City of Port Adelaide Enfield and City of Prospect

Barker Inlet Central Stormwater Management Plan

Progress Report

31 Hauteville Terrace Eastwood SA 5063 | P 08 8172 1088 | www.southfront.com.au

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Southfront

31 Hauteville Terrace Eastwood SA 5063

Phone: 08 8172 1088 Email: enquiry@southfront.com.au

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1 Introduction

This Stormwater Management Plan (SMP) for Barker Inlet Central catchments has been prepared for the City of Port Adelaide Enfield, the City of Prospect and the City of Charles Sturt in accordance with the requirements of the Stormwater Management Planning Guidelines (Stormwater Management Authority, 2007).

The Plan will provide an overview of the existing catchments and issues relating to current stormwater management in the Barker Inlet Central catchments. It also provides an overview of the opportunities to improve stormwater management to both address flood protection and the sustainable management of this resource and the environment.

This Plan has been developed strictly in accordance with the guideline framework whereby productive and sustainable use of stormwater, reduction of pollution impacts and the enhancement of the environment are key principles, in addition to flood minimisation.

The strategies outlined in this Plan are proposed as a means of ensuring that above goals are achieved in an integrated and coordinated manner. This document contains:

- A summary of existing information relevant to management of stormwater in the catchment;
- Catchment specific objectives for management of stormwater runoff from the catchment;
- Potential management strategies that may be used to meet the identified management objectives;
- Estimated costs and benefits associated with each of the strategies; and
- A clear definition of the priorities, responsibilities and timeframe for implementation of the Stormwater Management Plan.

In addition to Council staff, the Plan was prepared in consultation with Department for Environment and Water (staff) and the Stormwater Management Authority, who together form the Project Steering Committee (PSC).

2 Catchment Features

2.1 Study Area

The Study Area for this Stormwater Management Plan consists of three major catchment areas;

- Hindmarsh-Enfield-Prospect (HEP);
- Dunstan Road; and
- North Arm West (NAW).

Together these catchments collect water from as far away as the suburbs of Bowden, Nailsworth, Woodville Gardens, Mansfield Park and Wingfield and ultimately discharge into the Barker Inlet Wetland.

The total catchment area for the Barker Inlet Central catchment is approximately 2300 hectares, spanning across three Council areas; City of Port Adelaide Enfield, City of Prospect and the City of Charles Sturt.

The Study Area and major catchment boundaries are presented in Figure 2-1.

2.2 Topography

The topography of the catchment varies across the Study Area. A surface elevation model across the Study Area was derived from the Digital Terrain Model (DTM) provided by the City of Port Adelaide Enfield. The Study Area can be broadly divided up into three zones; the lower northern and western zone, the Prospect escarpment zone and the south-eastern plateau, as summarised below:

- The lower northern and western zone is relatively flat, grading downhill at less than 1% in a south to north direction from Bowden to the Barker Inlet wetland outlet. As the catchment approaches the outlet into the Barker Inlet wetland the grade becomes very flat and low-lying with an approximate elevation of 2m AHD at the discharge point.
- The Prospect escarpment is a steep zone, located roughly between Churchill Road and Prospect Road (running north-south). Elevations drop from approximately 45m AHD to 15m AHD over a distance of approximately 800 metres in an east to west direction.
- The south-eastern plateau, located roughly east of Prospect Road, is a relatively flat, elevated zone, with surface elevations ranging from 45 to 60 m AHD. The area grades downhill in a south-east to north-west direction at approximately 1%.

The topographic map of the Study Area is presented in Figure 2-2.

2.3 Drainage Infrastructure

2.3.1 Existing Infrastructure

The City of Port Adelaide Enfield, the City of Prospect and the City of Charles Sturt each maintain GIS databases of existing stormwater infrastructure, which have been utilised for a number of tasks within the Plan including model construction and strategy development.

The catchment is primarily drained via underground drainage systems which discharge into the three major open channels; the HEP, Dunstan Road and NAW channels. Figure 2-3 provides an overview of the location and extent of existing stormwater infrastructure within the Study Area. A summary profile of the existing infrastructure is also provided in Table 2-1.

Table 2-1 – Existing Stormwater Infrastructure Summary

Asset Class	Description	Quantity
Pipes	150 mm dia	31 m
	225 mm dia	612 m
	300 mm dia	20,088 m
	375 mm dia	28,235 m
	450 mm dia	15,845 m
	525 mm dia	9,594 m
	600 mm dia	10,940 m
	675 mm dia	6,912 m
	750 mm dia	5,338 m
	825 mm dia	3,780 m
	900 mm dia	5,331 m
	1050 mm dia	3,811 m
	1200 mm dia	2,176 m
	1350 mm dia	1,734 m
	1500 mm dia	2,458 m
	1650 mm dia	2,211 m
	1800 mm dia	1,504 m
	1950 mm dia	1,277 m
Box Culverts	< 1200 mm wide	7,799 m
	=> 1200 mm wide	17,675 m
Nodes	Side-entry pit	3027
	Headwall	73
	Field Gully / Grated Inlet	313
	Junction Box	1,951
Pump Stations	N/A	1
Gross Pollutant Traps	Basket GPT / Trash Rack	13
Soakage Systems	Soakage Pits	2
Detention Basins	N/A	32
Other Basins	Bioretention / Infiltration / Sedimentation	17
Wetlands	N/A	2
Streetscape Raingardens	N/A	11
Vegetated Swale / Channel	N/A	9

2.3.2 Stormwater Asset Age

GIS data from The City of Port Adelaide Enfield and The City of Prospect includes an estimate of the construction date of existing stormwater infrastructure. The age of existing stormwater infrastructure is shown in Figure 2-4.

Very few stormwater drains in the study area were constructed prior to 1950, with the majority having been built between 1970 and 1990. In the suburbs to the west of South Road, including Angle Park, Ferryden Park and Mansfield Park, the vast majority of stormwater drains were constructed after 1990. To the east of South Road, the industrial area stormwater drains were almost all constructed between 1970 and 1990, with a small number of connections built since 1990. In the City of Prospect, most drains were built between 1970 and 1990, however the large drains beneath Churchill Road, Regency Road and Prospect Road are considerably older, having been built between 1950 and 1970.

City of Charles Sturt stormwater infrastructure GIS data did not include information pertaining to asset age.

2.3.3 Previously Known Stormwater Management Issues

City of Port Adelaide Enfield

The City of Port Adelaide Enfield maintains a database of known flooding issues throughout the Council area. Within the Barker Inlet Central Study Area, 73 incidents have been recorded since 2004, ranging from blocked SEPs and kerbside ponding to roadway and property inundation. Many of the recorded incidents were shown to occur adjacent to the large open channels conveying stormwater to the Barker Inlet Wetland, but isolated incidents have also occurred elsewhere in the minor systems. Some key locations shown to experience flooding are summarised below:

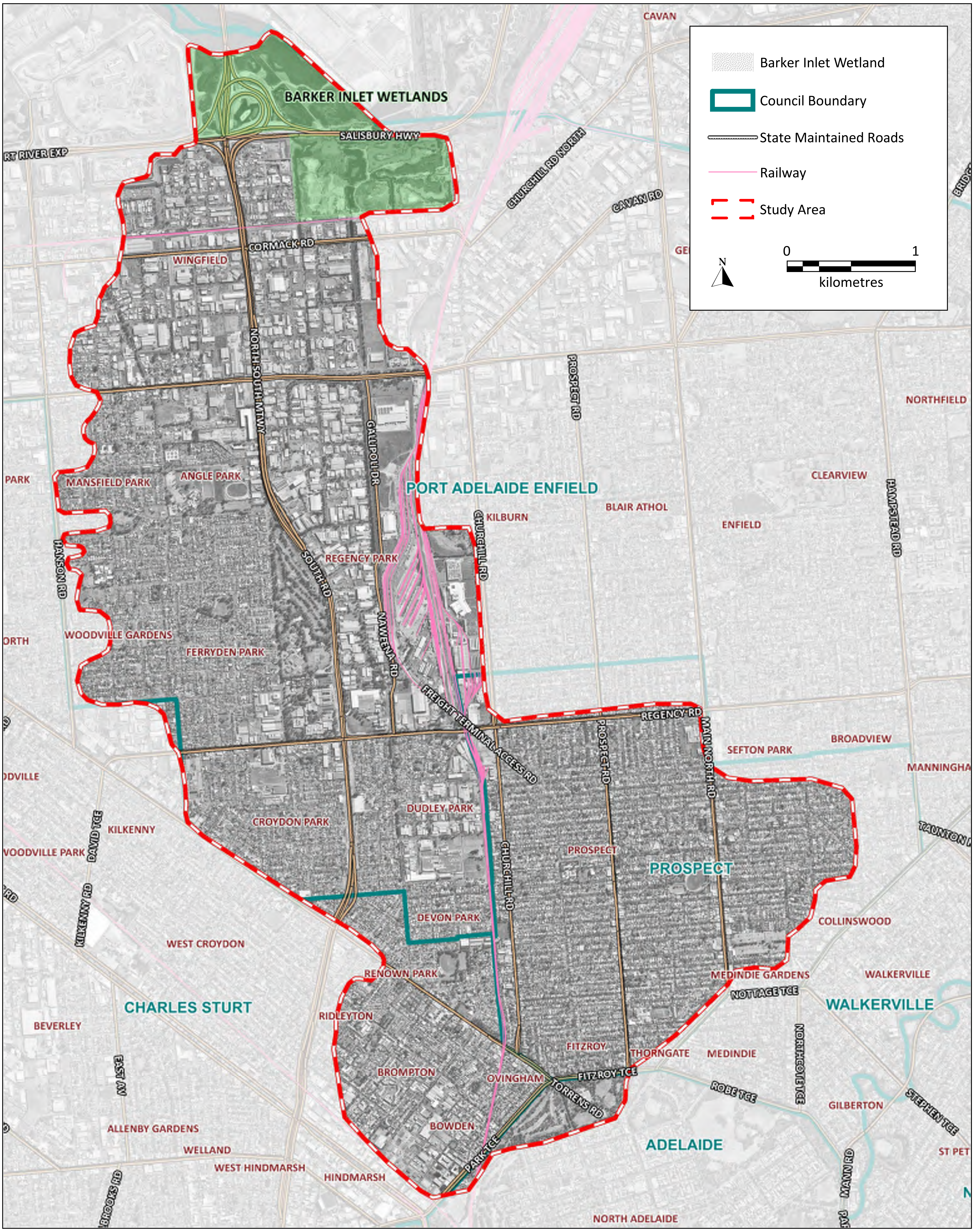
- David Street, Wingfield: Road and property flooding, over 1m
- Chapman Street, Mansfield Park: Excessive surface flows
- Days Road, Croydon Park: Property inundation
- Albion Street, Wingfield: Road flooding
- Staite Street, Wingfield: Road flooding
- Parkard Avenue, Croydon Park: Road flooding
- Durham Terrace, Ferryden Park: Road flooding

City of Prospect

Known flooding problems throughout the City of Prospect have been well documented in previous studies, such as the HEP Initial Urban Stormwater Master Plan (Tonkin Consulting, 2004) and the Princes and Charles Street Network Assessment (Southfront, 2019). These studies identified many properties potentially at risk of flooding for a range of storm events throughout the City of Prospect. The worst affected regions were shown to be at the bottom of the Prospect escarpment, where land quickly transitions from steep slopes to relatively flat. The worst affected areas include:

- Churchill Road, Prospect;
- Charles Street and Princes Street, Prospect;
- Alexandra Street, Prospect;

- Victoria Street, Prospect;
- William Street, Prospect.



