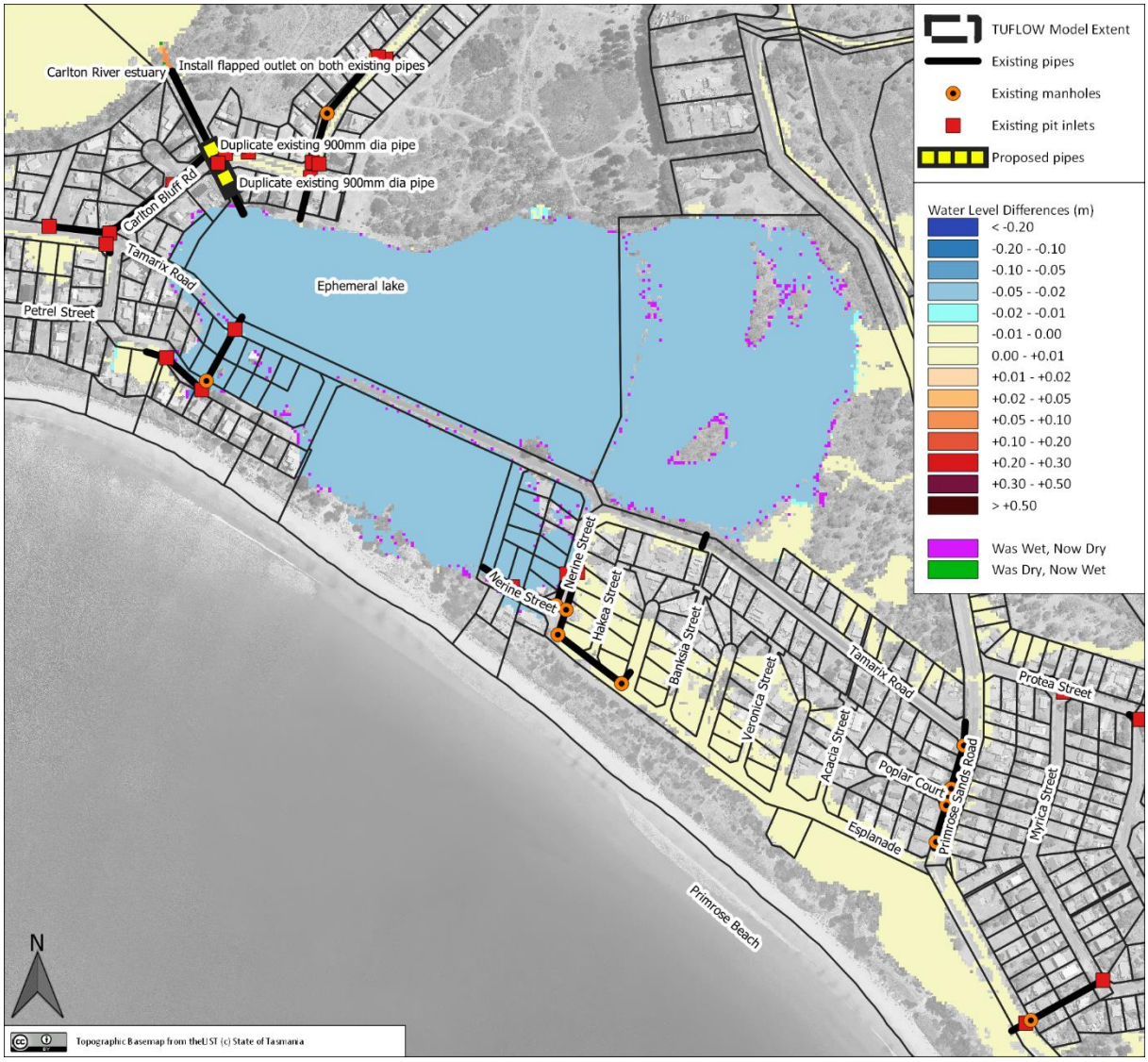

Figure 5.18: Management measure FM-SBS-12 – proposed works and peak water level differences (1% AEP event)

5.6.12.3 Hydraulic modelling of the proposed works

The TUFLOW hydraulic model has been used to assess the changes in flooding behaviour with the inclusion of the proposed works. The resulting peak water level differences for the 1% AEP event are shown in Figure 5.18, where these differences represent the change in peak water level compared with the existing case modelling. The model results indicate the following changes in flooding behaviour for a 1% AEP event:

- Reduced peak flood levels for some areas south of Tamarix Road of up to 0.04m for a 1% AEP event with negligible change in the same area for a 5% AEP event;
- Reduced peak flood levels within the ephemeral lake of up to 0.04m in a 1% AEP event and up to 0.03m in a 5% AEP event;
- Increased flow through the stormwater drainage network that crosses Carlton Bluff Road.

The predicted reduction in flood damages, implementation cost and benefit-cost ratio are provided in Table 5.23. This indicates that the proposed works results in a small reduction in flood damages and very low benefit-cost ratio. It must be noted that the economic assessment does not explicitly account for the reduction in flood risk on roads as it only accounts for tangible damages (i.e. property damage).

Further details of the economic assessment of the management measures, including details of the cost estimates, are provided in Section 6, whilst the multi-criteria assessment of the management measures (including assessment of intangible damages such as reduced flood risk on roads) is detailed in Section 7.

Table 5.23: Damages, cost and benefit-cost ratio for Management Measure FM-SBS-12

Measure ID	Reduction in Average Annual Damage (AAD)	Reduction in NPV Damages	Cost Estimate of Implementation (NPV)	Benefit-Cost Ratio relative to Baseline
FM-SBS-12	$1,000	$10,000	$265,000	0.04

5.6.12.4 Summary

Management measure FM-SBS-12 achieves reductions in peak flood levels in the Tamarix Road area, with minor reductions in the extent of flooding. However, the proposed works do not eliminate flooding in the areas at risk of flooding.

This management measure has been prepared on the basis of the modelling prepared for this study, where the flooding characteristics are influenced by a number of factors at this location. What is not well understood are what roles the ephemeral lake and connectivity with the estuary play with respect to existing flood risk, including effects of tide, antecedent conditions and losses via infiltration. As given in the Section 5.9, it is recommended that further assessment be undertaken to understand these interactions and effects on flooding before progressing this management measure.

5.6.13 FM-SBS-13 – Combination of FM-SBS-12 and FM-SBS-13

5.6.13.1 Existing flood risk

This management measure addresses existing flood risk at location 17 identified in Table 3.6 and Figure 3.6. Details of the flood risk are summarised in Section 5.6.11.1 and Section 5.6.12.1.

5.6.13.2 Details of the proposed management measure

This management measure is a combination of FM-SBS-11 and FM-SBS-12, where both of these measures aim to reduce the flood risk in the Tamarix Road area.

The layout of the proposed works associated with the management measure is presented in Figure 5.19.

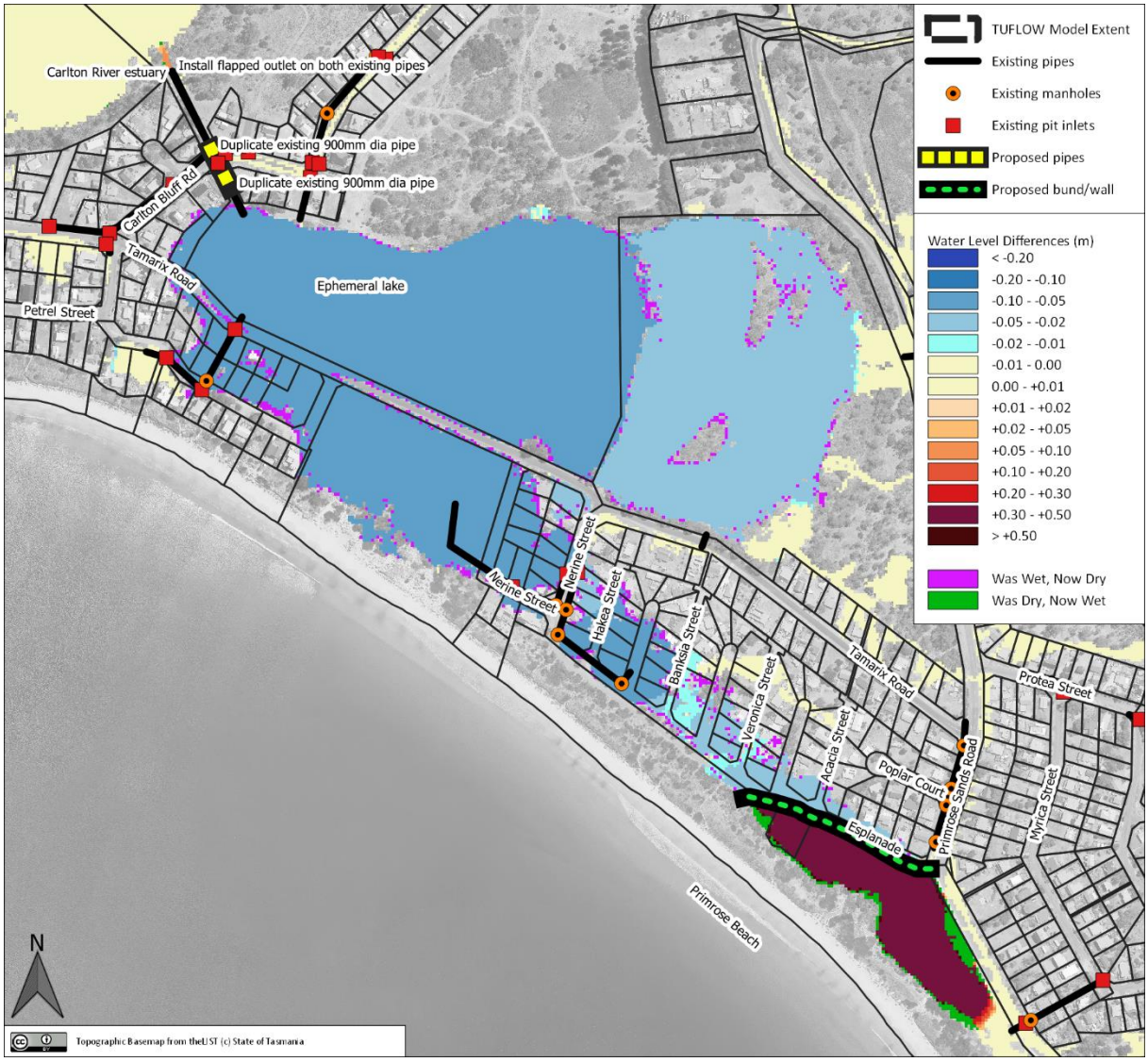

Figure 5.19: Management measure FM-SBS-13 – proposed works and peak water level differences (1% AEP event)

5.6.13.3 Hydraulic modelling of the proposed works

The TUFLOW hydraulic model has been used to assess the changes in flooding behaviour with the inclusion of the proposed works. The resulting peak water level differences for the 1% AEP event are shown in Figure 5.19, where these differences represent the change in peak water level compared with the existing case modelling. The model results indicate the following changes in flooding behaviour for a 1% AEP event:

- Reduced peak flood levels for some areas south of Tamarix Road of up to 0.04m for a 1% AEP event with negligible change in the same area for a 5% AEP event;
- Reduced peak flood levels within the ephemeral lake of up to 0.04m in a 1% AEP event and up to 0.03m in a 5% AEP event;
- Increased flow through the stormwater drainage network that crosses Carlton Bluff Road.

The predicted reduction in flood damages, implementation cost and benefit-cost ratio are provided in Table 5.24. This indicates that the proposed works results in a small reduction in flood damages and very low benefit-cost ratio. It must be noted that the economic assessment does not explicitly account for the reduction in flood risk on roads as it only accounts for tangible damages (i.e. property damage).

Further details of the economic assessment of the management measures, including details of the cost estimates, are provided in Section 6, whilst the multi-criteria assessment of the management measures (including assessment of intangible damages such as reduced flood risk on roads) is detailed in Section 7.

Table 5.24: Damages, cost and benefit-cost ratio for Management Measure FM-SBS-13

Measure ID	Reduction in Average Annual Damage (AAD)	Reduction in NPV Damages	Cost Estimate of Implementation (NPV)	Benefit-Cost Ratio relative to Baseline
FM-SBS-13	$9,000	$90,000	$742,000	0.12

5.6.13.4 Summary

Management measure FM-SBS-13 achieves reductions in peak flood levels in the Tamarix Road area, with minor reductions in the extent of flooding. However, the proposed works do not eliminate flooding in the areas at risk of flooding.

This management measure has been prepared on the basis of the modelling prepared for this study, where the flooding characteristics are influenced by a number of factors at this location. What is not well understood are what roles the ephemeral lake and connectivity with the estuary play with respect to existing flood risk, including effects of tide, antecedent conditions and losses via infiltration. As given in the Section 5.9, it is recommended that further assessment be undertaken to understand these interactions and effects on flooding before progressing this management measure.

5.6.14 FM-SBS-14 – Drainage upgrade – Primrose Sands Road cross-drainage adjacent to the RSL

5.6.14.1 Existing flood risk

This management measure addresses existing flood risk at location 18 identified in Table 3.6 and Figure 3.6.

Runoff from east of Primrose Sands Road drains via multiple flow paths to the sag point adjacent to the Primrose Sands RSL. The existing cross-drainage pipe culvert has insufficient capacity to convey all runoff from the catchment, resulting in water spilling across the road in the direction of the ephemeral lake north of Tamarix Road. The maximum flood hazard category on Primrose Sands Road is H1 (defined as "*Generally safe for vehicles, people and buildings*").

5.6.14.2 Details of the proposed management measure

The aim of this management measure is to minimise the flood risk on Primrose Sands Road and comprises an upgrade to the existing pipe culvert with 3 / 2100 x 600mm RCBC.

The layout of the proposed works associated with the management measure is presented in Figure 5.20.

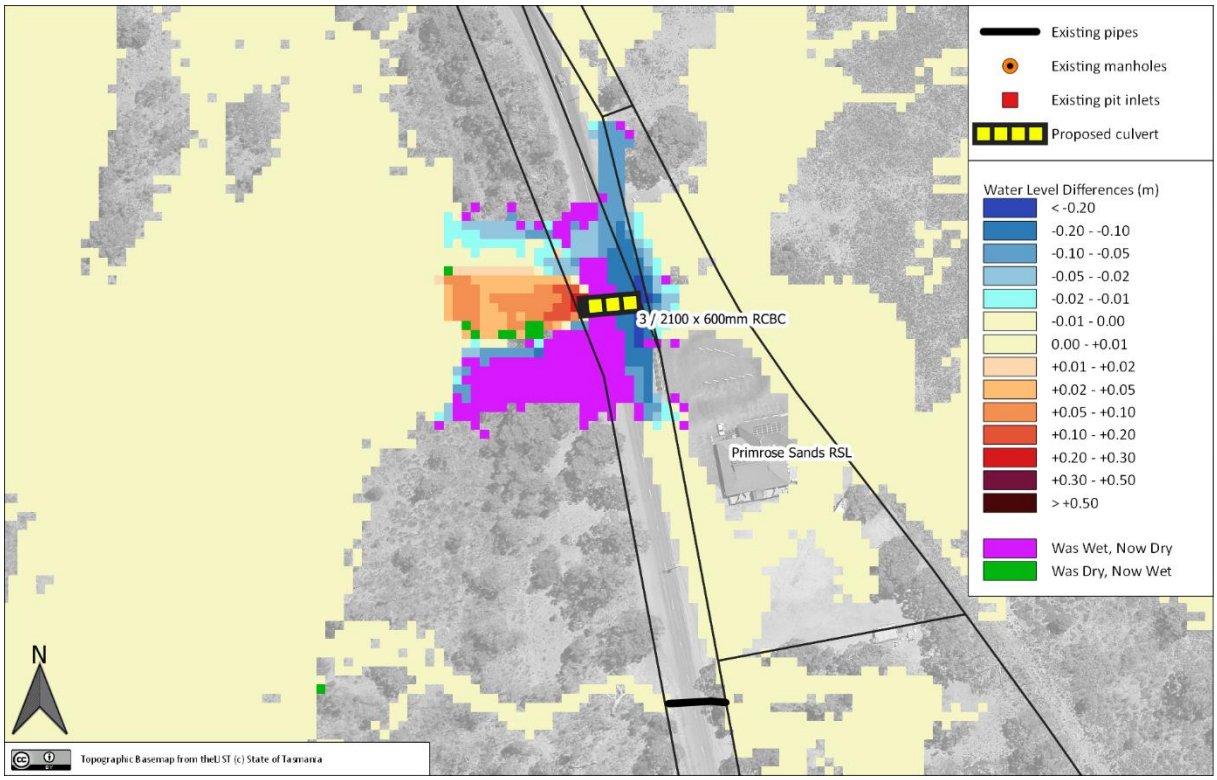

Figure 5.20: Proposed works - Management Measure FM-SBS-14

5.6.14.3 Hydraulic modelling of the proposed works

The TUFLOW hydraulic model has been used to assess the changes in flooding behaviour with the inclusion of the proposed works. The resulting peak water level differences for the 1% AEP event are shown in Figure 5.20, where these differences represent the change in peak water level compared with the existing case modelling. The model results indicate the following changes in flooding behaviour for a 1% AEP event:

- Reduced flooding on Primrose Sand Road from a flooded width of approximately 70m to a width of approximately 12m for a 1% AEP event, with no flooding of the road predicted in a 2% AEP event;
- Minor reductions in peak flood level upstream of the road, in line with the larger capacity cross-drainage structure; and
- Minor increases in peak flood level downstream of the road with the effect dissipating to nil increase after 50m.
- Localised changes in peak flood hazard category in line with the localised changes in peak flood level.

The predicted reduction in flood damages, implementation cost and benefit-cost ratio are provided in Table 5.25, which indicates there is no change in flood damages due to the works associated with this management measure. It must be noted that the economic assessment does not explicitly account for the reduction in flood risk on roads as it only accounts for tangible damages (i.e. property damage).

Further details of the economic assessment of the management measures, including details of the cost estimates, are provided in Section 6, whilst the multi-criteria assessment of the management measures (including assessment of intangible damages such as reduced flood risk on roads) is detailed in Section 7.

Table 5.25: Damages, cost and benefit-cost ratio for Management Measure FM-SBS-14

Measure ID	Reduction in Average Annual Damage (AAD)	Reduction in NPV Damages	Cost Estimate of Implementation (NPV)	Benefit-Cost Ratio relative to Baseline
FM-SBS-14	$0	$0	$325,000	0.0

5.6.14.4 Summary

Management measure FM-SBS-14 achieves a reduction in flood risk on Primrose Sands Road. Whilst the proposed works do not prevent all flooding of the road in a 1% AEP event, it would be possible to prevent flooding through raising of the road through the sag point in conjunction with the proposed culvert upgrade, where this could be explored as part of future design processes should this management measure be implemented.

5.6.15 FM-SBS-15 – Warning signage – Fulham Road

5.6.15.1 Existing flood risk

This management measure addresses existing flood risk at location 20 identified in Table 3.8 and Figure 3.8.

Runoff from a number of overland flow paths drain to the low-lying area on the northern side of Fulham Road at the south-western side of the Dunalley locality. The modelling indicates that approximately 600m of Fulham Road and approximately 100m of Gellibrand Street are predicted to be flooded in a 1% AEP event, with a maximum flood hazard category of H3 affecting the road (defined as "*unsafe for vehicles, children and the elderly*").

5.6.15.2 Details of the proposed management measure

On the basis that Fulham Road is not a major traffic route compared with the Arthur Highway through Dunalley, this management measure does not seek to reduce the flood risk through any targeted structural upgrade. The proposed works for this measure comprises the installation of three flood warning signs on both approaches of Fulham Road and on Gellibrand Street.

The layout of the proposed works associated with the management measure is presented in Figure 5.21.

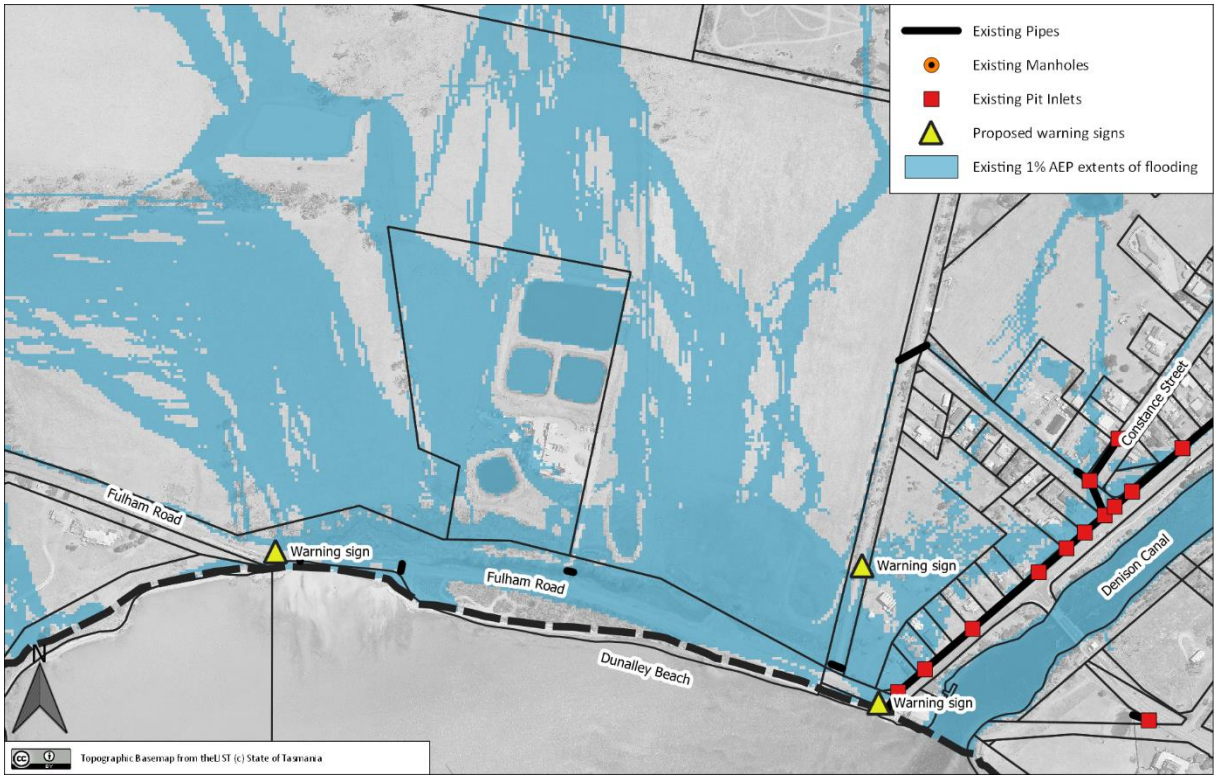

Figure 5.21: Proposed works - Management Measure FM-SBS-15

5.6.15.3 Hydraulic modelling of the proposed works

This management measure has not been assessed with the hydraulic model as there is no measurable effect of the warning signs of flooding characteristics. As such there are no changes in flood damages to be calculated for this management measure, as summarised in Table 5.26.

Further details of the economic assessment of the management measures, including details of the cost estimates, are provided in Section 6, whilst the multi-criteria assessment of the management measures (including assessment of intangible damages such as reduced flood risk on roads) is detailed in Section 7.

Table 5.26: Damages, cost and benefit-cost ratio for Management Measure FM-SBS-08

Measure ID	Reduction in Average Annual Damage (AAD)	Reduction in NPV Damages	Cost Estimate of Implementation (NPV)	Benefit-Cost Ratio relative to Baseline
FM-SBS-15	$0	$0	$6,000	0.00

5.6.15.4 Summary

Management measure FM-SBS-15 serves to reduce risk to road users through the provision of targeted warning signs. Should the usage of Fulham road increase in the future, it may be necessary to assess other structural measures to reduce the flood risk on the road.

5.6.16 FM-SBS-16 – Drainage upgrade – Gilpins Creek cross-drainage culvert at Church Street West

5.6.16.1 Existing flood risk

This management measure addresses existing flood risk at location 21 identified in Table 3.8 and Figure 3.8.

Gilpins Creek drains to Blackman Bay through the Dunalley locality, with crossings at Church Street West and at the Arthur Highway in the lower reaches. At the Church Street West crossing, the existing cross-drainage structure has limited capacity resulting in water flowing across the road with a maximum flood hazard category of H5 (defined as "*Unsafe for all people and vehicles. Buildings require special engineering design and construction*") in a 1% AEP event. Modelling undertaken for this study indicates that water flows over the road for relatively frequent events.

Details of the existing structure (modelled as twin 900mm diameter pipes) have been estimated during site inspection at this location.

5.6.16.2 Details of the proposed management measure

This management measure aims to minimise the flood risk on Church Street West and comprises an upgrade of the existing structure with a box culvert (3 / 2100 x 1500mm RCBC). The road level has also been raised in order to accommodate the proposed box culvert whilst maintaining minimum cover.

The layout of the proposed works associated with the management measure is presented in Figure 5.22.

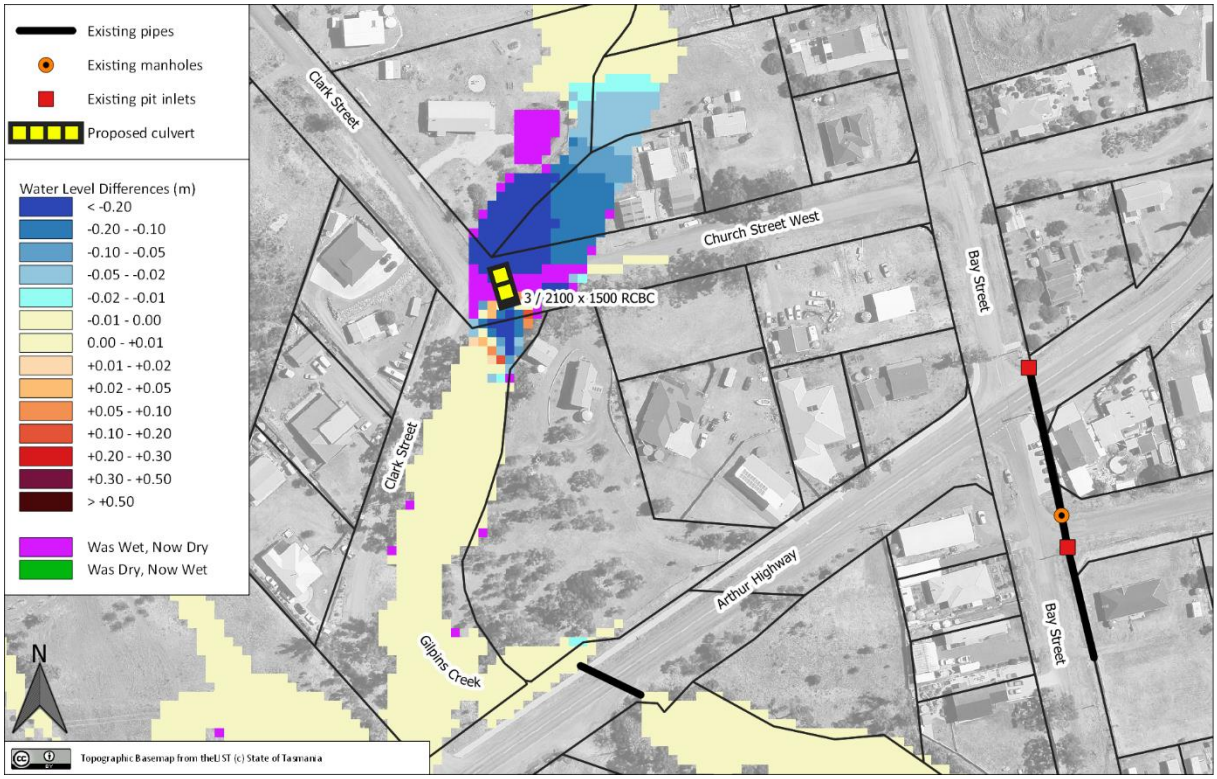

Figure 5.22: Proposed works - Management Measure FM-SBS-16

5.6.16.3 Hydraulic modelling of the proposed works

The TUFLOW hydraulic model has been used to assess the changes in flooding behaviour with the inclusion of the proposed works. The resulting peak water level differences for the 1% AEP event are shown in Figure 5.22, where these differences represent the change in peak water level compared with the existing case modelling. The model results indicate the following changes in flooding behaviour for a 1% AEP event:

- Elimination of flooding across Church Street West; and
- Reduced peak flood levels immediately upstream of the road.

The predicted reduction in flood damages, implementation cost and benefit-cost ratio are provided in Table 5.27. This indicates that the proposed works results in a small reduction in flood damages and very low benefit-cost ratio. It must be noted that the economic assessment does not explicitly account for the reduction in flood risk on roads as it only accounts for tangible damages (i.e. property damage).

Further details of the economic assessment of the management measures, including details of the cost estimates, are provided in Section 6, whilst the multi-criteria assessment of the management measures (including assessment of intangible damages such as reduced flood risk on roads) is detailed in Section 7.

Table 5.27: Damages, cost and benefit-cost ratio for Management Measure FM-SBS-16

Measure ID	Reduction in Average Annual Damage (AAD)	Reduction in NPV Damages	Cost Estimate of Implementation (NPV)	Benefit-Cost Ratio relative to Baseline
FM-SBS-16	$0	$0	$349,000	0.0

5.6.16.4 Summary

Management measure FM-SBS-16 achieves a reduction in flood risk on Church Street West. Flood levels upstream of the proposed culvert are reduced compared with existing indicating that the proposed culvert negates any flooding impact due to the raising of the road associated with this measure.