Data Sources:
NearMap (Aerial Photograph)
DataSA (Council Boundaries, State Maintained Roads)

Barker Inlet Central
Stormwater Management Plan

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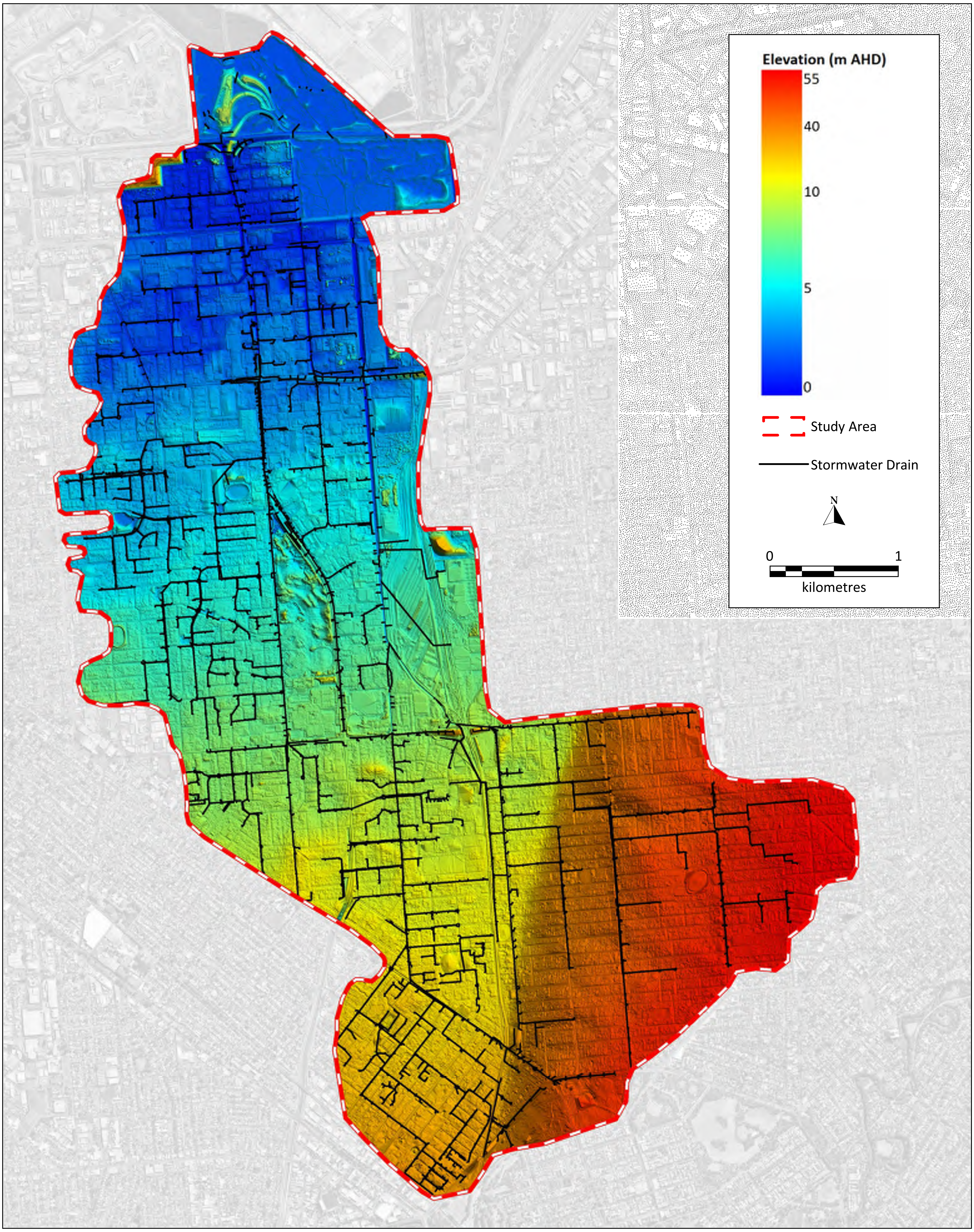
Study Area
Figure 2.1



Data Sources:
City of Port Adelaide Enfield (Drainage Data, DTM)
City of Prospect (Drainage Data)
City of Charles Sturt (Drainage Data, Existing WSUD)

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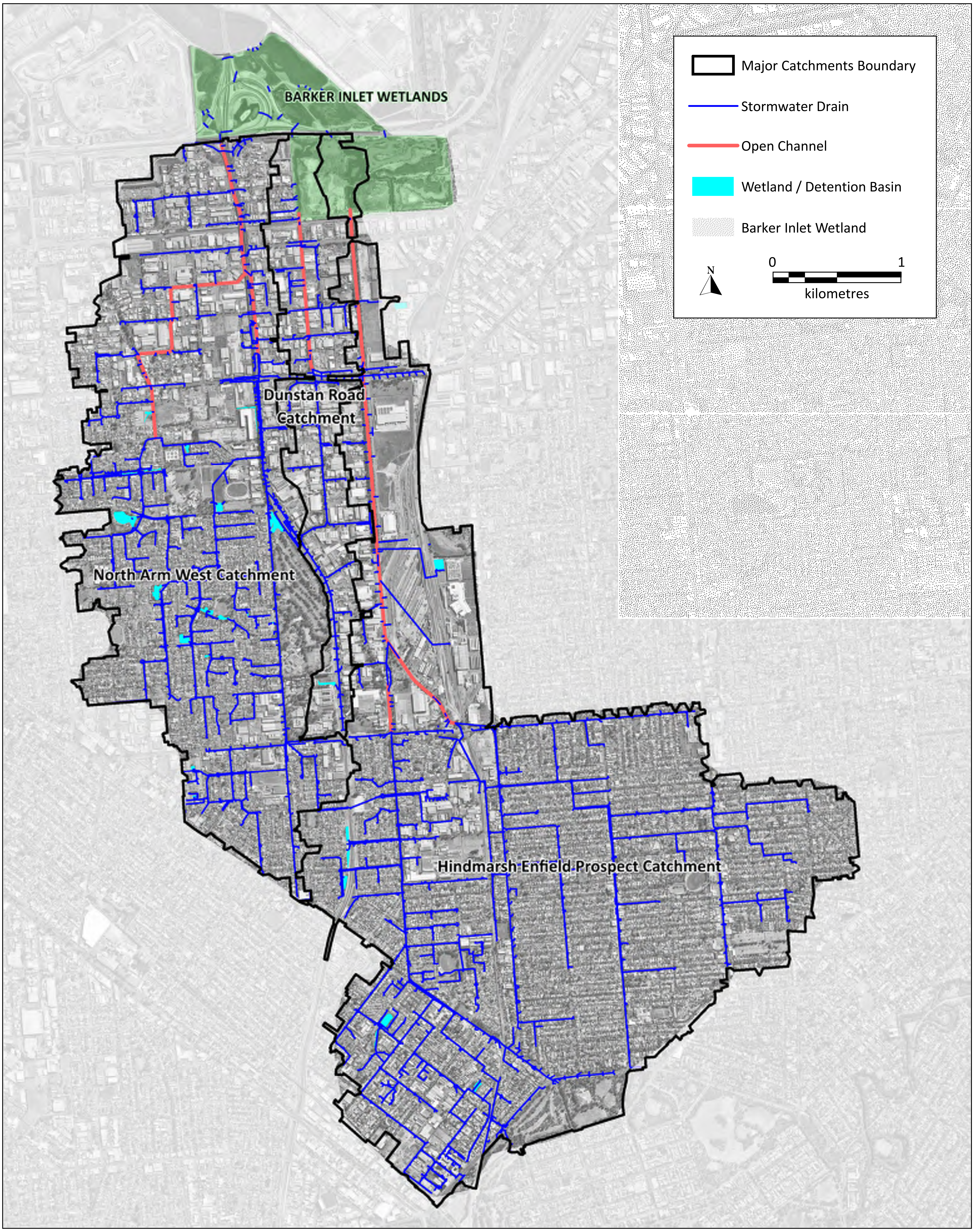
Topography
Figure 2.2



Data Sources:
City of Port Adelaide Enfield (Drainage Data)
City of Prospect (Drainage Data)
City of Charles Sturt (Drainage Data)
NearMap (Aerial Photograph)