5.7 Property-scale management measures

Property-scale management measures seek to reduce the flood risk at existing property, noting that once a structure has been built, the potential to reduce flood damage at existing at the property scale is limited (AIDR, 2017a). The property-scale management measures considered as part of this study are listed in Table 5.28.

Table 5.28: Potential property-scale management measures

Measure ID	Description
PS-01	Individual house raising
PS-02	Government house buyback
PS-03	Flood proofing of buildings
PS-04	Planning and development controls

5.7.1 Measure PS-01 – Individual house raising

For suitable properties, it may be possible to raise the house to minimise property damage by reducing the frequency of above-floor flooding and the scale of post-event clean-up, and by potentially reducing the post-event trauma and stress on individuals. House raising is generally best suited to timber-frames and clad structures and generally excludes single, double brick or slab-on-ground structures. It must be noted that even where house raising is possible, a residual flood risk (including risk to life) often still persists at this property.

A catalogue of building types has not been provided for the study area. Available photographic data and observations made during site inspections indicate that there is a range of building types across the study area, and there are numerous properties in flood affected areas for which house raising would not be considered feasible, i.e. many houses are of brick and/or slab-on-ground construction. For these reasons, house raising has not been considered further as a viable management measure for implementation as part of the stormwater system management plan. However, as part of the Community Awareness and Flood Readiness program (refer to Measure CS-03, Section 5.8.3), it is recommended that Council provide information for property owners regarding house raising works for due consideration by the owner.

5.7.2 Measure PS-02 – Government house buyback

In a given flood-prone area, there may be isolated locations where flood hazard is high and there is significant danger to people during flood events, and it may be deemed impractical or uneconomical to mitigate the existing flood risk. In these locations, it may be appropriate to consider house buyback as an alternative to structural management measures. Through removal of a given house or building from a flood-prone area, flood damages to the building and risk to life are effectively eliminated. Typically, this process requires the purchase of targeted/specific properties with subsequent demolition and removal of the building. Dependent on the residual flood risk and flood hazard at that location, the land could be returned permanently to open space, or there may be an opportunity for construction of a new building/house taking into account the known flooding behaviour.

Whilst a house buyback scheme can present itself as a viable management measure to reduce flood risk in suitable locations, implementing the scheme often attracts a relatively high capital cost and can result in significant social disruption.

This particular management measure is not considered to be appropriate for the Sorell stormwater catchment for the following reasons:

- Relatively high property values and number of properties that would need to be acquired in order to make this measure effective;

- There is the potential for reduction in flood risk and flood damage through the implementation of structural mitigation measures; and
- Modelling does not indicate any flood-prone properties with excessive flood hazard due to stormwater.

On this basis, a government house buyback scheme has not been considered further at this time for the study area. However, this should be reviewed periodically following receipt of new data (including improved calibration data).

5.7.3 Measure PS-03 – Flood proofing of buildings

Flood proofing of buildings in stormwater catchments generally employs automatic or manual barrier systems designed to prevent water entering a building during a flood event. Such measures need to consider the overall design of the building, with allowances made for multiple entry points and the potential flood forces that may be experienced during a flood. Whilst new buildings would ideally be constructed to be flood-free or have minimal flood risk, flood proofing addressed during the design and construction of a given building is likely to be more effective than a retrofit solution. Nevertheless, appropriate retrofit solutions at a given property may assist with reducing flood risk and flood damage.

Flood proofing measures at individual buildings are considered to be suitable for implementation across the study area for existing properties identified as being at risk of flooding for the following reasons:

- Large areas of the stormwater catchment are considered to be fully developed which may limit the feasibility of structural mitigation measures;
- Individual building/house raising has a relatively high capital cost and is not considered feasible for the Sorell stormwater catchment (refer to Section 5.7.1); and
- Flood proofing measures generally incur a low capital cost and can be effective at reducing or eliminating flood damages for a given property.

Typically, the property owner would be responsible for the capital costs and implementation of flood proofing measures. In order to provide property owners with the necessary information to undertake flood proofing measures, Council can provide the required details to property owners via the recommended community awareness program which is discussed further in Section 5.8.3.

5.7.4 Measure PS-04 – Planning and development controls

Council has the ability to manage flood risk across the Sorell Municipality through the application of planning and development controls for both new development and infill development, whilst also considering the cumulative impacts of development. The predicted flooding mechanisms, scale of flood affectation and scale of flood hazard varies across the Sorell Municipality, therefore requiring a range of planning and development controls to address the variation in flood risk. The existing policies, strategies and planning controls applicable to the Sorell Municipality and the study area are discussed in Section 4.3.

Given that the nature of planning and development controls will typically only apply when changes at a particular property is proposed (e.g. new development or redevelopment), the enforcement of these controls is necessary to ensure the benefits (i.e. reduced flood risk) are realised in the future. Furthermore, inappropriate new or infill development may add to potential flood damage, create

later demand for mitigation measures expenditure and increase the scale and difficulty of emergency response (AIDR, 2017a), highlighting the importance of enforcement of these controls.

In the context of this stormwater management plan, this management measure relates to the review and modification of Council's existing planning and development controls, or indeed the preparation of new development control plans, to address specific planning and development matters related to the management of stormwater. These matters include (but are not limited to):

- Impact of development on flood behaviour;
- Filling and associated compensatory storage/excavation;
- Minimum fill and floor levels;
- Flow-through fencing;
- On-site detention; and
- Water quality improvements.

This management measure recommends that Council reviews its existing planning system and development controls to ensure stormwater matters have been duly considered.

In additional to planning and development controls that can be applied across the entire municipality, local planning controls can be developed for specific locations and areas where unique flood risks exist where it may not be feasible or possible to mitigate these risks through structural measures. Of the catchments assessed in this study, locations where local controls may be applicable are:

- Lewis Court (Lewisham), where existing properties are affected by flooding from China Creek; and
- Tamarix Road (Primrose Sands), where numerous residential properties lie in a flood-prone area associated with the overland flow path draining to the ephemeral lake on the northern side of Tamarix Road.

5.7.4.1 Impact of development on flood behaviour

AIDR (2017a) discusses that development may alter flood behaviour by diverting flow or altering flow paths due to changes to topography and/or structures within the floodplain or overland flow paths. These changes may include filling, topographic reshaping, placement of infrastructure, and increased rate/volume of runoff.

It is recommended that additional development controls be drafted that quantify acceptable off-site impacts due to proposed development, and to define key design principles to be applied at property that is affected by flooding or overland flow. These key design principles include (but are not limited to):

- The development shall not have an adverse impact on surrounding properties through the diversion, concentration or ponding of flows;
- The development shall accommodate the passage of flow over the site, and where applicable, shall be designed to withstand damage due to scour, debris or buoyancy forces;
- The development must not be sited where flows may result in a hazardous situation for future occupants in terms of depth and velocity of flows through the property;

- Flows shall be directed through common areas and should not be directed through private courtyards or on-site detention systems;
- The flowpath must not be obstructed by landscaping, kerbing, retaining walls or fencing;
- Design elements such as concrete or paving shall be used to fix critical levels in flowpaths to minimise interference by future occupiers; and
- The development must provide adequate freeboard to finished floor levels.

Furthermore, it is recommended that Council consider specifying details of acceptable hydrological and/or hydraulic analysis methodologies employed in the support of a given development application. For example, specifications that detention basin sizing should be undertaken using rainfall-runoff hydrological calculations and that empirical Rational Method calculations are unacceptable.

5.7.4.2 Filling and compensatory storage (excavation)

AIDR (2017a) discusses the scenario whereby some development projects seek approval based upon a balance of fill and compensatory excavation, and continues with the following supporting discussion:

- Excavation and filling are not always directly comparable, as excavation is more likely to take place on the lower part of the floodplain/site, while fill will take place on the higher parts.
- Under these conditions, the net effect will be that any additional storage created through excavation will be lost if the excavated area fills with floodwater before the flood peak arrives resulting in an adverse impact due to the fill when major floods occur.
- Fill should be excluded from flow conveyance areas because of the effect on flow conveyance.
- In flood storage areas, there will often be a need to place limits on the location, level and quantity of fill and excavation in consideration of the cumulative effect of potential excavation or filling projects across the whole floodplain.

Following the same design principles outlined in Section 5.7.4.1, filling and/or compensatory storage associated with a given development application must be shown to produce acceptable off-site impacts. It is recommended that Council considers implementing requirements for compensatory storage associated with proposed development.

5.7.4.3 Minimum fill and floor levels

AIDR (2017a) discusses that it is common practice to set minimum fill levels for a given development to reduce the frequency and exposure of the land and its occupants to a flood threat. The objective of applying a minimum fill level is to ensure that risk to life and potential flood damage are both reduced. The minimum fill level is often determined based on a flood planning level, where this flood planning level:

- may vary depending on the magnitude of flood event to be used and nature of the development (e.g. facilities such as hospitals may require floor levels above the PMF level); and
- generally also includes an allowance for freeboard.

It is recommended that Council considers implementing requirements for minimum fill and floor levels associated with proposed development, guided by a flood planning level.

5.7.4.4 Fencing

AIDR (2017a) discusses that fences, whether solid or open, can affect flood behaviour by altering flow paths. The impact will depend upon the type of fence and its location relative to the flow path. The objective of applying a development control in relation to fencing is to ensure that:

- Fencing does not cause the obstruction of free-flow of overland flow or floodwater; and
- Fencing does not become unsafe during floods, i.e. potentially becomes moving debris which poses a risk to life or the integrity of structures.

In areas where fences may impact on flood behaviour, development controls can be used to address:

- The type of fencing permitted;
- A limit on its location or height;
- A limit on erection of solid fencing, particularly to ground level, across flow paths.

It is recommended that Council considers implementing controls in relation to fences within flood-prone areas including overland flow paths.

It should be noted that two locations across the study where fences are currently known to affect existing overland flow paths have been identified in the structural management measures assessment (refer to Section 5.6.8 and Section 5.6.9).

5.7.4.5 On-site detention

The development of a catchment to create urban areas generally results in an increase in stormwater runoff due to the introduction of or increase in impervious surfaces. Building hard surfaces such as pavements, roofs and site drainage increase the volume and speed of stormwater runoff, whilst also reducing the capacity of stormwater to soak into the ground (Sydney Water, 2014). This increased runoff may result in an increase in flooding downstream of the subject development area or an increase in pollutant runoff. To prevent adverse impacts downstream of a given site, an on-site stormwater detention (OSD) system can be utilised, where the primary function of the OSD is to provide temporary storage of stormwater runoff.

It is recommended that Council develop an on-site detention policy which would be applicable across the entire Municipality of Sorell, where the aim of the policy is to minimise flooding from stormwater runoff due to development. This policy may include (but not be limited to) the following key elements:

- Definition of where on-site detention shall be required (e.g. all multi-dwelling houses and residential flats, all commercial and industrial development, residential site where the impervious area exceeds 70%);
- Specification of performance criteria for the design of the on-site detention system (typically permissible site discharge and site storage requirements); and
- General requirements to be applied in the design of OSD systems.

5.7.4.6 Water quality improvements

Stormwater quality across the Sorell municipality is managed, in part, through the Sorell Interim Planning Scheme as discussed in Section 4.3.2 and Section 8.1.4. The planning scheme sets out the requirements for use or development of land and gives acceptable stormwater quality targets for new development.

Whilst there are relatively high proportions of the subject areas of interest already developed which reduces the opportunities for at-site treatment, it is recommended that Council develop a policy for Water Sensitive Urban Design (WSUD) and Integrated Urban Water Management (IUWM). It is further recommended that this policy accommodates relevant recommendations provided in the previously completed *Sorell Stormwater Management Plan* (BMT WBM, 2011) and *Southern Beaches Stormwater Management Plan* (SKM, 2017).

5.8 Community/catchment-scale management measures

Community or catchment-scale management measures aim to reduce the flood risk and/or reduce the impacts of flooding at a community scale, rather than at specific locations or properties. The community or catchment-scale management measures considered as part of this study are listed in Table 5.29.

Table 5.29: Potential community/catchment-scale management measures

Measure ID	Description
CS-01	Enhanced Flood/Storm Warning
CS-02	Enhanced Emergency Response
CS-03	Community Awareness and Flood Readiness

5.8.1 Measure CS-01 – Enhanced flood/storm warning

A flood or storm warning system can form an important element of flood response arrangements for any community. It may be technically simple or complex, and should consider the local flood behaviour, the needs of the emergency response agencies and the community. Effective flood or storm warning messages communicate to the public the threat posed by a given event, the action they should take in response to the threat and the assistance that may be available to them. The careful use of language in flood warnings is critical to help people understand the flood threat and to encourage them to act appropriately (AIDR, 2017a).

Section 4.5.3 discusses the existing flood and storm warning arrangements applicable to the Sorell Municipality and study area stormwater catchments. Whilst there is presently no formal flood warning service for stormwater or overland flooding that is applicable to the study area, warning services currently provided by the BoM and SES include:

- Detailed Severe Thunderstorm Warnings; and
- Severe Weather Warnings.

The subject stormwater catchments are relatively small with multiple flow paths draining to their receiving waters. The effectiveness of warnings issued based on rainfall or flooding that has already occurred is limited by the rapid catchment response as this typically does not allow sufficient time for

the public to prepare and take action to minimise risk to property or life. Given the likely limited effectiveness of a flood warning system for the subject stormwater catchments, it is not considered to be appropriate for a formal flood warning system to be established.

In lieu of a formal flood warning system, the use of existing warnings provided by the BoM and SES can be enhanced through the development of a community awareness and flood readiness program, as discussed further in Section 5.8.3 (Measure CS-03). It is recommended that Council continue to provide support to the BoM and SES in the issuing of these warning services.

Council (in conjunction with the SES and BoM) may also wish to consider improving and enhancing the provision of real-time data during rainfall events to provide more accurate warnings about the severity of an on-going rainfall event. This could be achieved through use of the existing rainfall gauging at Hobart Airport and Dunalley (i.e. pluviometer), or research could be undertaken to determine whether data from the BoM radar site at Koonya can be processed and interpreted to provide real-time data during rainfall events.

5.8.2 Measure CS-02 – Enhanced emergency response

Emergency management operations in response to flooding typically lies with the Tasmania State Emergency Service (SES), with assistance provided by other organisations including Tasmania Police, Tasmania Fire Service, Ambulance Tasmania, Bureau of Meteorology and Sorell Council.

The Sorell stormwater catchment has no formal flood warning service, and flooding is generally characterised by a rapid catchment response following intense rainfall resulting in overland flooding and flooding along existing drainage paths. For flooding conditions of this nature, the emergency management role and response of the SES is generally limited to responding to calls for assistance with recovery following the event.

To assist SES with this role, it is recommended that the outputs and findings of this study be provided to the SES to ensure they hold the necessary information and data that may be required during future operational response. These outputs may include flood mapping which would identify potentially flooded properties and roads.

5.8.3 Measure CS-03 – Community awareness and flood readiness

The Report of the Independent Review into the Tasmanian Floods of June and July 2016 (Blake, 2017) provides a detailed analysis of the issues of awareness, preparedness and resilience, as applied to flood events affecting the community. This report found that all levels of government in Australia have a role to inform citizens of impending natural disasters, which includes raising awareness and the need for communities to prepare in advance for flood events. Blake (2017) also provides a specific recommendation that the SES and Tasmania Fire Service share resources and align their community education programs and adopt an all-hazards approach to awareness.

This management measure (CS-03) recommends the development of a Community Awareness and Flood Readiness Program, where the objectives of this program may include the following:

- Increase public awareness of the general risks associated with all potential floods;
- Increase public awareness of the extent of flood-prone land and flood hazard, particularly for people living or working in a flood-prone area;

- Inform the community of Council's existing planning and development controls and policies associated with development;
- Better facilitate the delivery of and increase awareness on how to receive flood or storm warnings; and
- Increase public awareness and general education on how to understand and react to flood or storm warnings.

It is further recommended that these objectives be achieved through coordination between the SES and Sorell Council, which may include the following elements:

- Develop dedicated flood or storm information pages on the Sorell Council website
    - e.g. the Launceston City Council website has an easily found page for emergency management with a link to information on flooding and stormwater);
    - provide direct links to the SES website;
    - include details regarding insurance matters;
    - include details of flood evacuation routes;
    - include details for property owners regarding individual house raising and flood-proofing measures;
    - provide a facility for public to upload images of flooding;
- Make flood mapping data available via the Sorell Council website or on request
    - It is understood that the SES is currently developing a flood mapping tool to cover all of Tasmania, and it is therefore assumed that flood mapping outputs from studies undertaken by Council will be made available for inclusion in this tool. At the time of preparation of this report, the delivery date for this tool is not known.
- Notification to be given to property owners or tenants at properties identified as being located in a flood-prone area
    - Provide this information on a periodic basis, e.g. dedicated letter or brochure provided with rates notice
- Development of a formal flood/storm education and consultation program
    - May include face-to-face discussions or town hall-style community meetings.

These elements recommended for implementation as part of a Community Awareness and Flood Readiness program are summarised in Table 5.30.

The success of a community awareness and flood readiness program requires a combination of effective education and willingness by the community to be educated regarding flood risk. Furthermore, the education must be provided or made available at appropriate intervals as there is a risk that governments and communities, due to the passage of time, forget (Blake, 2017).

Table 5.30: Elements for a community awareness and flood readiness program

Element	Responsibility	Estimated Cost	Priority
Develop dedicated flood and/or storm information pages on the Sorell Council website	SC	Staff time	High
Make flood mapping data available via the Sorell Council website or on request	SC, SES	Staff time	High
Notification to be given to property owners or tenants at properties identified as being located in a flood-prone area	SC	Staff time	High
Development of a formal flood/storm education and consultation program	SC, SES	Staff time	High

5.9 Additional recommendations

The review of available data and hydraulic modelling outputs has identified a number of locations where targeted management measures have not been considered appropriate in the context of this study. In lieu of targeted management measures, specific recommendations to address the issues at these locations have been formulated, as summarised in Table 5.31. Whilst these do not constitute targeted management measures at this time, it is possible that further investigations may identify the need for a revision of the SSMP to include additional management measures (refer to Section 9.6 for discussion on SSMP review).

Table 5.31: Additional recommendations not addressed by management measures

Location and issue	Recommendation
Downstream of Townsends Lagoon (Lewisham) Currently held drainage network data is incomplete	Acquire detailed survey of all drainage infrastructure in this area to inform a more detailed hydraulic assessment.
Lewis Court (Lewisham) Properties at the eastern end of Lewis Court are known to have flooding problems due to runoff from the China creek catchment.	That Council supports the preparation of a home emergency plan with a focus on flooding. That future infill development of these properties be discouraged, or indeed prevented, via development controls specific for this location.
Tamarix Road area Outlet of the existing stormwater drainage network not currently known	Require detailed survey of all drainage infrastructure to inform a more detailed hydraulic assessment in this area.
Tamarix Road area Function and connectivity of the ephemeral lake and the Carlton River estuary not fully understood	Undertake a more detailed assessment of the flooding characteristics in the Tamarix Road area to determine what roles the ephemeral lake and connectivity with the estuary play with respect to existing flood risk, including effects of tide, antecedent conditions and losses via infiltration. Further assessment or design of management options would be informed by this supplementary analysis.
247 Carlton Beach Road Large floodplain area on private land that could be utilised to attenuate flooding in the Carlton area	Undertake discussions and negotiations with the property owner/developer to better understand the existing flow paths through this property, and to investigate changes to the terrain that could provide a reduction in flood risk for surrounding properties, where these works could be undertaken in conjunction with potential future development of this land.

6. Economic assessment of management measures

One element of the multi-criteria assessment of the range of proposed management measures (as discussed in Section 7) is the reduction in economic damages. This has been determined for this study via a benefit/cost analysis as follows:

- Costs for the implementation of each structural management measure have been estimated using the methodology outlined in Section 6.1.1
- The economic damages associated with each structural management measure have been calculated by applying the same methodology discussed in Section 11 of each *Hydrologic and Hydraulic Capacity Assessment* report prepared for each area of interest (refer to Section 1 for document references), thus permitting the reduction in damages to be calculated. A summary of the reduction in damages associated with the proposed management measures is given in Section 6.1.2.

6.1.1 Costings of potential management measures

Cost estimates for the measures developed in Section 5.4 have been undertaken using estimates from a range of sources that include:

- Rawlinsons Australian Construction Handbook (Rawlinsons, 2013); and
- Estimates from Clarence City Council for previous work undertaken in the Clarence LGA, where these estimates include provisions for:
    - Laying and jointing;
    - Excavation;
    - Backfilling to existing grade; and
    - Traffic management.

Table 6.1 summarises the estimated capital costs for the structural management measures, with a net present value (NPV) determined based on an annual maintenance cost of 1%. A contingency of 40% of the construction costs has been included in the total capital cost estimates to account for unknown quantities and risks at this stage of the infrastructure cycle (i.e. concept design). It follows that for any of the structural management measures presented herein the ultimate cost is likely to vary from that calculated at this stage, and more reliable cost estimates will be achieved during later stages of the design and construction process as details of these unknown quantities and risks become known. Whilst some allowances are provided for via the contingency amount, the costs presented herein don't include an appreciation of the extent of detailed geotechnical conditions, service relocation, land acquisition, rehabilitation, staging, changes in scope, design, approval, tendering and construction supervision, inflation and other market factors.

These cost estimates are commensurate with the level of detail required for this study and must be refined as part of preliminary and detailed design to ensure more accurate costs are obtained. Council should not rely on these figures for budgeting without consideration of all the potential costs and risks, noting that the final constructed cost may be higher than the cost estimates provided herein.

Notwithstanding, the costs estimated for this study are considered appropriate for determining the cost differences between measures and for calculating an indicative benefit-cost ratio. Implementation of the non-structural measures presented in Section 5.7 and Section 5.8 predominantly require staff time at Council and have not been explicitly costed here.

6.1.2 Estimate of economic damages for structural management measures

An assessment of the reduction in damages has been undertaken for the potential management measures presented in Section 5. A summary of this analysis is shown in Table 6.1, which includes the annual average damages, reduction in total damages compared to the current condition and the net present value.

6.1.3 Benefit-cost ratios for potential structural management measures

Benefit-Cost ratios provide a basis for assessing relative financial efficiency across a range of proposed management measures. The ratio is derived by comparing the NPV of benefits relative to the NPV of costs. The higher the ratio for a given management measure, that measure is considered to be more financially efficient compared with the other proposed measures, where a measure with a ratio greater than 1 has a positive financial return (AIDR, 2017b).

The results of calculation of benefit-cost ratios for structural management measures are summarised in Table 6.1, and these results have been subsequently used as one element in the multi-criteria analysis discussed in Section 7. It must be noted that a lower benefit-cost ratio does not suggest a particular measure should not proceed, but justification for implementation may depend on the consideration of other factors and elements such as those applied in the multi-criteria analysis.

Table 6.1: Economic assessment of potential flood modification / structural management measures

ID	Description	Average Annual Damage (AAD)	Reduction in AAD compared with baseline	NPV* of damages	Reduction in NPV* of damages	Estimated capital cost	NPV* of estimated capital cost	Benefit-Cost relative to baseline
EX-SOR	*Current catchment conditions - Sorell area of interest*	*$1,132,000*		*$16,755,000*				
FM-SOR-01[1]	Drainage upgrade: Tasman Highway at Stores Lane	$1,130,000	$2,000	$16,725,000	$30,000	$73,000	$84,000	0.36
FM-SOR-02[1]	Drainage upgrade: Tasman Highway cross-drainage at Stores Lane	$1,122,000	$10,000	$16,607,000	$148,000	$290,000	$331,000	0.45
FM-SOR-03[1]	Detention basin: NW of Tasman Highway at Stores Lane	$1,092,000	$40,000	$16,163,000	$592,000	$256,000	$292,000	2.03
FM-SOR-04	Drainage upgrade: Devenish Drive to Montagu Street outfall	$608,000	$524,000	$8,999,000	$7,756,000	$3,974,000	$4,523,000	1.71
FM-SOR-05	Detention basin and drainage upgrade: upstream of Gatehouse Drive development	$985,000	$147,000	$14,579,000	$2,176,000	$801,000	$912,000	2.39
FM-SOR-06	Drainage upgrade: Weston Hill Road near Valley View Close	$1,132,000	$0	$16,755,000	$0	$57,000	$65,000	0.0
EX-MID	*Current catchment conditions – Midway area of interest*	*$43,000*		*$637,000*				
EX-SBS-LEW	*Current catchment conditions – Southern Beaches area of interest – Lewisham*	*$178,000*		*$1,788,000*				
EX-SBS	*Current catchment conditions – Southern Beaches area of interest – Dodges Ferry*	*$661,000*		*$6,638,000*				
FM-SBS-01	Drainage upgrade: Old Forcett Road near Lewisham Scenic Drive	$660,000	$1,000	$6,628,000	$10,000	$316,000	$360,000	0.03
FM-SBS-02	Drainage upgrade: Intersection of Okines Road and Old Forcett Road to outlet	$647,000	$14,000	$6,497,000	$141,000	$2,013,000	$2,291,000	0.06
FM-SBS-03	Drainage upgrade: Cross-drainage adjacent to 542 Old Forcett Road	$651,000	$10,000	$6,538,000	$100,000	$725,000	$826,000	0.12
FM-SBS-04	Drainage upgrade: Combination of FM-SBS-02 and FM-SBS-03	$635,000	$26,000	$6,377,000	$261,000	$2,738,000	$3,116,000	0.08
FM-SBS-05	Drainage upgrade: Western side of Old Forcett Road at Dodges Ferry Recreation Park	$657,000	$4,000	$6,598,000	$40,000	$415,000	$473,000	0.08
FM-SBS-06	Drainage upgrade: Carlton Beach Road and Seventh Avenue to outfall	$636,000	$25,000	$6,387,000	$251,000	$1,217,000	$1,385,000	0.18
FM-SBS-07	Drainage upgrade: Mongana Street to Blue Lagoon, crossing Carlton Beach Road	$660,000	$1,000	$6,628,000	$10,000	$1,054,000	$1,200,000	0.01
FM-SBS-08[2]	Fence removal: flow path west of Signal Hill Rd	$661,000	$0	$6,638,000	$0	$0[2]	$0	n/a
EX-SBS	*Current catchment conditions – Southern Beaches area of interest – Carlton*	*$623,000*		*$6,256,000*				
FM-SBS-09[2]	Fence removal: western side of Moomere St	$623,000	$0	$6,256,000	$0	$0[2]	$0	n/a
FM-SBS-10	Drainage upgrade: Freedom Close to estuary via new overland flow path	$621,000	$2,000	$6,236,000	$20,000	$484,000	$551,000	0.04
EX-SBS	*Current catchment conditions – Southern Beaches area of interest – Primrose Sands*	*$325,000*		*$3,264,000*				
FM-SBS-11	Defences: Terrain raising to prevent water spilling across Esplanade to Tamarix Road area	$317,000	$8,000	$3,184,000	$80,000	$420,000	$478,000	0.17
FM-SBS-12	Drainage upgrade: Increased capacity for Carlton Bluff Rd drainage	$324,000	$1,000	$3,254,000	$10,000	$232,000	$265,000	0.04
FM-SBS-13	Combination of FM-SBS-12 and FM-SBS-13	$316,000	$9,000	$3,174,000	$90,000	$652,000	$742,000	0.12
FM-SBS-14	Drainage upgrade: Primrose Sands Road cross-drainage adjacent to the RSL	$325,000	$0	$3,264,000	$0	$285,000	$325,000	0.0
EX-SBS	*Current catchment conditions – Southern Beaches area of interest – Dunalley*	*$54,000*		*$543,000*				
FM-SBS-15	Warning signage: Fulham Road	$54,000	$0	$543,000	$0	$5,000	$6,000	0.0
FM-SBS-16	Drainage upgrade: Gilpins Creek cross-drainage culvert at Church Street West	$54,000	$0	$543,000	$0	$306,000	$349,000	0.0

*NPV = Net Present Value calculated for a period of 50 years with a discount rate of 7%

1 Three separate potential management measures have been identified at the intersection of the Tasman Highway and Stores Lane. Advancement of any specific measure at this location should be undertaken in consultation with the Department of State Growth and their planned upgrade of the highway at this location
2 Assumes that there is no capital cost to be borne by Council

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7. Multi-criteria assessment of potential management measures

A multi-criteria assessment of potential management options has been undertaken based on guidance provided in AIDR (2017a) and AIDR (2017b). The assessment matrix developed for this analysis incorporates category-specific criteria and enables their relative importance to be evaluated. The assessment criteria can apply across a range of economic, social and environmental categories. The combination of relative importance of each criterion and weighting assigned to that criterion for each management measure permits a total score to be calculated, permitting a rank to be assigned for each management measure. This rank can then be used to infer priorities for implementation as part of the stormwater system management plan.

The categories and criteria considered in the assessment matrix are summarised in Table 7.1.

Table 7.1: Ranking of potential management measures

Category	Criteria
Safety of people	Reduction of flood hazards Improvements for flood evacuation in extreme events
Social	Increase community growth Disruption/relocation due to management measure Minimise social disruption during flooding
Economic	Life-cycle capital cost Reduction in flood damages Benefit-cost ratio relative to existing conditions
Flood behaviour impacts	Negative or positive impacts of change in hydraulic behaviour Reduce number of houses impacted
Feasibility	Physical or technical feasibility Financial (Council) Potential for state or federal funding
Compatibility	Other hazards and urban drainage Environmental management measures
Key infrastructure	Improved availability and function

The adopted criteria and assigned scoring may require further adjustment following future community consultation that may be undertaken by Council.

The results from the multi-criteria analysis showing the ranking of proposed management measures are given in Table 7.2.