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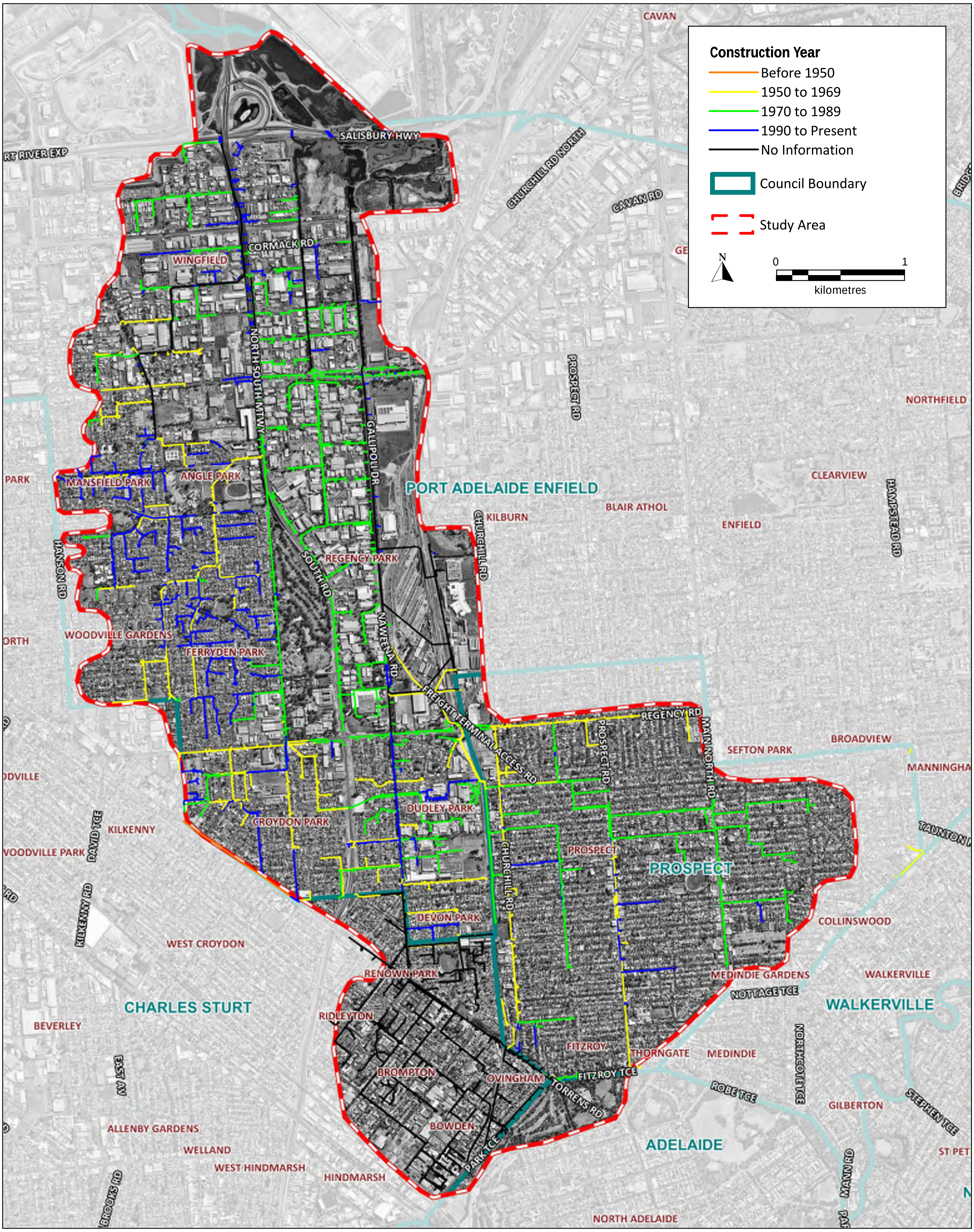
Barker Inlet Central
Stormwater Management Plan

Existing Stormwater Infrastructure & Catchment Plan
Figure 2.3



Data Sources:
NearMap (Aerial Photograph)
DataSA (Council Boundaries, State Maintained Roads)
City of Port Adelaide Enfield, City of Prospect, City of Charles Sturt (Stormwater Pipes, Construction Year)

Barker Inlet Central
Stormwater Management Plan

Stormwater Drain Year of Construction
Figure 2.4

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2.4 Land Subsidence

Land subsidence has been identified as a possibility within the Barker Inlet Wetlands and the surrounding coastal regions in studies dating back to the 1970's. The key factors found to have contributed to historical land subsidence are land reclamation by filling, groundwater withdrawal and land reclamation through wetland draining. It is also possible that long term subsidence of the St Vincent Basin may be a contributing factor, albeit to a lesser extent.

The *Port Adelaide Seawater Stormwater Flooding Study* (Tonkin Consulting, 2005), which assessed data from the *Beach Erosion Assessment Study* (Culver, 1970), adopted a land subsidence rate of 2.1 mm/yr across the Study Area (which includes the downstream portion of the Barker Inlet Central catchment and the Barker Inlet Wetland).

2.5 Barker Inlet Wetland

2.5.1 General Description and Layout

The Barker Inlet Wetland (BIW) is a constructed wetland system, situated at the downstream end of the study area, on either side of the Port River Expressway. The wetlands were constructed in 1994 to address a range of environmental and water quality impacts in the area and also provide habitat for wildlife.

Prior to construction of the wetlands, stormwater discharged directly into North Arm Creek and the Barker Inlet mangrove forest. The wetland was designed to use vegetation, enhanced sedimentation, fine filtration and biological pollutant uptake processes to improve water quality before it is discharged into the North Arm Creek and the Gulf of St Vincent. The total area of the wetlands is 337 hectares.

An SA Water managed aquifer recharge (MAR) scheme was also constructed in 2013 to utilise the improved water quality, however is currently not operating (see Sections 2.5.4 and 2.10.3 for further details).

The wetland is divided into three major zones; the Southern Basin (freshwater zone), the Northern Ephemeral Area (brackish zone) and the Marine Intertidal Basin. A sea wall exists on the northern edge of the wetlands with tidal gates/flood outlets at the eastern end allowing for transfer of water between North Arm Creek (tidally influenced) and the wetlands themselves. The layout of the wetland is shown in Figure 2-5.

Stormwater from the Dunstan Road, HEP and North Arm East (NAE) catchments discharges into the freshwater Southern Basin. The freshwater ponds vary in depth of over 2 metres deep under static conditions. The Northern Ephemeral Area (on the northern side of Port River Expressway) receives water from the NAW catchment and overflows from the Southern Basin.

Flows in the Northern Ephemeral Area flow into the Marine Intertidal Basin through low flow culverts within an intertidal bund between the two zones (with flap gates to prevent seawater passing from north to south). A number of structures control flow through the wetlands. The Northern Ephemeral Area was recently reconstructed as a part of the Northern Connector Road Project, where a large section of wetland was removed in order to accommodate construction of on and off ramps and bridge abutments. The new wetland layout was designed to ensure it achieved the same or improved stormwater quality improvements as the pre-development wetland. The eastern side of the Northern Basin and the Southern Basin remained unchanged as a part of this development (DP-0206 Barker Inlet Wetland - Design Report, Jacob-Arup Joint Venture (JAJV), 2017).

Freshwater/brackish water enters the Marine Intertidal Basin (MIB) from the Northern Ephemeral Area when conditions allow. Seawater enters from the MIB from North Arm Creek through the tidal gates on each high tide. The following section describes the operation of these gates in more detail.

Figure 2-5 – Barker Inlet Wetlands Layout (Post Northern Connector Construction)

2.5.2 Inlet/Outlet Structures and Operations

The operation of the inlet/outlet structures is managed manually to prevent water levels in directly upstream marine intertidal basins exceeding 0.5 m AHD (BIW Hydrology Report, Barrie Ormsby, 2009).

The tidal gates are throttled by penstock gates to limit to amount of water entering the marine intertidal basin from North Arm Creek and prevent seawater overtopping the intertidal bund. The gates are usually set to provide a water level of 0.3 mAHD. This operation was proposed to be continued post completion of the Northern Connector project.

Operation details during storm events are documented in the *Management Plan for the Barker Inlet Wetlands* (City of Salisbury, 1998). The Management Plan states the following on pages 27 and 65:

"during storms, when storm tide surges or king tides may occur, all gates must be closed.

Storm events are often associated with storm and king tides, which may reach up to RL 3.00 AHD, which will prevent drainage of floodwaters through the sea wall. Under these conditions, it is imperative that the penstock gates on the tidal inlet culverts are closed while high tides persist. If they are not closed, tidal inflow combined with storm water inflow may raise water levels in the wetlands above the nominal maximum flood level, which may cause backwater flooding in the inlet drains and adjacent properties.

High tides associated with storm events may occur at any time throughout the year but especially during winter and spring. Generally, during these periods and for tides forecast above 2.5m, the penstock gates on the tidal inlet culverts should be set as follows, two closed and two half open."

The City of Port Adelaide Enfield is responsible for the operation and management of the tidal gates.

The major inlet/outlet culverts through the sea wall are summarised below and shown in Figure 2-6:

- Seawall outlet – 3 x 2700 x 1200 box culverts with penstock tidal gates
- Seawall outlet – 4 x 750 mm RCPs with flap gates (North Arm Creek side) and penstock gates (wetland side)
- Seawall outlet – 6 x 1500 mm RCPs with flap gates (North Arm Creek side) and penstock gates (wetland side)
- Seawall outlet – 3 x 1050 mm RCPs with flap gates (North Arm Creek side) and penstock gates (wetland side)
- Tidal inlet – 2 sets of 2 x 1500 x 600 box culverts with penstock gates

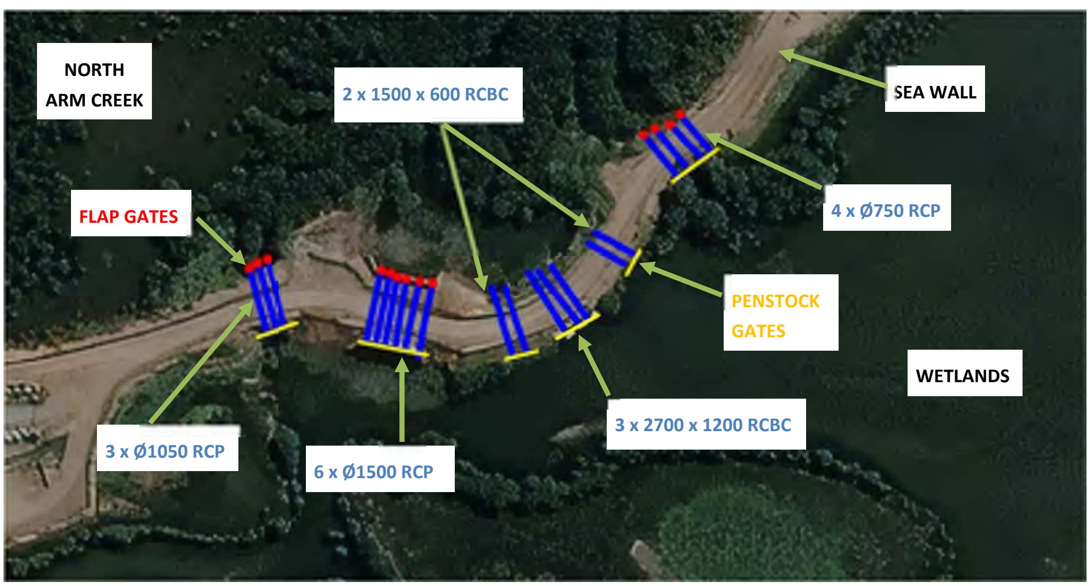


Figure 2-6 – Barker Inlet Wetland Outlet Structure Arrangement with penstock gates (yellow) and flap gates (red)

The structural condition five of the older outlet penstock/flap gates is known to be in poor condition (i.e. all structures except the 6 x 1500 mm diameter RCPs constructed as part of Northern Connector works). This is due to the age of the infrastructure and harsh, saline environment causing the gates to corrode over time. This has compromised the ability of the seawall to prevent excessive seawater ingress into the wetland, particularly during times of high tide. It also has potential to cause sea water ingress into the freshwater zones of the wetland and potentially exacerbate flooding upstream of the wetland during flood events. The compromised sea wall gates will also leave the wetland and upstream catchment vulnerable to climate change induced sea level rise.