Table 7.2: Ranking of potential management measures

ID	Description	Report Section	Rank
PS-04	Planning and Development Controls	5.7.4	1
CS-03	Community Awareness and Flood Readiness	5.8.3	2
CS-02	Enhanced Emergency Response	5.8.2	3
FM-SOR-05	Detention basin – south of Valley View Drive	5.4.5	4
FM-SOR-04	Drainage Upgrade – Devenish Drive to Montagu Street Outfall	5.4.4	5
FM-SBS-08	Fence removal – flow path west of Signal Hill Road	5.6.8	6
FM-SOR-03	Detention basin – NW of Tasman Highway at Stores Lane	5.4.3	7
CS-01	Enhanced Flood/Storm Warning	5.8.1	8
FM-SBS-10	Drainage upgrade – Freedom Close to estuary via new overland flow path	5.6.10	9
FM-SBS-06	Drainage upgrade – Carlton Beach Road and Seventh Avenue to outfall	5.6.6	10
FM-SBS-04	Drainage upgrade – Combination of FM-SBS02 and FM-SBS-03	5.6.4	11
FM-SOR-02	Drainage upgrade – Tasman Highway cross-drainage at Stores Lane	5.4.2	12
PS-03	Flood Proofing of Buildings	5.7.3	13
FM-SBS-15	Warning signage – Fulham Road	5.6.15	14
FM-SBS-09	Fence removal – western side of Moomere Street	5.6.9	15
FM-SBS-02	Drainage upgrade –Intersection of Okines Rd & Old Forcett Rd to outlet	5.6.2	16
FM-SBS-16	Drainage upgrade – Gilpins Creek cross-drainage culvert at Church Street West	5.6.16	17
FM-SBS-14	Drainage upgrade – Primrose Sands Road cross-drainage adjacent to the RSL	5.6.14	18
PS-01	Individual house raising	5.7.1	19
FM-SBS-07	Drainage upgrade – Mongana St to Blue Lagoon, crossing Carlton Beach Road	5.6.7	20
FM-SBS-01	Drainage upgrade – Old Forcett Road near Lewisham Scenic Drive	5.6.1	21
FM-SOR-01	Drainage upgrade – Tasman Highway at Stores Lane	5.4.1	22
FM-SBS-05	Drainage upgrade – Western side of Old Forcett Road at Dodges Ferry Recreation Park	5.6.5	23
FM-SBS-03	Drainage upgrade – Cross-drainage adjacent to 542 Old Forcett Road	5.6.3	24
FM-SBS-11	Defences – Terrain raising at the Esplanade near Tamarix Road	5.6.11	25
FM-SBS-13	Defences + drainage upgrade – combination of FM-SBS-11 and FM-SBS-12	5.6.13	26
FM-SBS-12	Drainage upgrade – Increased capacity for Carlton Bluff Rd drainage	5.6.12	27
FM-SOR-06	Drainage Upgrade – Weston Hill Road near Valley View Road	5.4.6	28
PS-02	Government House Buyback	5.7.2	29

8. Water quality assessment

8.1 Water quality strategies, objectives and targets

Runoff from the areas of interest drains to a number of bodies of water which includes Pitt Water (including Orielton Lagoon), Frederick Henry Bay and Blackman Bay. Orielton Lagoon is a wetland of international significance, recognised as both a Tasmanian Nature Reserve and an international Ramsar site.

Details of selected strategies and policies that address water quality improvements are provided herein, where these are applicable generally to all catchments and specifically for sensitive sites such as Pitt Water and Orielton Lagoon. Discussion on other relevant strategies and policies are summarised in BMT WBM (2011) and SKM (2017).

8.1.1 State Policy on Water Quality Management 1997

The State Policy on Water Quality Management was prepared to "*achieve the sustainable management of Tasmania's surface water and groundwater resources by protecting or enhancing their qualities while allowing for sustainable development in accordance with the objectives of Tasmania's Resource Management and Planning system*". The objectives of this policy are to:

- Focus water quality management on the achievement of water quality objectives which will maintain or enhance water quality and further the objectives of Tasmania's Resource Management and Planning System;
- Ensure that diffuse source and point source pollution does not prejudice the achievement of water quality objectives and that pollutants discharged to waterways are reduced as far as is reasonable and practical by the use of best practice environmental management;
- Ensure that efficient and effective water quality monitoring programs are carried out and that the responsibility for monitoring is shared by those who use and benefit from the resource, including polluters, who should bear an appropriate share of the costs arising from their activities, water resource managers and the community;
- Facilitate and promote integrated catchment management through the achievement of the preceding objectives; and
- Apply the precautionary principle to all outcomes and actions adopted to achieve water quality objectives.

8.1.2 State Stormwater Strategy 2010

The State Stormwater Strategy helps to address recommendations of the Tasmanian State Policy on Water Quality Management 1997, advocating a range of Water Sensitive Urban Design (WSUD) principles and discussing a range of treatment methods for the management of stormwater runoff.

8.1.3 Pitt Water Nature Reserve Management Plan 2013

The Pitt Water Nature Reserve Management Plan is aimed at ensuring the long term viability of the values for which the reserve was established to protect. The plan outlines the legislative management objectives for nature reserves, as well as reserve specific objectives, prescriptions, strategies and actions.

There are a number of key processes that have the potential to detrimentally affect the values of the reserve. Key management initiatives in this plan include directions to:

- improve water quality, particularly in Orielton Lagoon through better stormwater management;
- ensure the continuation of important weed removal activities, including Weeds of National Significance;
- manage access to the reserve to reduce disturbance to birds as well as lessen other potential threats, such as pollution. The most noteworthy access strategies are the seasonal restriction of access to Woody Island to minimise the disturbance of sea-eagles during the breeding season and prohibition on use of motorised vessels (when under power);
- provide guidance for the formalisation of a pre-existing occupation of the reserve to improve environmental outcomes; and
- improve liaison with local municipal councils, landowners and interested groups or community members to minimise threats and assist with the implementation of management actions recommended for adjacent land. This is important because many threats to the reserve originate beyond its boundaries. The plan also outlines opportunities for improving community engagement and understanding about the threats to the values of the reserve.

8.1.4 Sorell Interim Planning Scheme 2015

- Stormwater quality targets provided in the Sorell Interim Planning Scheme 2015 (refer to Section 4.3.2 for further discussion) are as follows:80% reduction in the average annual load of total suspended solids (TSS) based on typical urban stormwater TSS concentrations;
- 45% reduction in the average annual load of total phosphorus (TP) based on typical urban stormwater TP concentrations; and
- 45% reduction in the average annual load of total nitrogen (TN) based on typical urban stormwater TP concentrations.

8.2 Existing stormwater quality treatment

8.2.1 Sorell area of interest

Runoff from the Sorell stormwater catchment drains to Orielton Lagoon and Pitt Water either directly via the existing stormwater system, or via Sorell Rivulet. There are a number of existing water quality treatment devices and treatment trains as shown in Figure 8.1 and summarised in Table 8.1.

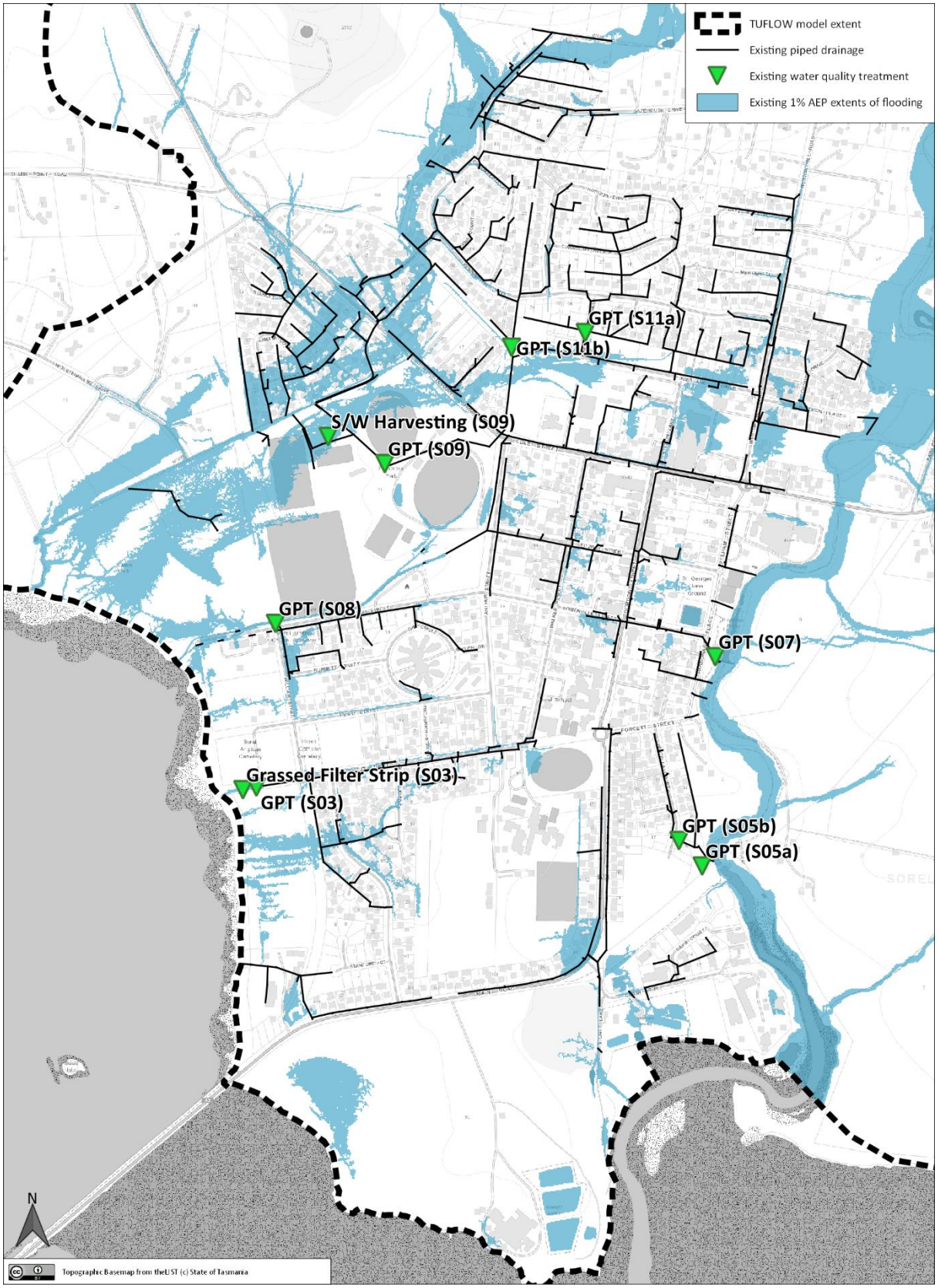

Figure 8.1: Existing water quality treatment devices – Sorell area of interest

Table 8.1: Existing water quality treatment – Sorell area of interest

Type & drainage line	Description
GPT (S03) & Grassed Filter Strip (S03)	GPT located at the western end of Forcett Street and upstream of the vegetated filter strip immediately upstream of the outfall to Orielton Lagoon.
GPT (S05a & S05b)	Two *Ecosol* GPTs located at the southern extent of Whitelea Court and upstream of the outfall to Sorell Rivulet.
GPT (S07)	*Ecosol* GPT located within Pioneers Park on Parsonage Place and immediately upstream of the outfall to Sorell Rivulet.
GPT (S08)	*HumeCeptor* GPT located near the intersection of William Street and Montagu Street, at the outfall to the open channel on Montagu Street
GPT (S09)	*HumeGard* GPT located on the piped drainage that feeds the stormwater harvesting system in Pembroke Park
S/W Harvesting (S09)	Existing stormwater harvesting system in Pembroke Park
GPT (S11a and S11b)	Two GPTs located on the existing piped drainage where these drainage lines take flow from the residential development north of Pennington Drive

8.2.2 Midway area of interest

Runoff from the Midway stormwater catchment drains directly to Orielton Lagoon and Pitt Water via the existing stormwater system. There are a number of existing water quality treatment devices as shown in Figure 8.2 and summarised in Table 8.2.

Table 8.2: Existing water quality treatment – Midway area of interest

Type & drainage line	Description
GPT (M09)	*Ecosol* GPT located on Penna Road and upstream of the outfall to Pitt Water
GPT (M10)	*Ecosol* GPT located on Penna Road and upstream of the outfall to Pitt Water
GPT (M11a)	GPT located in the roundabout at the intersection of Penna Road and Sweetwater Road, with raingarden on the western side of Penna Road
GPT (M12)	*Ecosol* GPT located at the northern extent of Midway Point Esplanade and upstream of the outfall to Orielton Lagoon
GPT (M13)	*Ecosol* GPT located on Midway Point Esplanade and upstream of the outfall to Orielton Lagoon
GPT (M19)	*Ecosol* GPT located on Lake Vue Parade and upstream of the outfall to Orielton Lagoon
GPT (M23)	*Ecosol* GPT located at downstream extent of subdivision on Penna Beach Street

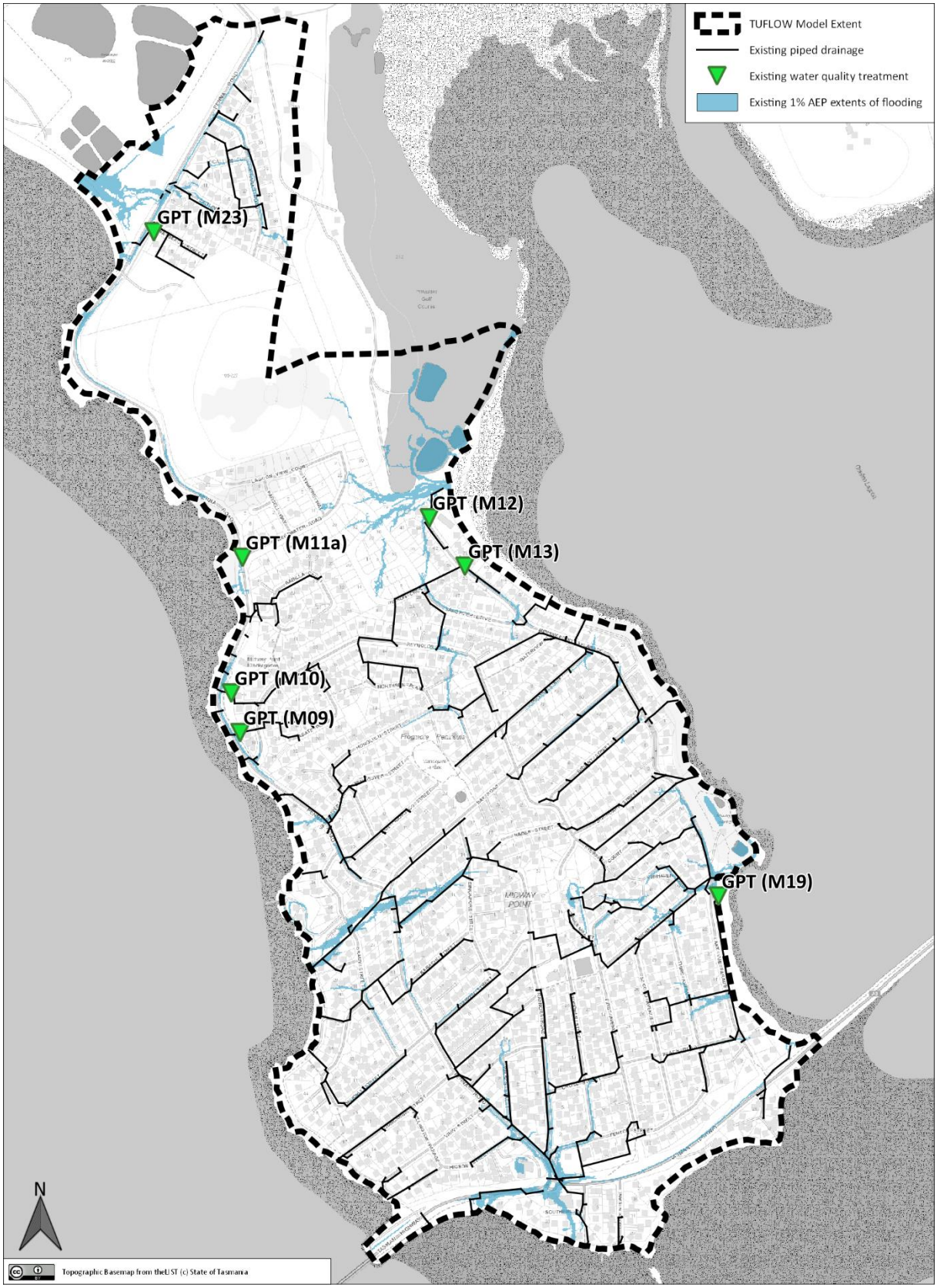

Figure 8.2: Existing water quality treatment devices – Midway area of interest

8.2.3 Southern Beaches area of interest

Runoff from the localities in the Southern Beaches area of interest drains to Pitt Water, Frederick Henry Bay or Blackman Bay, generally directly via the existing stormwater system. There are currently no known water quality treatment measures across the Southern Beaches area of interest, noting that there is a combination of piped and channel outfalls to the receiving waters.

8.2.4 Municipality-wide treatment

As discussed in BMT WBM (2011), Council's existing maintenance and management practices have the potential to directly or indirectly impact stormwater quality in the Sorell catchment, where these activities include:

- Inspection cleaning and maintenance of stormwater pits
- Cleaning of GPTs
- Sewer overflow management practices
- Vegetation management and weed removal
- Garbage collection; and
- Street sweeping.

The effectiveness of the existing water quality treatment devices is directly affected by these activities.

8.3 Potential stormwater quality management measures

With reference to the analysis provided in BMT WBM (2011), potential stormwater quality management measures can be grouped broadly into the following three areas:

- Retro-fitting, including rainwater tanks, WSUD elements, educational signage, habitat rehabilitation;
- Proactive planning and development controls to minimise the impacts of future development on stormwater quality; and
- Community stormwater quality awareness programs.

Since the completion of the previous Sorell Stormwater Management Plan (BMT WBM, 2011), certain elements advocated in that plan have been implemented (e.g. stormwater harvesting system in Pembroke Park). However, many of the strategies recommended in that report are still valid, particularly where certain management measures are opportunistic in nature. It is recommended that the strategies presented in BMT WBM (2011) (excluding those that have been implemented) be adopted for this current SSMP.

In addition to these broad groups of management measures and with consideration of the potential measures for management of flood risk discussed in Section 5, other opportunities for the management of water quality from the Sorell catchment are as follows:

- Sorell area of interest:

  - GPT to be provided in conjunction with drainage network changes on the Tasman Highway at the intersection with Stores Lane (management measures FM-SOR-01, FM-SOR-02, FM-SOR-03; Section 5.4.1, Section 5.4.2, Section 5.4.3);
  - Bio-retention/wetland at the downstream extent of the Montagu Street drain (management measure FM-SOR-04, Section 5.4.4);
  - Additional stormwater harvesting in Pembroke Park or Miena Park (management measure FM-SOR-04, Section 5.4.4);
- Southern Beaches area of interest:
  - GPT provided in conjunction with drainage network changes at the intersection of Richards Avenue and Short Street (management measure FM-SBS-01, Section 5.6.1);
  - Vegetated filter (e.g. bio-retention/wetland) located either within the existing Council reserve bounded by Rantons Road and Old Forcett Road or within Lagoon Park south of the Dodges Ferry Primary School (management measures FM-SBS-02, FM-SBS-03, FM-SBS-04, Section 5.6.2, Section 5.6.3, Section 5.6.4);
  - GPT provided in conjunction with drainage network changes at the western end of Seventh Avenue (management measure FM-SBS-06, Section 5.6.6);
  - Potential for stormwater harvesting within the Dodges Ferry Recreation Park;
- Municipality-wide:
  - Stabilisation of drain/channel outfalls
  - Increased number of GPTs both internal to stormwater sub-catchments and upstream of outfalls with no GPT;
  - Construction of additional vegetated filter strips/swales upstream of outfalls;
  - Incorporate WSUD into infrastructure upgrades, such as the planned Tasman Highway diversion (will require working with Department of State Growth); and
  - Inclusion of water quality issues as part of a community awareness program (management measure CS-03, Section 5.8.3).

It is recommended that these management measures be assessed further as part of a feasibility study for any of the flood risk management measures. Similarly, it is recommended that Council assess the feasibility of the retro-fit of WSUD elements when undertaking any new or upgrade works across the catchment.

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9. Stormwater System Management Plan

9.1 Introduction

This stormwater system management plan has been prepared to assist with ensuring there is an appropriate level of understanding and management of the flood risk and public stormwater systems within the study area stormwater catchments, whilst also considering water quality objectives. The analysis undertaken in preparing this study has defined the flooding behaviour across the study area stormwater catchments, identifying overland flow paths and flood affected land. This has allowed for a range of structural and non-structural flood risk management measures to be identified and analysed, as described herein.

9.2 Recommended measures for managing flood risk

The suite of recommended measures for managing flood risk are presented in Figure 9.1 for the Sorell area of interest, Figure 9.2 for the Midway area of interest and Figure 9.3 for the Southern Beaches area of interest, with the various elements summarised in the following tables:

- Table 9.1 for Flood Modification/Structural Management Measures;
- Table 9.2 for Property-Scale Management Measure; and
- Table 9.3 for Community / Catchment-Scale Management Measures.

The recommended management measures have been derived through consideration of the results of the multi-criteria analysis (i.e. relative ranking of each potential management measure) and effectiveness of the measures at reducing flood risk. On this basis, some of the potential management measures discussed in Section 5 are not explicitly recommended for inclusion in the stormwater system management plan.

For all structural management measures assessed in this study there is a residual flood risk at this location due to:

- Insufficient capacity of the drainage network, even with the inclusion of the proposed works;
- Potential blockage of the stormwater drainage network; or
- Flooding from events with magnitude greater than what has been modelled for this study.

Costings of the potential management measures are preliminary and are of a level of detail that is appropriate for conceptual level designs, and these must be refined as part of preliminary and detailed design to ensure more accurate costs are obtained. A contingency of 40% of the construction costs has been included in the total capital cost estimates to account for unknown quantities and risks at this concept design stage. It follows that for any of the structural management measures the ultimate cost is likely to vary from that calculated at this stage, and more reliable cost estimates will be achieved during later stages of the design and construction process as details of these unknown quantities and risks become known. Whilst some allowances are provided for via the contingency amount, the costs presented herein don't include an appreciation of the extent of detailed geotechnical conditions, service relocation, land acquisition, rehabilitation, staging, changes in scope, design, approval, tendering and construction supervision, inflation and other market

factors. Council should not rely on these figures for budgeting without consideration of all the potential costs and risks, noting that the final constructed cost may be higher than the cost estimates provided.

Table 9.1: Recommended flood modification/structural management measures

ID	Description	Estimated Capital Cost (NPV)	Priority
	Tasman Highway at Stores Lane [#]	TBC	High
FM-SOR-01	Drainage Upgrade 1 - Channel Works	($84,000)	
FM-SOR-02	Drainage Upgrade 2 - Channel Works + Cross Drainage	($331,000)	
FM-SOR-03	Detention Basin	($292,000)	
FM-SOR-04	Drainage Upgrade – Devenish Drive to Montagu Street Outfall	$4,523,000	High
FM-SOR-05	Detention basin – south of Valley View Drive	$912,000	High
FM-SBS-01	Drainage Upgrade – Old Forcett Road near Lewisham Scenic Drive	$360,000	Low
FM-SBS-02	Drainage Upgrade – Intersection of Okines Road and Old Forcett Road to outlet	$2,291,000	Medium
FM-SBS-03	Drainage Upgrade – cross-drainage adjacent to 542 Old Forcett Road	$826,000	Low
FM-SBS-04	Drainage Upgrade – combination of FM-SBS-02 and FM-SBS-03	$3,116,000	Medium
FM-SBS-05	Drainage Upgrade –western side of Old Forcett Road at Dodges Ferry Recreation Park	$473,000	Low
FM-SBS-06	Drainage Upgrade – Carlton Beach Road and Seventh Avenue to outfall	$1,385,000	Medium
FM-SBS-07	Drainage Upgrade – Mongana Street to Blue Lagoon, crossing Carlton Beach Road	$1,200,000	Low
FM-SBS-08	Fence removal – flow path west of Signal Hill Road	$0	High
FM-SBS-09	Fence removal – western side of Moomere Street	$0	Medium
FM-SBS-10	Drainage Upgrade – Freedom Close to estuary via new overland flow path	$551,000	Medium
FM-SBS-14	Drainage Upgrade – Primrose Sands Road cross-drainage adjacent to the RSL	$325,000	Low
FM-SBS-15	Warning signage – Fulham Road	$6,000	Medium
FM-SBS-16	Drainage Upgrade – Gilpins Creek cross-drainage culvert at Church Street West	$349,000	Low

[#] The assessment undertaken for this study has included three different options for the management of flooding at the intersection of the Tasman Highway at Stores Lane, specifically management measures FM-SOR-01, FM-SOR-02 and FM-SOR-03. Whilst it is not realistic, nor is it the intention, for all of these measures to be implemented, the analysis of multiple measures at this location has been

undertaken to permit an assessment of their relative benefits to ultimately lead to an informed decision regarding the most appropriate measure to be implemented at this location. Given the planned upgrade of the Tasman Highway at this location, it is recommended that Council table and discuss the merits of these management measures with the Department of State Growth and Department of Education (i.e. for measure FM-SOR-03) to determine which measure should be adopted. On this basis, this plan provides for one of these management measures to be implemented at this location and it is recommended that this be undertaken through consultation with the relevant state departments.

Table 9.2: Recommended property-scale management measures

ID	Description	Estimated Capital Cost (NPV)	Priority
PS-01	Individual house raising	n/a	Low
PS-03	Flood Proofing of Buildings	n/a	Medium
PS-04	Planning and Development Controls	Staff Time	High

Table 9.3: Recommended community/catchment-scale management measures

ID	Description	Estimated Capital Cost (NPV)	Priority
CS-01	Enhanced Flood/Storm Warning	Staff Time	Medium
CS-02	Enhanced Emergency Response	Staff Time	High
CS-03	Community Awareness and Readiness Program	Staff Time	High

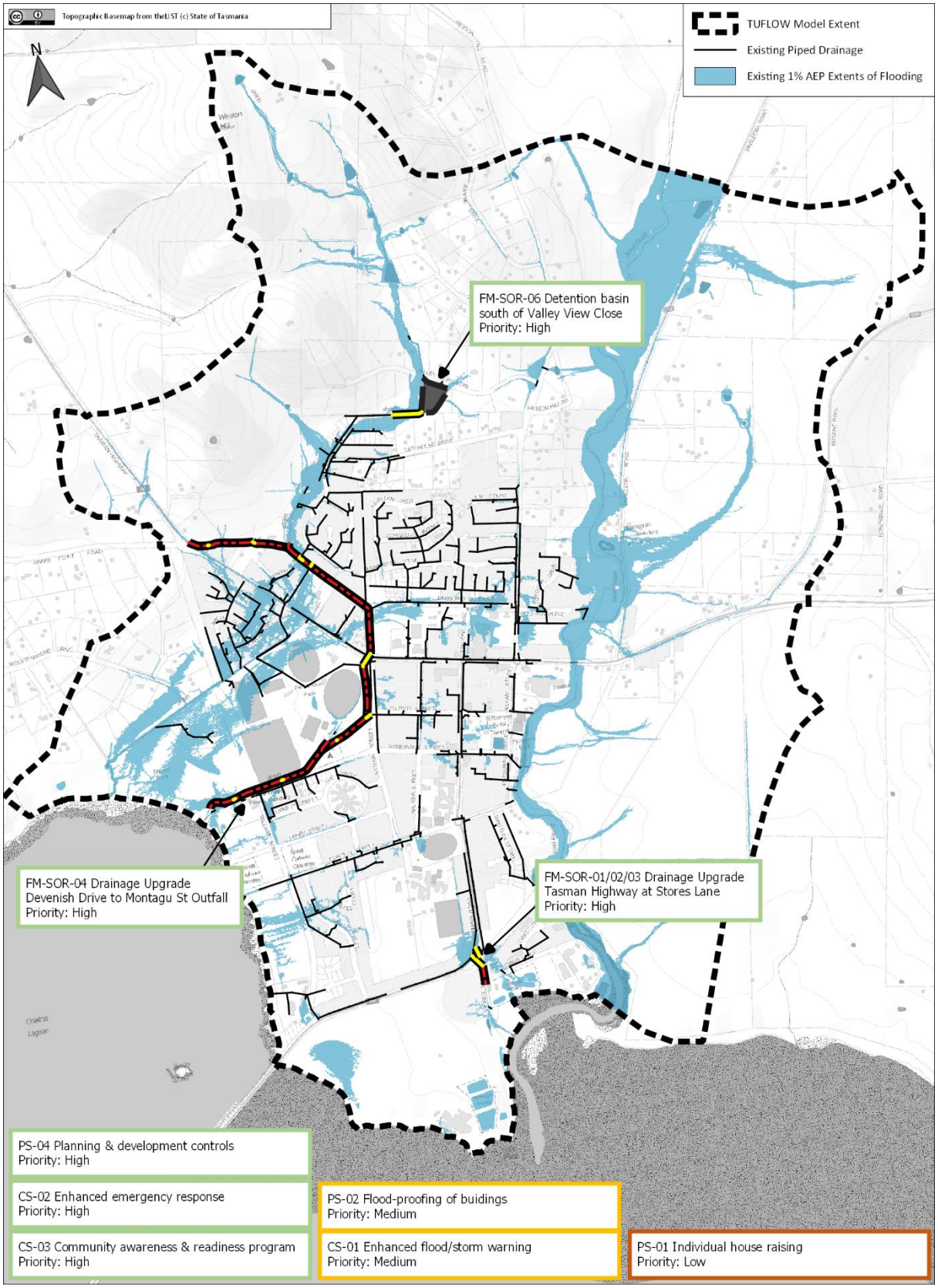

Figure 9.1: Recommended measures for managing flood risk – Sorell area of interest