As per the Barker Inlet Management Plan (City of Salisbury, 1998), the Barker Inlet Wetlands were carefully constructed to provide habitat for a wide range of plant and animal species in a variety of ecosystems.

Should the tidal gates not be replaced, high tides may regularly lead to seawater infiltrating up through the wetlands and into the freshwater zones of the wetland. The intrusion of seawater on the freshwater environments (and much more frequently into the brackish and intertidal zones) could potentially detrimentally affect the flora and fauna habitats within these portions of the wetland, exacerbated over time with sea level rise.

2.5.3 Environment and Habitat

The wetlands provide habitats to numerous native birds with over 130 different bird species recorded in the area. The wetlands provide habitat for other native fauna such as reptiles, frogs and fish. Additionally, the wetlands protect the downstream mangroves and seagrass habitats by improving the water quality of stormwater inflows.

2.5.4 Managed Aquifer Recharge (MAR) Scheme

A Managed Aquifer Recharge (MAR) system is operated by SA Water from the wetland. The system has a design capacity to harvest, treat, store, and recover 400 ML/annum (Kretschmer, 2017). Urban stormwater runoff enters the Barker Inlet Wetland where it undergoes passive treatment to meet the required water quality criteria prior to injection. The harvested stormwater can then be utilised by industrial, commercial and irrigation customers in the Regency Park area. Further detail on the MAR scheme is provided in Section 2.10.3.

2.5.5 Water Quality Monitoring

Previous monitoring of water quality has been conducted at the wetlands. The most comprehensive program was undertaken from 1995 to 1998, soon after construction. Catchment water quality was monitored at the major inlets to the wetland and the pollution reduction performance was monitored at the intertidal bund outlet to the marine basin and at the outlet of the Southern NAE pond to the Northern Ephemeral Area. It was found that wetland was achieving the design outcome of an efficient system in improving water quality and meeting the improvement targets (DP-0206 Annexure F2 Wetland Water Treatment - Modelling Report, Jacob-Arup Joint Venture (JAJV), 2017).

More recent water quality monitoring has been conducted; however, these programs have not been as comprehensive and have only tested water quality at the wetland outlet to the intertidal basin. Hence, the wetland pollutant load reduction cannot be determined. The data generally indicates that the wetland has maintained its desired performance, but that water quality and pollutant loads have been affected by the recent major construction projects within the catchment (e.g. Northern Connector).

2.5.6 Water Quality Issues

European Carp are known to have infested the wetland are affecting the water quality. The greatest impact is increased in suspended solids/turbidity levels due to the feeding habits of the carp which constantly damage vegetation and resuspend sediments. The carp are removed from the wetlands every two years; however, it is difficult to remove all the smaller specimens. It takes a further two years for the carp population to grow to a size that can cause damage to the system (DP-0206 Annexure F2 Wetland Water Treatment - Modelling Report, Jacob-Arup Joint Venture (JAJV), 2017).

Additionally, recent construction projects such as the Northern Connector and South Road Superway have also resulted in temporary increases of sediments entering the wetlands during their construction phases.

The MAR scheme is currently not running as a result of these water quality issues.

2.5.7 Acid Sulfate Soils

Potential acid sulfate soils (PASS) and Monosulfidic Black Ooze (MBO) may be present within the Barker Inlet Wetalnds area (Thomas et al 2003). Disturbed or excavated PASS or MBO has the potential to generate sulfuric acid when exposed to oxygen, posing a potential environmental or human health hazard. An Acid Sulfate Soils Management Plan (ASSMP) was developed for the Northern Connector project (WSP, 2007) which summarised results from ASS testing along the project alignment. WSP 2017 reported that based on the location of acid sulfate soil sampling and results there is a strong indication of PASS beneath the Barker Inlet Wetland area.

Consideration of local soil conditions is recommended for all new stormwater infrastructure such that it is resilient in consideration of achieving minimum service life requirements. Consideration of local environmental conditions during design (e.g. pipe class and concrete mix design to withstand aggressive soil conditions) is recommended.

2.6 Tidal Interactions

The *Port Adelaide Seawater Stormwater Flooding Study* (Tonkin Consulting, 2005) performed a statistical analysis of daily rainfall and high tide records at the Outer and Inner Harbour gauges, and concluded that there was no reliable correlation between rainfall event probability and storm tide probability (i.e. there is no strong tendency, say, for rainfall to be greater when storm surges occur). However it is possible for high tide events to coincide with rainfall in the catchment, which is an important consideration for the performance of gravity drainage networks.

The possible impacts of sea level rise on the performance of the stormwater drainage network of the Barker Inlet Central catchments has been investigated by the modelling tasks undertaken for this Plan. It should be noted that due to the operational outlet structures at the BIW sea wall, the tide level itself will not impact on the flood levels within the wetland. However the timing and period of the high tide will affect flood levels (i.e. how long the tidal gates are closed and whether high tide coincides with the flood peak entering the wetland).

This Plan has adopted a Design 'Average' Tide Cycle with a peak level of 1.25 mAHD (the Outer Harbour Mean High Water Springs (MHWS) peak level of 0.95 mAHD plus 300mm sea level rise). Sea level rise assumption (300mm to 2050) was confirmed after correspondence with SA Coast Protection Board. Wave set-up and wave run-up were not considered as recommended by the SA Coast Protection Board. For the 2D floodplain modelling, the timing of the tide cycle peak was set to coincide with that of the peak storm inlet for the critical storm duration.

2.7 Rainfall

2.7.1 Statistical Analysis

Average annual rainfall varies across the Barker Inlet Central Study Area with higher annual average rainfall occurring towards the southern end of the Study Area. Towards the southern end of the project area average rainfall is recorded as 537 mm from the nearby North Adelaide rainfall gauge (1883 – 2019, station 23011). At the northern end of the Study Area average annual rainfall is closer to 433 mm which was acquired from the Torrens Island rainfall gauge (1928 – 2013, station 23018).

Table 2-2 below provides a comparison of rainfall gauges within the Study Area and nearby surrounds, highlighting the variability in average annual rainfall across the Study Area (data obtained from Bureau of Meteorology).

Table 2-2 – Rainfall Gauges surrounding the Study Area

Gauge Location	Average Annual Rainfall (mm)	Period
Adelaide (Torrens Island)	433	1928-2012
Adelaide (Dry Creek Saltworks)	429	1960-2010
Dry Creek (Wingfield)	337	2007-2016
Adelaide (Pooraka)	482	1876-2019
Kilburn	409	2006-2019
Regency Park	347	2007-2019

Prospect	493	1932-1971
North Adelaide	537	1884-2019

For modelling purposes, daily rainfall data from the nearby Bureau of Meteorology Adelaide (Pooraka) rainfall gauge (Station 23026), was used as a representation of the rainfall in the area. The annual average rainfall at this station is 482 mm providing a value that better represents the total Barker Inlet Central area.

Statistical analysis of the variation in annual rainfall is also provided by the Bureau of Meteorology, as summarised in Table 2-3 and Figure 2-7, which reports monthly deviations from the annual mean and describes monthly trends.

Table 2-3—Rainfall Data for Barker Inlet Central (Station 23026)

Statistic	Annual (mm)	% Difference to Mean
Mean Rainfall (mm)	481.9	-
Lowest	254.4	-47%
5th %ile	316.1	-34%
10th %ile	347.9	-28%
Median	463.3	-4%
90th %ile	644	+34%
95th %ile	664.4	+38%
Highest	784.8	+63%

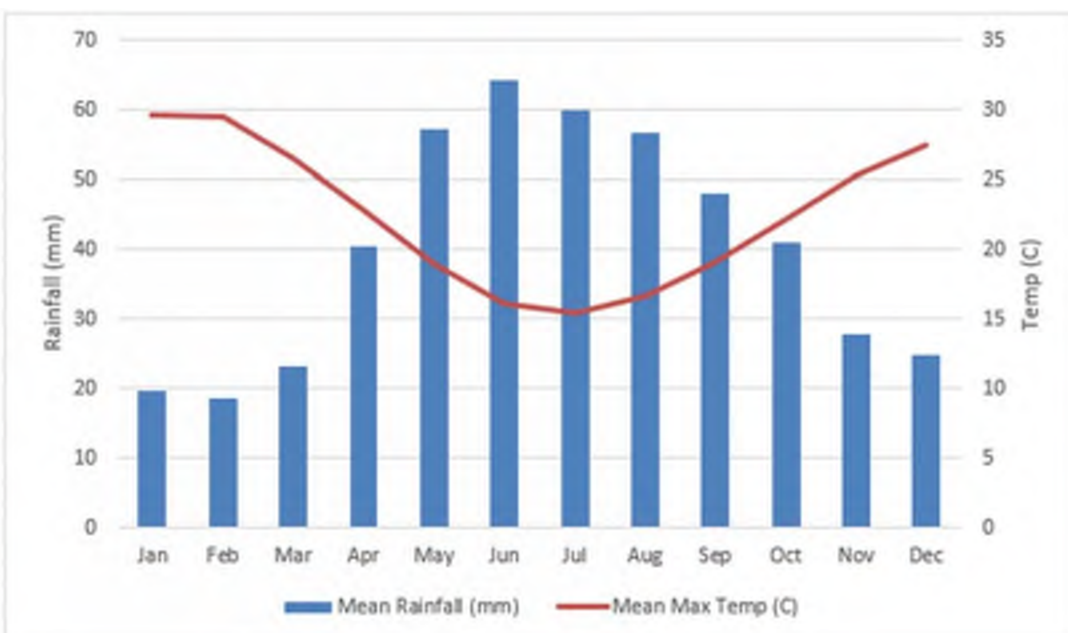


Figure 2-7 – Mean Rainfall and Maximum Temperatures

2.7.2 Design Rainfalls

Design rainfall Intensity-Frequency-Duration (IFD) data has been prepared for the Barker Inlet Central region utilising the ARR 2019 online procedure provided by the Bureau of Meteorology. This data is presented in Table 2-4 for Frequent to Infrequent rainfall intensities.