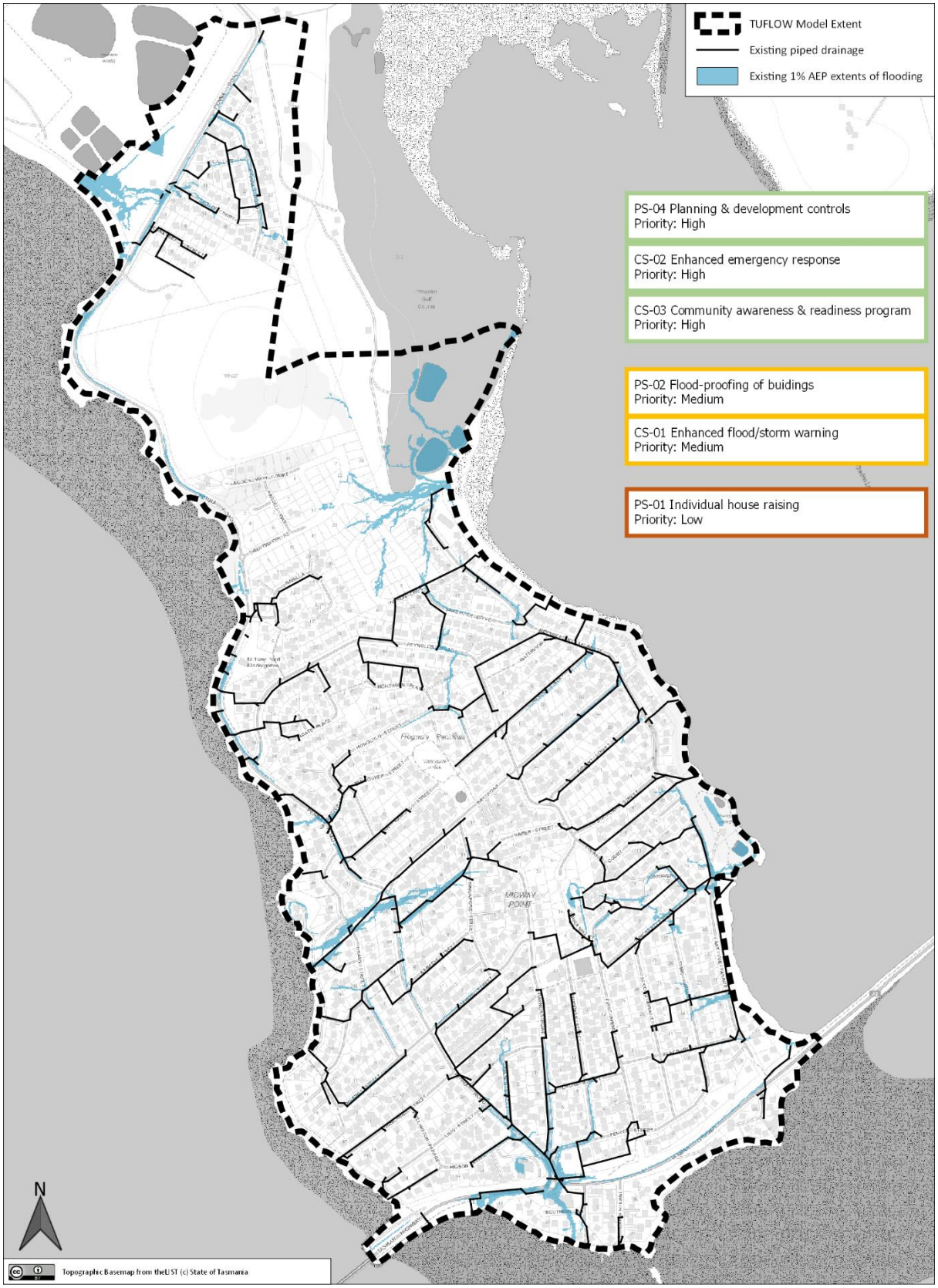

Figure 9.2: Recommended measures for managing flood risk – Midway area of interest

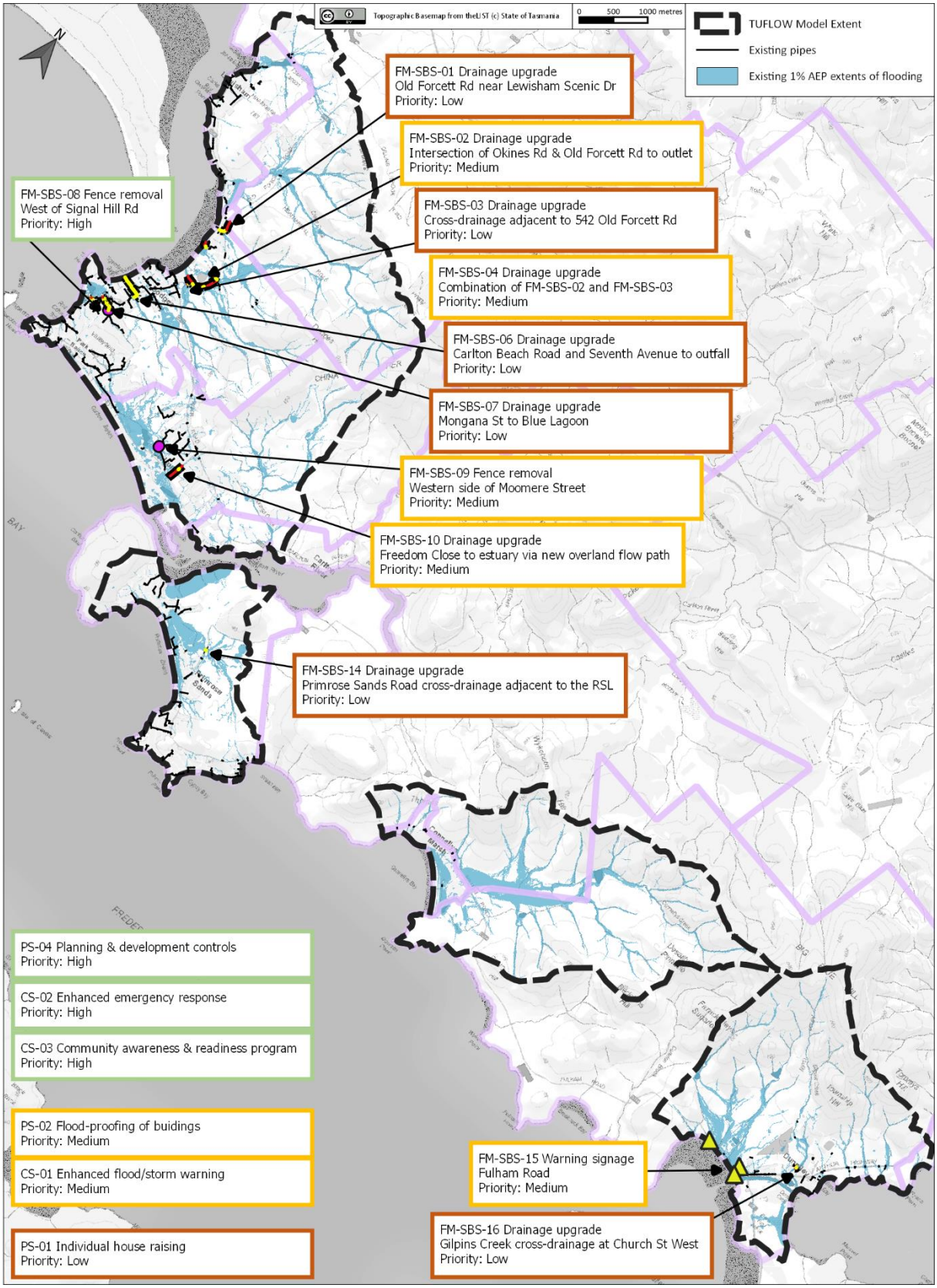

Figure 9.3: Recommended measures for managing flood risk – Southern Beaches area of interest

9.3 Recommended measures for managing water quality

It is recommended that the analysis, outcomes and strategies (excluding those already implemented) from the previous Sorell Stormwater Management Plan (BMT WBM, 2011) that address water quality issues be adopted for this current SSMP.

Other potential water quality management measures arising from the analysis for this current SSMP that are considered to be complementary to the objectives of the flood risk management measures are as follows:

- Sorell area of interest:
    - GPT to be provided in conjunction with drainage network changes on the Tasman Highway at the intersection with Stores Lane (management measures FM-SOR-01, FM-SOR-02, FM-SOR-03; Section 5.4.1, Section 5.4.2, Section 5.4.3);
    - Bio-retention/wetland at the downstream extent of the Montagu Street drain (management measure FM-SOR-04, Section 5.4.4);
    - Additional stormwater harvesting in Pembroke Park or Miena Park (management measure FM-SOR-04, Section 5.4.4);
- Southern Beaches area of interest:
    - GPT provided in conjunction with drainage network changes at the intersection of Richards Avenue and Short Street (management measure FM-SBS-01, Section 5.6.1);
    - Vegetated filter (e.g. bio-retention/wetland) located either within the existing Council reserve bounded by Rantons Road and Old Forcett Road or within Lagoon Park south of the Dodges Ferry Primary School (management measures FM-SBS-02, FM-SBS-03, FM-SBS-04, Section 5.6.2, Section 5.6.3, Section 5.6.4);
    - GPT provided in conjunction with drainage network changes at the western end of Seventh Avenue (management measure FM-SBS-06, Section 5.6.6);
    - Potential for stormwater harvesting within the Dodges Ferry Recreation Park;
- Municipality-wide:
    - Stabilisation of drain/channel outfalls
    - Increased number of GPTs both internal to stormwater sub-catchments and upstream of outfalls with no GPT;
    - Construction of additional vegetated filter strips/swales upstream of outfalls;
    - Incorporate WSUD into infrastructure upgrades, such as the planned Tasman Highway diversion (will require working with Department of State Growth); and
    - Inclusion of water quality issues as part of a community awareness program (management measure CS-03, Section 5.8.3).

Implementation of these water quality management measures should be opportunistic and seek to capitalise on new or upgrade works being undertaken by Council or other relevant authority (e.g. Department of State Growth). On this basis, a program for implementation has not been prepared for these measures.

9.4 Program for implementation

An indicative program for the implementation of the recommended measures for managing flood risk is provided in Figure 9.4. This has been prepared on the basis that measures with 'high' priority are to be implemented during the first 5-year period, 'medium' priority to be implemented over years 5-15, and 'low' priority over years 15-20 and beyond.

9.5 Sources of funding

Implementation of certain elements of the SSMP may be possible with one-off sources of funding at a given point in time (e.g. government grant). However, as suggested by Reese (2017), the successful implementation of the SSMP will require funding that is stable, adequate, flexible and equitable (SAFE), thereby ensuring funding allocated solely for this purpose over the life-cycle of Council's capital works program. It is therefore considered important to seek funding from a range of sources to ensure the successful implementation of the SSMP.

Potential sources of funding for further analysis and implementation of the stormwater system management plan and specific management measures may include the following:

- Sorell Council's capital works fund/budget;
- A new levy introduced via Council rates to specifically address the elements of the SSMP
    - Existing stormwater levies (where charged) are typically allocated to the maintenance of the existing stormwater system and do not accommodate new works;
    - Should a new levy be charged, the funds should be directed solely to the implementation of the SSMP;
- Increased contributions made as part of the development application process;
- Grants that may be available from state or federal government agencies;
- Funding directly from state or federal government agencies where there is an overlap of responsibility with respect to the proposed works (e.g. planned upgrade of the Tasman Highway);
- Natural Resource Management (NRM) South
    - Where a specific management measure may lead to environmental benefits (e.g. improved water quality), implementation of that measure may qualify for funding via NRM south.

ID	Locality	Description
FM-SOR-01/02/03	Sorell	Tasman Highway at Stores Lane
FM-SOR-04	Sorell	Drainage Upgrade - Devenish Drive to Montagu Street Outfall
FM-SOR-05	Sorell	Detention Basin - South of Valley View Drive
FM-SOR-06	Sorell	Drainage Upgrade - Weston Hill Road near Valley View Road
FM-SBS-01	Dodges Ferry	Drainage upgrade - Old Forcett Rd near Lewisham Scenic Drive
FM-SBS-02	Dodges Ferry	Drainage upgrade - Intersection of Okines Rd and Old Forcett Rd to outlet
FM-SBS-03	Dodges Ferry	Drainage upgrade - cross-drainage adjacent to 542 Old Forcett Rd
FM-SBS-04	Dodges Ferry	Drainage upgrade - Combination of FM_SBS_02 and FM_SBS_03
FM-SBS-05	Dodges Ferry	Drainage upgrade - Western side of Old Forcett Road at Dodges Ferry Recreation Park
FM-SBS-06	Dodges Ferry	Drainage upgrade - Carlton Beach Road and Seventh Avenue to outfall
FM-SBS-07	Dodges Ferry	Drainage upgrade - Mongana St to Blue Lagoon, crossing Carlton Beach Rd
FM-SBS-08	Dodges Ferry	Fence removal - Flow path west of signal Hill Rd
FM-SBS-09	Carlton	Fence removal - Western side of Moomere St
FM-SBS-10	Carlton	Drainage upgrade - Freedom Close to estuary via new overland flow path
FM-SBS-11	Primrose Sands	Defences - Terrain raising to prevent water spilling across the Esplanade to Tamarix Rd area
FM-SBS-12	Primrose Sands	Drainage upgrade - Increased capacity for Carlton Bluff Rd drainage
FM-SBS-13	Primrose Sands	Defences + drainage upgrade - Combination of FM_SBS_11 and FM_SBS_12
FM-SBS-14	Primrose Sands	Drainage upgrade - Primrose Sands Rd cross-drainage adjacent to the RSL
FM-SBS-15	Dunalley	Warning signage - Fulham Rd
FM-SBS-16	Dunalley	Drainage upgrade - Gilpins Creek cross-drainage culvert at Church St West
PS-01	Municipality-wide	Individual House Raising
PS-02	Municipality-wide	Government House Buyback
PS-03	Municipality-wide	Flood Proofing of Buildings
PS-04	Municipality-wide	Planning and Development Controls
CS-01	Municipality-wide	Enhanced Flood/Storm Warning
CS-02	Municipality-wide	Enhanced Emergency Response
CS-03	Municipality-wide	Community Awareness and Flood Readiness

Figure 9.4: Program for implementation of recommended measures for managing flood risk

9.6 Stormwater system management plan review

As advocated in LGAT (2016), this stormwater system management plan should be considered to be a 'living document' that is periodically reviewed to take account of current knowledge, changing conditions within the catchment and changing community attitudes to the management of stormwater and other water resources making up the water cycle. It is recommended that Council reviews the SSMP at least every 5 years, or aligned with the periodic review of Council's asset management plans. It is further recommended that the proposed management strategy and specific management measures to be adopted for the subsequent 10-year period be identified in Council's asset management plan.