Table 2-4 – IFD Design Rainfall Intensities (mm/hr); Frequent and Infrequent Storm Events

Duration	Annual Exceedance Probability (AEP)						
	63.2%	50%	20%	10%	5%	2%	1%
1 min	75	86.3	125	155	187	235	275
2 min	66.2	75.9	110	136	164	207	243
3 min	58.9	67.6	97.9	121	146	184	216
4 min	53.3	61.2	88.6	110	133	167	195
5 min	48.8	56.1	81.3	101	122	152	179
10 min	35.3	40.7	59.1	73.2	88.4	111	130
15 min	28.4	32.7	47.6	59	71.2	89.2	104
30 min	19	21.8	31.7	39.2	47.4	59.4	69.7
1 hour	12.3	14.1	20.4	25.2	30.5	38.3	44.9
2 hour	7.81	8.94	12.9	15.9	19.2	24	28.2
3 hour	5.97	6.82	9.78	12.1	14.5	18.1	21.2
6 hour	3.74	4.26	6.06	7.43	8.9	11	12.8
12 hour	2.32	2.63	3.7	4.51	5.36	6.55	7.54
24 hour	1.41	1.59	2.21	2.67	3.15	3.79	4.31
48 hour	0.842	0.945	1.29	1.54	1.79	2.12	2.38
72 hour	0.617	0.689	0.925	1.09	1.27	1.49	1.66

2.7.3 Impact of Climate Change

Climate change leads to changes in the frequency, intensity, spatial extent, duration and timing of extreme weather and climate events. Within a stormwater management context, potential future changes in rainfall patterns are of particular interest, as these result in changes to levels of flood protection, stormwater drainage performance and the availability of stormwater for harvesting and reuse.

Australian Rainfall and Runoff – Book 1 (2019) provides an approach for addressing the risks posed by climate change in projects and decisions that involve estimation of design flood characteristics. It draws on the most recent climate science, particularly the release of the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (IPCC, 2013) as well as the new climate change projections for Australia (CSIRO and Bureau of Meteorology, 2015).

The procedure relies on the Climate Futures web tool developed by the CSIRO where projected changes from Global Climate Models (GCMs) can be explored for fourteen 20-year periods based on four Representative Concentration Pathways (RCPs) for greenhouse gas and aerosol concentrations that were used to drive the GCMs. The pathways are provided by regional Natural Resource Management (NRM) clusters (divided into 11 regions nationally), with the Barker Inlet Central catchment falling within the Southern and South Western Flatlands (East) region.

ARR 2019 recommends the use of RCPs 4.5 and 8.5 (low and high concentration pathways, respectively) for rainfall intensity impact assessment. Further details can be found at the Australian Climate Futures website (https://www.climatechangeinaustralia.gov.au).

For this study, the assumed climate future outlook taken was predictions up to the year 2050. Using the web tool, Table 2-5 indicates the IPCC GCM consensus for rising temperatures as a result of rising greenhouse emissions for high and low scenarios for the region.

Table 2-5 – Global Climate Model Consensus

RCP Scenario	GCM Consensus	Projected Annual Mean Surface Temperature Change (^{o}C)
4.5	Warmer (45 of 46)	+ 0.5 to + 1.5
8.5	Warmer (27 of 48), Hotter (21 of 48)	+ 0.5 to + 1.5 + 1.5 to + 3.0

ARR 2019 recommends using the temperature midpoint of the projected annual mean surface temperature change in order to calculate changes to the projected rainfall intensity using the following equation:

$$I_p = I_{ARR} \times 1.05^{T_m}$$

Where I_p is the projected rainfall intensity, I_{ARR} is the design rainfall intensity for current climate conditions, 1.05 is the assumed temperature scaling based on the approximately exponential relationship between temperature and humidity, and T_m is the temperature at the midpoint of the selected class interval.

As the models could not come to a consensus for both RCP scenarios, the temperature midpoint of the wider interval +0.5 to +3.0 ^{o}C (1.75 ^{o}C) was used. Therefore, $I_p = I_{ARR} \times 1.09$ (i.e. a 9% intensity increase for 2050). The Intensity-Frequency-Duration data for Frequent and Infrequent storms is shown in Table 2-6 with this climate change factor applied. The modelling of future and proposed drainage infrastructure will utilise these rainfall intensities.

Table 2-6 – IFD Design Rainfall Intensities (mm/hr) with Climate Change Factor (2050)

Duration	Annual Exceedance Probability (AEP)						
	63.2%	**50%**	**20%**	**10%**	**5%**	**2%**	**1%**
1 min	81.8	94.1	136	169	204	256	300
2 min	72.2	82.7	120	148	179	226	265
3 min	64.2	73.7	107	132	159	201	235
4 min	58.1	66.7	96.6	120	145	182	213
5 min	53.2	61.1	88.6	110	133	166	195

10 min	38.5	44.4	64.4	79.8	96.4	121	142
15 min	31.0	35.6	51.9	64.3	77.6	97.2	113
30 min	20.7	23.8	34.6	42.7	51.7	64.7	76.0
1 hour	13.4	15.4	22.2	27.5	33.2	41.7	48.9
2 hour	8.51	9.7	14.1	17.3	20.9	26.2	30.7
3 hour	6.51	7.43	10.7	13.2	15.8	19.7	23.1
6 hour	4.08	4.64	6.61	8.10	9.7	12.0	14.0
12 hour	2.53	2.87	4.03	4.92	5.84	7.14	8.22
24 hour	1.54	1.73	2.41	2.91	3.43	4.13	4.70
48 hour	0.92	1.03	1.41	1.68	1.95	2.31	2.59
72 hour	0.67	0.75	1.01	1.19	1.38	1.62	1.81

The Climate Futures web tool also showed that 38 of 68 GCMs suggest annual rainfall will decrease within the Southern and South Western Flatlands NRM Cluster. GCM consensus results for RCP scenarios 4.5 and 8.5 are shown in Table 2-7.

Table 2-7 – GCM Predicted Changes to Annual Rainfall (2050)

RCP Scenario	GCM Consensus Rainfall	Projected Annual Rainfall Change (%)
4.5	Drier (29 of 68) Little Change (28 of 68)	-15 to -5 -5 to 5
8.5	Drier (25 of 70) Little Change (27 of 70)	-15 to -5 -5 to 5

As can be seen, GCM consensus for both RCP scenarios indicates annual rainfall becoming 'drier' or having 'Little Change' by the year 2050. Taking the midpoint of the wider range (-15% to +5%), an average annual rainfall reduction of 5% by 2050 is predicted. In the context of the stormwater harvest yield and water quality modelling for this SMP, it is proposed to modify the existing rainfall record for the Barker Inlet Central study area (or data from a suitable nearby gauge) with a 5% reduction to the mean annual rainfall.

2.8 Existing Land Use and Zoning

The existing land usage across the Barker Inlet Central study area has been sourced from the Valuer General's Generalized Land Use dataset (April 2019). This GIS layer is based on actual land use rather than zoning, and for the study area can be broken down as follows:

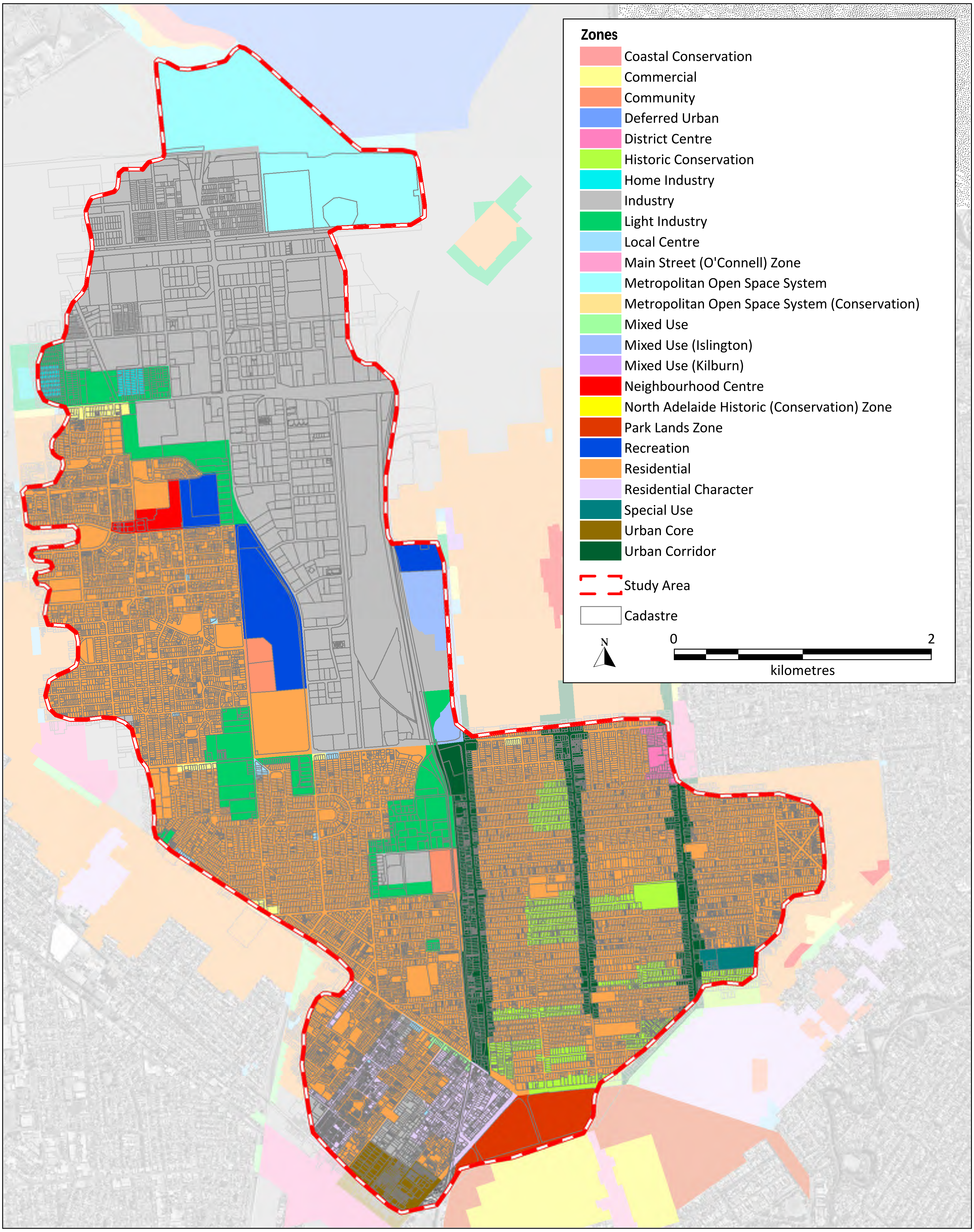
- 826 ha of Residential, 79 ha of Vacant Residential and 19 ha of Non Private Residential;
- 373 ha of Utility/Industry, 22 ha of Food Industry and 0.2 ha of Mine Quarry;
- 243 ha of Commercial and 83 ha of Retail Commercial;
- 50 ha of Education and 53 ha of Public Institution;
- 57 ha of Recreation and 40 ha of Golf;

- 30 ha of Reserve; and
- 146 ha of Vacant.

The diversity of land use is also reflected in the land development categorization, as summarised below:

- Residential Zone covering 1123 ha (46% of the Study Area);
- Industrial Zone covering 794 ha (32% of the Study Area);
- Commercial Zone covering 170 ha (7% of the Study Area);
- Open Space Zone covering 153 ha (6% of the Study Area);
- Recreation Zone covering 96 ha (4% of the Study Area);
- Heritage Zone covering 76 ha (3% of the Study Area);
- Miscellaneous Zone covering 30 ha (1% of the Study Area);
- Community Facilities Zone covering 16 ha (1% of the Study Area); and
- Deferred Urban Zone covering 0.2 ha (0.01% of the Study Area).

Figure 2-8 summarises the spatial extent of the land use zoning within the Barker Inlet Central Study Area.



Data Sources:
NearMap (Aerial Photograph)
DataSA (Land Use Zones)

Barker Inlet Central
Stormwater Management Plan

Land Use Zoning
Figure 2.8

southfront

2.9 Land Development Potential

InfraPlan have undertaken an assessment of the development potential for the Study Area to identify relevant and anticipated development trends. The assessment has assisted in spatially identifying potential increases to impervious areas. InfraPlan has applied several assessment approaches to represent development potential, and the likely outcomes from development over a 30-year timeframe.

The basis of the assessment included the strategies, policies and targets outlined in documents such as the 30-year Plan for Greater Adelaide, the Integrated Transport and Land Use Plan, the Planning, Development and Infrastructure Act (2016), the Residential Development Code and Council's Development Plan.

Infraplan have produced an indicative spatial distribution of redevelopment parcels across the residential areas, and this spatial analysis has formed the basis for the calculation of catchment-specific impervious fractions to be adopted for the hydrological modelling of the future development scenario of the residential areas.

Parcels in the Regional Centre, Commercial and Industrial Zones were not included in this analysis as generally these types of development will not further increase impermeable areas due to the nature and scale of existing land uses.

2.10 Groundwater Assessment

Wallbridge Gilbert Aztec (WGA) have undertaken a hydrogeological assessment to evaluate the soil and groundwater conditions, groundwater use, historical and seasonal groundwater levels and provide insight into the performance of the Barker Inlet Managed Aquifer Recharges (MAR) scheme operated by SA Water the capacity for the scheme to play a role in mitigating flooding events. A summary of the key findings is presented in this section, and a full report is included in Appendix A.

2.10.1 Local Hydrogeology

Shallow groundwater within the project area consists of perched discontinuous aquifers within the Pooraka and St Kilda Formations. Groundwater is usually intersected in drillholes at depths between 3-10m below ground level. Salinity levels of shallow groundwater is reported as having an average 6,597mg/L and a yield of 0.92 L/s. Groundwater within the study area is generally used for domestic purposes. Most grasses experience damages at salinity levels greater than 2,000 mg/L.

It is likely that groundwater recharge is occurring through the open unlined stormwater channels, though limited residence time in unlined channels may be a restriction to recharge capacity. It is estimated that the permeability of the Pooraka Formation is approximately 8.1x10-3 m/day.

The recharge rates are estimated from 0.8 % (Goyder, 2015) to 5 % of rainfall (Georgiou et al, 2011) which equates to between 3.3 mm/yr and 20.9 mm/yr within the Study Area. This large range of uncertainty could be reduced through a program of data collection and analysis.

Groundwater in the study area flows in a north-westerly direction. Outflow from the Q1 aquifer to the ocean is small, as the potentiometric surface gradient at the coast is flat and the transmissivity is relatively low.

Ninety-nine shallow groundwater wells are operating within the Study Area. The use of this groundwater is restricted to small-scale stock and domestic use in areas of low salinity. No large scale extraction exists in the area due to low yield, moderate salinity and low sustainability at high extraction rates.

Contaminants within the soil that may interact with shallow groundwater include: nutrients (arsenic, barium, beryllium, chromium, cobalt, copper, cyanide, iron, lead, manganese, molybdenum, nickel, selenium and zinc), hydrocarbons, solvents, garden waste, bacteria, pesticides and sediment.

2.10.2 Knowledge Gaps

Knowledge gaps have been determined in regards to shallow groundwater interaction with unlined stormwater drains. This restricts the ability to accurately predict the amount of water being lost or gained in reaches along the drainage channels. Given the discontinuous lateral extent of shallow Quaternary aquifers, further investigation could result in a change in the interpretation of the shallow groundwater, effects of stormwater runoff and subsequent flood modelling. It is suggested that a series of shallow monitoring wells within proximity of the unlined stormwater drains would allow monitoring aquifer parameters/baseflow and assessment of risks associated with shallow groundwater into the future.

2.10.3 Barker Inlet Wetlands MAR Scheme

The Barker Inlet Managed Aquifer Recharge system is located in Wingfield and was constructed as a response to the millennium drought. The system has the capacity to harvest, treat, store, and recover 400 ML/annum and is managed and operated by SA Water. Stormwater enters the Barker Inlet Wetland where it undergoes passive treatment enabling it to then be injected into the aquifer.

Water quality issues and below average rainfall have hindered the operation of the MAR system and it has not achieved the design harvest volumes. The presence of European carp in the wetlands increases the turbidity of the water which results in the water being out of specification for recharge.

In addition to the water quality issues, serious vandalism has also occurred resulting to power interruptions to the system. The estimated cost of repair and reinstating operations is over $100,000. Due to the various complications that have arisen with the scheme, it is not currently a priority for SA Water.

3 Stormwater Management Plan Objectives

3.1 Stormwater Management Authority Guidelines

The development of a catchment-based Stormwater Management Plan requires the identification of specific objectives that are relevant to the local context, and measurable. The *Stormwater Management Planning Guidelines* (Stormwater Management Authority, 2007) stipulate that:

"As a minimum, objectives are to set goals for:

- *An acceptable level of protection of the community and both private and public assets from flooding;*
- *Management of the quality of runoff and effect on the receiving waters, both terrestrial and marine where relevant;*
- *Extent of beneficial use of stormwater runoff;*
- *Desirable end-state values for watercourses and riparian ecosystems;*
- *Desirable planning outcomes associated with new development, open space, recreation and amenity;*
- *Sustainable management of stormwater infrastructure, including maintenance."*

3.2 State Government WSUD Objectives

A number of documents have been published which have attempted to define desirable catchment-wide stormwater management performance measures, in relation to water quality improvements to manage marine impacts (CSIRO, 2007), and to mandate Water Sensitive Urban Design principles in new development (Department for Water, 2012).

The document titled *WSUD – Creating more liveable & water sensitive cities in South Australia* (DEWNR, 2013) outlines the following water pollutant reduction targets:

- Suspended solids 80%;
- Phosphorous 60%;
- Nitrogen 45%; and
- Gross Pollutants 90%.

These targets have been selected as a basis for water quality improvement objectives for this Stormwater Management Plan.

3.3 AMLR NRM Board Plan

The *Adelaide and Mount Lofty Ranges Natural Resources Management (AMLR NRM) Plan 2014-15 to 2023-24* (Adelaide and Mount Lofty Ranges Natural Resources Management Board, 2013) was developed in partnership with the community and key stakeholders. At the time of the commencement of this SMP, this document was still relevant and applicable to this SMP, however the NRM Act 2004 has since been repealed and replaced by the Landscape SA Act 2019, which resulted in the creation of the Green Adelaide Board in July 2020.

The NRM plan provided leadership, encouraged community action and fostered valuable partnerships for better managing the region's natural resources. The plan included long-term goals and targets for the condition of natural resources in the region. The Board's investment priorities were defined over a three-year period and delivered through a range of strategic actions.

The Plan set out a 10-year strategic plan for the region that was consistent with the vision of the State NRM Plan. The Strategic Plan was supported by a *Business and Operational Plan 2016-17 to 2018-19* (Adelaide and Mount Lofty Ranges Natural Resources Management Board, 2016b) which outlined how the Board will invest the money that it raises through levies and other funding sources.

The plan referred to 20-year Regional Targets that were developed in 2008 to support the vision and goals expressed in the previous iteration of the NRM Plan. Those targets relevant to stormwater management in the Port River East Study Area are shown in Table 3-1.

Table 3-1—AMLR NRM 20 Year Regional Targets extract

Target	Explanation	Indicator
T1 - The region will have system capacity to harvest up to 35GL of stormwater	Projects such as stormwater wetlands and harvesting systems are being developed in the Region and the stormwater target is intended to be ambitious reflecting community desires.	Volume of stormwater generated and used; Volume of stormwater discharged to coast or marine environment.
T2 - Aquatic ecosystems and groundwater condition is maintained or improved	"Defined environmental values" refers to the process for stakeholder agreement to a set of environmental values and water quality objectives under the Environment Protection (Water Quality) Policy. Long-term monitoring of water quality is vital to protecting environmental values. Of course, it is not possible to monitor everything so key water quality parameters will be monitored across the Region.	Exceedance of specified water quality parameters (e.g. turbidity, nutrients, salinity, pH).
T3 - All water resources used within sustainable yield (allowing for variability)	This target is about ensuring that the long term use of water in the Region is sustainable, that is that the use of water for a range of purposes does not have an unacceptable impact on the environment. This target includes "allowing for variability" in recognition of future changes to water supply as a result of climate change impacts.	Volume of water allocated and used; Groundwater level; Surface water flow; Water required for the environment compared to water provided for the environment.
T7 - Condition and function of ecosystems (terrestrial, riparian) recovered from current levels	Although some native vegetation remains in the Region, it is not fully functional, because of degradation due to edge effects, fragmentation, weed invasion, grazing and inappropriate fire regimes. This means it does not provide the	Condition of native vegetation (terrestrial, riparian, water dependent ecosystems).