LGAT (2016) recognises that despite the best planning, on occasion, proposed works within a catchment need to be modified or elevated in priority as a result of unforeseen circumstances. It is considered to be appropriate for the SSMP to be amended to account for these circumstances, provided that the proposed changes are consistent with the overall strategy and properly integrate with existing or proposed infrastructure, including any SSMP for an adjoining catchment.

10. Limitations and qualifications

The Sorell Stormwater System Management Plan has been prepared using the best available information and data at the time of preparation of the study. Whilst the objectives of the study have been achieved, the currency and accuracy of the modelling and analysis are affected by (but not limited to) the following:

- The configuration and size of all pit inlets has been determined based on broad classification of pit inlet types provided by Esk Mapping & GIS, noting that the grate and/or lintel dimensions have not been measured;
- Lower areas of the study area may be affected by extreme tides. Whilst this SSMP considers the interaction of tidal condition with the performance of the stormwater drainage network, the study does not consider flooding from extreme tidal conditions or its joint probability with stormwater flooding;
- A requirement of the SSMP was to consider and include all pipes with a dimeter of 300mm and greater. It follows that numerous smaller pipes exist across the study area that have not been considered as part of this study;
- The subject stormwater catchments are ungauged and there is an absence of data to permit model calibration or validation. Current and future overland flows and flood levels may therefore differ from those predicted and presented in this study;
- Design event modelling has utilised guidance provided in Australian Rainfall and Runoff 1987 (ARR 1987). It must be noted that future studies and modelling may require the mandated use of methodologies outlined in Australian Rainfall and Runoff 2019 (ARR2019). Sensitivity testing undertaken for this study (as detailed in the *Hydrologic and Hydraulic Capacity Assessment* reports) indicates that the application of ARR 2019 rainfall parameters yields less conservative flood conditions compared with ARR 1987 and may therefore result in lower design flood levels;
- Economic damages resulting from flooding have been calculated based on the assumptions and depth-damage curves discussed in Section 6. It follows that should more detailed data be made available (such as individual building construction types and property values) that the estimated damages may vary from those presented in this report;
- The structural management measures developed for this SSMP are conceptual level and further feasibility studies (including survey) should be undertaken before proceeding to future detailed design;
- Analysis of the various structural management measures has been undertaken based on current climate and catchment conditions. It is recommended that should any of the measures be taken forward for feasibility and ultimately detailed design analysis, that assessment should include an assessment of future climate.
- Costings of the potential management measures are preliminary and are of a level of detail that is appropriate for conceptual level designs and must be refined as part of preliminary and detailed design to ensure more accurate costs are obtained. A contingency of 40% of the construction costs has been included in the total capital cost estimates to account for unknown quantities and risks at this concept design stage. It follows that for any of the

structural management measures the ultimate cost is likely to vary from that calculated at this stage, and more reliable cost estimates will be achieved during later stages of the design and construction process as details of these unknown quantities and risks become known. Whilst some allowances are provided for via the contingency amount, the costs presented herein don't include an appreciation of the extent of detailed geotechnical conditions, service relocation, land acquisition, rehabilitation, staging, changes in scope, design, approval, tendering and construction supervision, inflation and other market factors. Council should not rely on these figures for budgeting without consideration of all the potential costs and risks, noting that the final constructed cost may be higher than the cost estimates provided.

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Appendices

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A Flooding problem locations not considered further for management measures

A.1 Sorell area of interest

Item	Description
Location ID	Item 6 Table 3.1
Location	West of Dodges Court to west of Nash Street
Description of flooding problem	Ponding in trapped low points and overland flow along the surface depression with some flow being trapped behind the existing embankment that runs along the western boundary of the residential development (i.e. west of Nash Street). Predicted flood hazard category of up to H1.
Discussion / recommendations	Local effect with low flood hazard.

Item	Description
Location ID	Item 8 Table 3.1
Location	Runoff being directed onto TasWater land
Description of flooding problem	Stormwater drainage on Giblin Drive directs runoff onto TasWater land south of Giblin Drive affecting the treatment ponds.
Discussion / recommendations	Various works are planned in this area in relation to the Tasman Highway upgrade. Flooding at this location should be reassessed following completion of the design for the highway upgrade.

Item	Description
Location ID	Item 9 Table 3.1
Location	Property at 3 Weston Hill Road
Description of flooding problem	Runoff ponds in private land at 3 Weston Hill Road with hazard category up to H2.
Discussion / recommendations	Any future flood mitigation or management on this site should be addressed by the property owner or potential future developer.

A.2 Midway area of interest

Item	Description
Location ID	Item 1 Table 3.2
Location	Tasman Highway at Penna Road
Description of flooding problem	Overland flow from multiple flow paths that generally follow the road network converge at the intersection of the Tasman Highway and Penna Road. The lower pipes along these flow paths reach capacity in events with magnitude less than 18% AEP (5 year ARI). Excess surface water floods the southern-most part of Penna Road before flooding across the Tasman Highway. Water continues both westwards along the highway and southwards through property to Pitt Water.
Discussion / recommendations	Flood risk at this location mainly affects the Tasman Highway and is therefore the responsibility of the Department of State Growth. It is recommended that outputs from this study be used by DSG to inform future upgrade works.

Item	Description
Location ID	Item 2 Table 3.2
Location	Lake View Parade at Suncrest Street
Description of flooding problem	Overland flow from multiple flow paths that generally follow the road network converge at the intersection of Lake View Parade and Suncrest Street. The lower pipes along these flow paths reach capacity in events with magnitude less than 18% AEP (5 year ARI). Excess surface water floods the eastern-most part of Suncrest Avenue and its intersection with Lake View Parade before discharging to Orielton Lagoon via overland flow.
Discussion / recommendations	Flooding of the roads at this location affects is not considered to adversely affect evacuation should it be required. Future upgrades of the stormwater drainage at this location should be addressed on an opportunistic basis (e.g. in conjunction with major roadworks).

Item	Description
Location ID	Item 3 Table 3.2
Location	Suva Street and Kessarios Park through to outfall
Description of flooding problem	Runoff flows along the length of Suva Street, with some water flowing through residential properties to then cross Penna Road at Kessarios Park. Flow continues along the length of Kessarios Park, crossing Brady Street then ultimately discharging to Pitt Water. In the 1% AEP event, there is a maximum flood hazard category of H1 across all parts of the overland flow path.

Discussion / recommendations	Flooding of the roads at this location affects is not considered to adversely affect evacuation should it be required. Future upgrades of the stormwater drainage at this location should be addressed on an opportunistic basis (e.g. in conjunction with major roadworks).

Item	**Description**
Location ID	Item 1 Table 3.2
Location	Penna Road north of Penna Beach Street
Description of flooding problem	Runoff from catchments to the east crosses Penna Road via two separate cross-drainage pipes, where both have a headwall within the longitudinal drainage ditch along the eastern side of Penna Road. In the 1% AEP event, runoff exceeds the capacity of these pipes with water spilling across Penna Road with a maximum depth of approximately 0.60m and flood hazard category of H1.
Discussion / recommendations	Flooding of the roads at this location affects is not considered to adversely affect evacuation should it be required. Future upgrades of the stormwater drainage at this location should be addressed on an opportunistic basis (e.g. in conjunction with major roadworks).

A.3 Southern Beaches area of interest

A.3.1 Lewisham

Item	Description
Location ID	Item 1 Table 3.3
Location	Intersection of Lewisham Road and Quarry Road at Townsends Lagoon
Description of flooding problem	Multiple flow paths converge near the intersection which lies at the north-west corner of Townsends Lagoon. Flooding of the road occurs due to combination of water backing up from the lagoon and under-capacity cross-drainage culverts. Maximum on-road flood hazard category of H2.
Discussion / recommendations	Interrogation of the flooding characteristics at this location showed that the peak flood conditions are governed by water backing up from the lagoon, indicating that cross-drainage upgrades are unlikely to alleviate flooding in this area.

Item	Description
Location ID	Item 2 Table 3.3
Location	Flow path downstream of Townsends Lagoon
Description of flooding problem	Water flows through light industrial business and across Lewisham Road. Existing drainage infrastructure in this area was not surveyed for this study; however the estimated drainage features appear to be under-capacity. Maximum on-road flood hazard category of H2.
Discussion / recommendations	Specific mitigation or management measures have not been assessed for this location on the basis that the configuration of the existing infrastructure is not known. Flooding is also likely to be affected by extreme tidal conditions (including projected sea level rise).

Item	Description
Location ID	Item 1 Table 3.3
Location	Lewis Court (China creek floodplain)
Description of flooding problem	A number of properties are flood affected from runoff in the China Creek catchment, indicating a mainstream flooding problem and not a stormwater issue. Maximum flood hazard category of H4 affecting existing property.
Discussion / recommendations	Recommended that no new structures or development be permitted in this area. Property owners may wish to consider flood proofing of buildings or raising the house to be above the predicted flood levels.

Item	Description
Location ID	Item 1 Table 3.3
Location	Lower reach of China Creek
Description of flooding problem	A number of properties within the China Creek floodplain are flood affected directly from China Creek, suggesting this is a mainstream flooding problem and not a stormwater issue. Maximum flood hazard category of H3 affecting existing property.
Discussion / recommendations	There are no viable structural management measures at this location. Flooding is also likely to be affected by extreme tidal conditions (including projected sea level rise).

A.3.2 Dodges Ferry

Item	Description
Location ID	Item 12 Table 3.4
Location	Blue Lagoon, including Kannah Street
Description of flooding problem	Water levels in the ephemeral Blue Lagoon pond up such that Kannah Street is entirely inundated, leading to flooding of the lower areas of the properties at this location. Maximum on-road flood hazard category of H3, and H2 affecting existing property.
Discussion / recommendations	Recommended that no new structures or development be permitted in this area. A new flood relief culvert draining the lagoon to the north was investigated but this was shown to be ineffective at lowering peak flood levels.

Item	Description
Location ID	Item 13 Table 3.4
Location	Carlton Beach Road west of Bally Park Road
Description of flooding problem	Runoff draining eastwards towards Carlton floods the lower areas (i.e. trapped sag points) adjacent to Carlton Beach Road. Maximum flood hazard category of H3 affecting existing property.
Discussion / recommendations	Flooding in this area occurs in naturally low-lying land adjacent to the road, with limited natural drainage to the east via an overland flow route to the Carlton River. There are no flood management measures that are considered to be viable at this location.

A.3.3 Carlton

Item	Description
Location ID	Item 14 Table 3.5
Location	Carlton Beach Road near Lagoon Road
Description of flooding problem	Runoff draining eastwards from Dodges Ferry and towards Carlton floods the lower areas (where some are trapped sag points) adjacent to Carlton Beach Road and Lagoon Road. Maximum on-road flood hazard category of H2, and H3 affecting existing property.
Discussion / recommendations	Flooding in this area occurs in naturally low-lying land, with limited natural drainage to the east via an overland flow route to the Carlton River. There are no flood management measures that are considered to be viable at this location.

Item	Description
Location ID	Item 14 Table 3.5
Location	Moomere Street
Description of flooding problem	Water flowing eastwards from the ephemeral lagoon at 248 Carlton Beach Road passes through property on both sides of Moomere Street, ultimately draining towards the Carlton River via the open channel running east from Moomere Street. Maximum on-road flood hazard category of H2, and H3 affecting existing property.
Discussion / recommendations	Flooding in this area occurs in naturally low-lying land, with limited natural drainage to the east via an overland flow route to the Carlton River. There are no flood management measures that are considered to be viable at this location.

A.3.4 Connellys Marsh

Item	Description
Location ID	Item 19 Table 3.7
Location	Knights Road and Beach Road area
Description of flooding problem	The low lying area along Knights Road and Beach Road is flooded from a combination of local runoff and water backing up from Connellys Bay via Connellys Creek, where the only free-draining outlet is via Connellys Creek. Maximum flood hazard category of H3 affecting the Knights Road area and H4 affecting the Beach Road area.
Discussion / recommendations	Flooding in this area occurs in naturally low-lying land, with limited natural drainage to the east to Connellys Creek. There are no flood management measures that are considered to be viable at this location. Flooding is also likely to be affected by extreme tidal conditions (including projected sea level rise).

A.3.5 Dunalley

Item	Description
Location ID	Item 22 Table 3.8
Location	139 Arthur Highway
Description of flooding problem	Runoff from catchments on the north-western side of the Arthur Highway ponds on the upstream side of the highway then floods the highway before flowing through to the Denison Canal. Maximum on-road flood hazard category of H1.
Discussion / recommendations	Recommended that Council work with the Department of State Growth to investigate drainage upgrades as part of future highway upgrades with the aim of reducing the flood risk at this location.

Item	Description
Location ID	Item 23 Table 3.8
Location	Arthur Highway at intersection with Imlay Street
Description of flooding problem	Runoff from catchments on the north-western side of the Arthur Highway exceeds the capacity of the existing cross-drainage culvert near the intersection with Imlay Street, resulting in water flowing across the highway and ultimately flowing through to Blackman Bay via East Bay. Maximum on-road flood hazard category of H1.
Discussion / recommendations	Recommended that Council work with the Department of State Growth to investigate drainage upgrades as part of future highway upgrades with the aim of reducing the flood risk at this location.

Item	Description
Location ID	Item 24 Table 3.8
Location	59-69 Arthur Highway
Description of flooding problem	Runoff from catchments on the north-western side of the Arthur Highway exceeds the capacity of the existing cross-drainage culvert, resulting in water flowing across the highway and ultimately flowing through to Blackman Bay. Maximum on-road flood hazard category of H1.
Discussion / recommendations	Recommended that Council work with the Department of State Growth to investigate drainage upgrades as part of future highway upgrades with the aim of reducing the flood risk at this location.

Item	Description
Location ID	Item 25 Table 3.8
Location	47 Arthur Highway
Description of flooding problem	Runoff from catchments on the north-western side of the Arthur Highway exceeds the capacity of the existing cross-drainage culvert, resulting in water flowing across the highway and ultimately flowing through to Blackman Bay. Maximum on-road flood hazard category of H1.
Discussion / recommendations	Recommended that Council work with the Department of State Growth to investigate drainage upgrades as part of future highway upgrades with the aim of reducing the flood risk at this location.

Item	Description
Location ID	Item 26 Table 3.8
Location	Arthur Highway north-east of Dunalley township
Description of flooding problem	Runoff from catchments on the north-western side of the Arthur Highway exceeds the capacity of the existing cross-drainage culverts, resulting in water flowing across the highway and ultimately flowing through to Blackman Bay. Maximum on-road flood hazard category of H1.
Discussion / recommendations	Recommended that Council work with the Department of State Growth to investigate drainage upgrades as part of future highway upgrades with the aim of reducing the flood risk at this location.