Target	Explanation	Indicator
	appropriate ecosystem services and habitat it might once have done. This target is about ensuring that the condition, structure and function of our remnant vegetation is improved.	
T8 - Extent of functional ecosystems (coastal, estuarine, terrestrial, riparian) increased to 30% of the Region (excluding urban areas)	For the Region to retain ecosystem function and to prevent further decline of native species, largescale restoration of native ecosystems is required. Restored ecosystems need to be carefully planned and designed (according to restoration priorities) so that they will provide equivalent structure, function and habitat features to that which would have occurred in the local area.	Distribution of native vegetation; Area of native vegetation.
T10 - Land based impacts on coastal, estuarine and marine processes reduced from current levels	The Adelaide Coastal Waters Study identified turbidity, from high levels of suspended solids related to stormwater and wastewater, as a contributing factor to seagrass loss and a major cause of poor recreational water quality. ACWS technical reports have established some relevant current baselines for evaluation of targets.	Catchment sediment load; Stormwater discharged to coast or marine systems.
T12 – All coast, estuarine and marine water resources meet water quality guidelines to protect defined environmental values		

3.4 Council Strategic Objectives

3.4.1 City of Port Adelaide Enfield

The goal of the City of Port Adelaide's Asset Management strategy is to provide a financially sustainable level of service at an acceptable level of risk, within Statutory and Legislative requirements, to present and future customers. The *Stormwater Asset Management Plan* (City of Port Adelaide Enfield, 2016) aims to ensure that Council's stormwater assets are equitably distributed and that infrastructure is provided and maintained in a fit for purpose condition.

The plan articulates technical standards for the performance of the drainage systems, notably:

- New or upgraded "Minor" (underground) drainage systems:
  - Gutter flow width for 0.2 EY (5 year ARI) storms to be no greater than 2.5m;
  - Gutter flow width at pedestrian crossings for 0.2 EY storms to be no greater than 1m;
  - Hydraulic grade line (HGL) for 0.2 EY storms to be minimum 150 mm below gutter level;
- "Major" (overland) drainage systems:

- No above flood inundation of properties for all events up to and including the 1% AEP (100 year ARI) storm;
- New developments to achieve 200 mm freeboard to the 1% AEP flood level.

City Plan 2030 articulates the City of Port Adelaide Enfield's vision for the year 2030 and provide clear directions to guide Council, the community and stakeholders towards achieving that vision. Council has set out preliminary strategic goals, objectives and priorities under the themes of Economy, Community, Environment, Place Making and Leadership.

Under the theme of Environment, City Plan 2030 includes the following:

Strategies:

- *Manage energy, water and waste resources sustainably*
- *Protect and restore our rivers, coast, water dependent and estuarine environments*
- *Empower community led approaches to environmental and climate change learning and action*
- *Plan for and manage the impacts of natural hazards and disasters*

Priorities:

- *Deliver the AdaptWest climate change adaptation priorities*
- *Invest a minimum $10M annually in stormwater infrastructure to assist in reducing the flood impact to our City*
- *Ensure our procurement practices support energy, water and waste efficiency outcomes*
- *Collaborate to improve the management of the Port River, Torrens River and the city's wetlands as healthy living ecosystems*
- *Develop a strategic approach to coastal adaptation, protection and management*
- *Provide opportunities for our community to become informed and learn about climate change and its impact*

3.5 City of Prospect

The City of Prospect *'Strategic Plan to 2020'* notes the following strategies and outcomes under the themes of People, Place and Environment:

- *Strategy 1.2: Environmentally active, sustainably focused*
  - *1.2.1: Community learning focused on environmental impacts and issues*

- *Strategy 2.4: A Greener Future*
  - *2.4.2: A City recognised for its flora, fauna and biodiversity*
  - *2.4.3: Committed to having a reduced environmental footprint*
  - *2.4.4: 'Green' strategies are established within development activities across the City*

The City of Prospect *'Open Space Strategy'* notes the following goals of public open space within the Council area:

Enable Biodiversity

- *Protect local and rare species and their habitats;*
- *Create stepping stones (e.g. large parks, pocketparks etc.) or corridors (e.g. linear parks) for local species migration/movements;*
- *Connect people with nature;*
- *Conserve an ecosystem balance.*

Environmental Benefits and Reducing Impacts of Climate Change:

- *Contribute to urban heat abatement;*
- *Trees, plants, grass and other porous surfaces found in green space contribute to improved stormwater management;*
- *Educating people on the environment.*

3.6 City of Charles Sturt

The City of Charles Sturt *'Water Infrastructure Asset Management Plan'* notes the following guidelines for stormwater management in the Council area:

- Stormwater runoff is contained in the underground system for rain events up to 1:5 year ARI (Average recurrence interval) rain event where possible. Stormwater runoff is contained within the road reserve for rain events up to 1:100 year ARI rain event where possible. This may not be practical to achieve at every location across the city due to the City being in the Adelaide flood plains. It is recognised major upgrades need to occur in many stormwater catchments. However, any increase in Community Level of Service will result in a significant rates increase.
- Implement sustainable stormwater management practices
  - Pursue **reuse of stormwater** to reduce reliance on potable water and ground water
  - Plan and manage stormwater assets to **reduce flood risk** and increase **resilience to climate change**
  - Continue to undertake a regulatory role in the education and enforcement of **stormwater pollution prevention**
  - Work with developers to plan and implement sustainable **Water Sensitive Urban Design (WSUD)**

3.7 Other Policy Documents

The following policy documents have also been used to guide the development of objectives for the Barker Inlet Central Stormwater Management Plan.

3.7.1 Coastal Waters

The *Adelaide Coastal Water Quality Improvement Plan* (EPA, 2013) provides a long-term strategy to achieve and sustain water quality improvement for Adelaide's coastal waters, and also highlights overlapping strategies relevant to the Barker Inlet Central Study Area including:

- *Adelaide Dolphin Sanctuary Management Plan* (DEH, 2008), which is a statutory plan under the Adelaide Dolphin Sanctuary Management Act 2005; and
- *Port Waterways Water Quality Improvement Plan* (EPA, 2008), which details targets to protect environmental values for water quality improvement, primarily with respect to nutrients in the Port waterways.

These plans share a common goal to improve water quality to a level that sustains the ecological processes, environmental values and productive capacity of the Port River estuary and Barker Inlet.

The *Port Waterways Water Quality Improvement Plan* (Environment Protection Authority, 2008) focussed primarily on the monitoring and management of the two main point sources for nutrient discharge into the Port Waterways; the Penrice Soda Products site and the Bolivar Wastewater Treatment Plant; both of which are excluded from the Study Area.

However the strategic intent of the Plan is consistent with the State Government WSUD objectives and AMLR NRM Board Plan with respect to water quality improvement and runoff volume reduction targets, stating that:

- "As the major point source loadings reduce, the focus of a revised WQIP is likely to shift towards the effect that other sources of nutrients have on the waterways"; and
- "The trend in catchment management to hold and reuse flows from catchments is advantageous to the waterways and encouraged from the perspective of the WQIP".

The *Coast Protection Board Strategic Plan 2012-2017* outlines the following strategic priorities:

- Adaptation of existing development to coastal hazards and the impacts of climate change.
- Ensure new development is not at risk from current and future hazards.
- Plan for resilience in coastal ecosystems to adapt to the impacts of climate change.

3.7.2 Climate Change

The following climate change documents have also been reviewed to inform the objectives for the SMP, noting that the specific assumptions for predicted changes to rainfall patterns and sea level rise that will be incorporated into the hydrological/hydraulic modelling of the future scenario are also presented in this report for approval by the Project Steering Committee:

- *Australian Climate Futures – Climate Futures Tool* (CSIRO, 2017);
- *Australian Rainfall and Runoff – Book 1, Chapter 6* (Geoscience Australia, 2019);
- *Western Adelaide Region Climate Change Adaptation Plan – Phase 1 Report* (Tonkin Consulting, 2015);
- *AdaptWest Research Paper – Assets, Infrastructure and Economy* (URPS, 2014);
- *Resilient East: Climate Ready Eastern Adelaide – URPS (2016);* and
- *Guidelines for Undertaking a Climate Change Adaptation Plan and Undertaking an Integrated Climate Change Vulnerability* (Local Government Association, 2012).

3.8 SMP Objectives

The consolidated objectives adopted to guide the development of this Stormwater Management Plan are summarised in Table 3-2 below.

Table 3-2—Barker Inlet Central SMP Objectives

No.	Goal	Objective
O1	Provide an acceptable level of flood protection to the community	Aspire to achieve no above floor inundation of properties for all events up to and including the 1% AEP (100 year ARI) storm. Where this is not practically achievable, a 5% AEP (20 year ARI) standard shall be sought. New developments to achieve a minimum 200mm freeboard to the 1% AEP flood level.
O2	Provide an acceptable level of performance in the minor (underground) drainage system and pits	Aspire to achieve minimum service standards for new or upgraded drainage systems as follows: ➤ Gutter flow width for 0.2 EY (5 year ARI) storms to be no greater than 2.5 m ➤ Gutter flow width at pedestrian crossings for 0.2 EY storms to be no greater than 1 m ➤ Hydraulic grade line (HGL) for 0.2 EY storms to be minimum 150 mm below gutter level
O3	Improve the quality of runoff and reduce the impact of stormwater on receiving waters	Reduce pollutant loads discharged from the catchment by the following averages: ➤ Suspended solids 80% ➤ Phosphorous 60% ➤ Nitrogen 45% ➤ Gross Pollutants 90% Integrate water quality improvement goals into Council development requirements.
O4	Make beneficial use of stormwater runoff	Identify precinct-level opportunities for beneficial reuse of stormwater. Encourage landowners to implement allotment-level opportunities for the retention and reuse of stormwater.
O5	Provide conditions which would allow desirable (improved) end-state values for receiving waterways to be achieved	Support ongoing strategies seeking to restore and sustain the ecological processes, environmental values and productive capacity of the Barker Inlet by minimising the urban runoff volume and nutrient loads discharged to the Barker Inlet Wetlands.
O6	Sustainable management of stormwater infrastructure, including maintenance	Stormwater infrastructure will be resilient in consideration of the likely impacts of climate change.

No.	Goal	Objective
		Durability criteria of new stormwater infrastructure to achieve minimum service life requirements with consideration of local environmental conditions (e.g. pipe class and concrete mix design to withstand aggressive soil conditions). Ensure appropriate monitoring and management plans are in place to maintain infrastructure and public safety.
O7	Desirable planning outcomes associated with new development and management of open space, recreation and amenity	Ensure new development complies with customised stormwater management development requirements, designed to achieve outcomes that are complimentary to the SMP objectives and goals. Including maximising the use of open space for stormwater/rainfall infiltration WSUD and/or stormwater reuse.
O8	Effective communication and consultation with catchment stakeholders, businesses and community members	Effectively engage with the community on stormwater management issues and proposed strategies including WSUD and stormwater reuse opportunities where possible. Raise awareness to enable businesses and the community to respond efficiently to extreme weather, tide and flood warnings. Identify opportunities for partnerships with the community and agencies in the development and implementation of strategies. Achieve increased alignment between the goals of the SMP and the activities of stakeholders and community volunteers.
O9	Multi-objective outcomes for stormwater management projects involving open space	Maintain the existing use of open space and provide new opportunities for public access and recreation where it is safe and practical to do so. Provide opportunities for sustainable landscaping, increased biodiversity, stormwater treatment and passive reuse. Maximise linkages with pedestrian and cycle networks. Develop flood mitigation solutions that minimise the frequency of inundation of active recreation areas, and permit more frequent inundation of passive recreation areas.

4 Stormwater Drainage Infrastructure Performance

4.1 Modelling Approach

The performance of the existing stormwater network was assessed using the modelling software DRAINS.

As described in the model documentation (Watercom, 2018), DRAINS is a multi-purpose Windows program for designing and analysing urban stormwater drainage systems and catchments. DRAINS can model drainage systems of all sizes, from small to very large (up to 10 km² using multiple sub-catchments with ARR 2016 and ILSAX hydrology, and larger using storage routing model hydrology).

Working through a number of time steps during the course of a storm event, it converts rainfall patterns to stormwater runoff hydrographs and routes these through networks of pipes, detention basins, channels and streams. In this process, it integrates:

- Design and analysis tasks;
- Hydrology (five alternative models) and hydraulics (two alternative procedures);
- Closed conduit and open channel systems;
- Headwalls, culverts and other structures;
- Stormwater detention systems; and
- Large-scale urban and rural catchments.

Within a single package, DRAINS can carry out hydrological modelling using ARR2016, ILSAX, rational method and storing routing models, together with unsteady hydraulic modelling of systems of pipes, open channels and in the premium hydraulic model, surface overflow routes. It includes an automatic design procedure for piped drainage systems, connections to CAD and GIS programs, and an in-built Help system.

DRAINS modelling of the Barker Inlet Central catchment was undertaken for the following scenarios:

- Assessment of the drainage performance standard of the existing stormwater network with the existing level of development for the 1 EY, 0.2 EY, 5% AEP, 2% AEP and 1% AEP storm events; and
- Assessment of the future drainage performance standard of the existing stormwater network with increased future development for the 1 EY, 0.2 EY, 5% AEP, 2% AEP and 1% AEP storm events.

The parameters required to develop the DRAINS model are described in detail below.

4.2 Drainage Data

The GIS stormwater asset datasets provided by the Councils formed the foundation of the drainage data for the DRAINS model. A series of modifications were made to prepare this data for use in the DRAINS model, including:

- Converting arc and polyline drain elements into single line segments;
- Snapping together drain line segments, and snapping drains to pits, where these have not been digitised accurately;
- Assigning surface levels to all inlets and junction boxes, using information from the DTM;
- Generating drain inverts where unavailable under the assumption of 600 mm cover to all drains with a positive gradient; and
- Modifying attribute data values to ensure a consistent format across the different Councils.

Where gaps in the drainage data were present, these were amended via site inspection or with additional external information such as inspection of the DTM or Google Maps Street View. Where critical information was still missing, such as critical pipe/culvert sizes, a physical inspection was undertaken.

4.3 Catchment Parameters

4.3.1 Existing Impervious Areas and Runoff Coefficients

Sample areas were chosen to assess the impervious site coverage across the study area. A number of residential sub-areas were analysed, each having a different level of urbanisation and development, and three of these are summarised below in Table 4-1 and Table 4-2. The specific regions were selected using aerial photography, as they were considered representative of the surrounding impervious site coverage.

Table 4-1 – Sample Sub Areas

Sample Sub-Area	Impervious Percentage	Pervious Percentage
Douglas Street, Ferryden Park (NAW Catchment)	76	24
Pulsford Road, Prospect (HEP Catchment)	66	34
East Street, Brompton (HEP Catchment)	60	40

Figure 4-1 – Sample Sub Areas

When deciding how to split the impervious fraction into directly connected and indirectly connected components, consideration has been given to the characteristics of the sample areas:

- Development that has occurred in the last 30 years can generally be assumed to have 'conventional' drainage systems connecting directly to the street, and a higher directly connected impervious area fraction. Older areas were observed on-site to generally have fewer stormwater connections to the street with a higher proportion of indirectly connected impervious area; and
- Areas with some redevelopment of older housing have a mixture of directly connected and indirectly connected allotments. Directly connected proportions for these areas varied with the level of redevelopment/subdivision that had occurred in each subcatchment.

Following from this, typical runoff coefficients for a residential subcatchment within each of the sample sub-areas were determined and are summarised in Table 4-2. These values were further varied on a subcatchment by subcatchment basis using the provided aerial photography.

Table 4-2 – Typical Runoff Coefficients for Residential Subcatchments

Sample Sub-Area	Directly Connected Impervious Area (%)	Indirectly Connected Impervious Area (%)	Grassed Area (%)
Douglas Street, Ferryden Park	61	15	24
Pulsford Road, Prospect	47	19	34
East Street, Brompton	44	16	40

For non-residential catchments, runoff coefficients were selected based on the land use visible in aerial photography. Commercial areas (i.e. along Main North Road) and industrial areas (i.e.

the industrial areas of Wingfield and Regency Park) were typically given very high impervious fractions of approximately 90%. Open areas such as reserves and golf courses were generally assigned very low impervious fractions, in the vicinity of 0 to 10%.

Impervious area percentages across the entire study area are shown in Figure 4-2.

4.3.2 Hydrological Model

The ILSAX model has been adopted as the hydrological model within DRAINS, with depression storages of:

- Paved = 1 mm;
- Supplementary paved = 1 mm; and
- Grassed = 45 mm.

A custom soil type was used, with values entered representing a continuing loss of 3 mm/hour.

4.3.3 Ultimate Development Runoff Coefficients

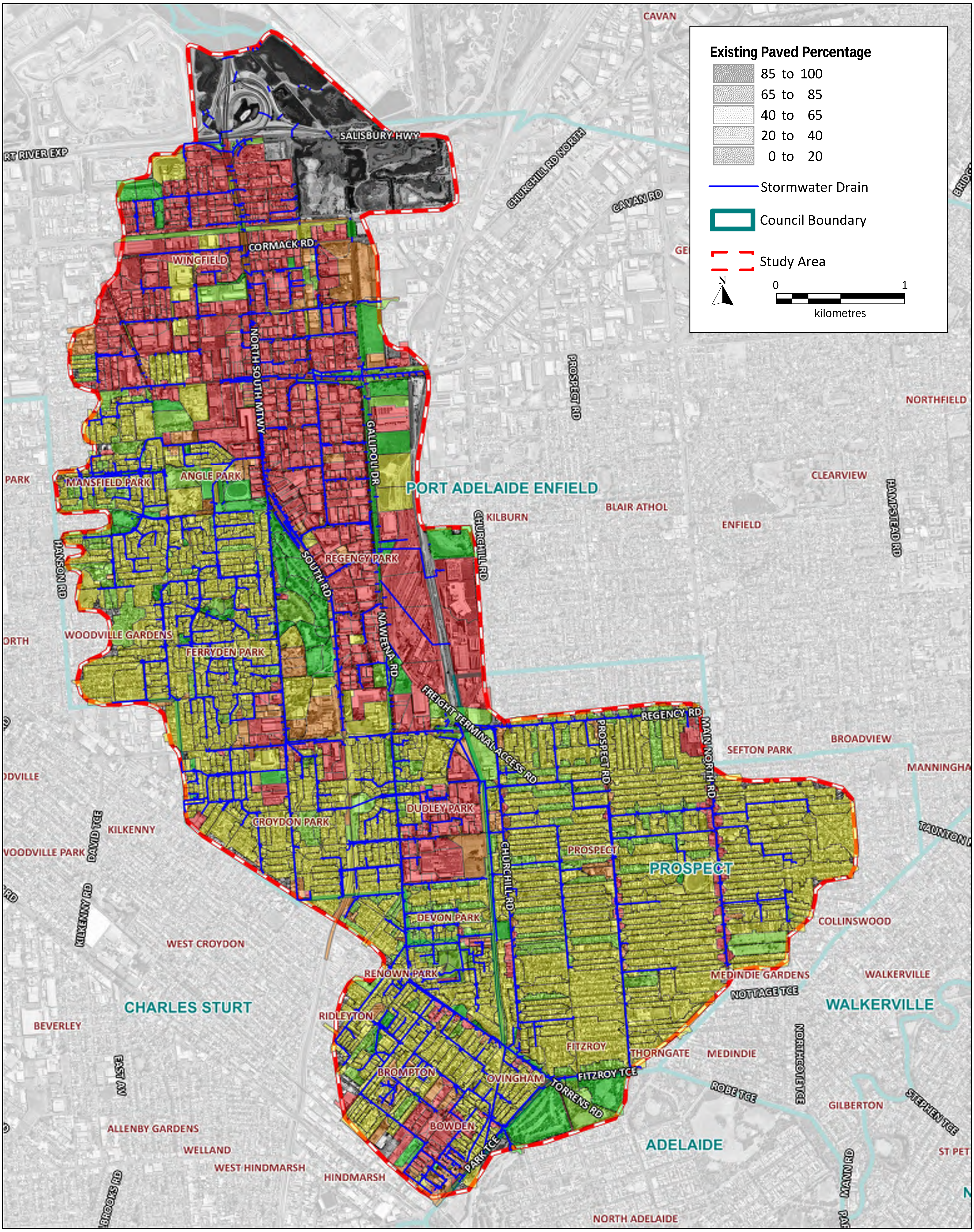
Consideration of the potential impact of likely future development on rates of stormwater runoff generation is required to ensure that the Stormwater Management Plan provides appropriate guidance into the future.

An assessment of development potential was undertaken by InfraPlan to assess the likelihood of development throughout the study area (See Section 2.9). This assessment assisted in spatially identifying potential sites where older housing stock is likely to be subject to infill development by subdivision. Following this, more than three thousand residential allotments were identified as being likely for future redevelopment.

An assumed impervious fraction of 85% (comprising 80% directly connected and 5% indirectly connected area) was applied to each allotment identified as having high potential for redevelopment. This fraction was applied to individual subcatchments (proportionally, by area) throughout the Study Area to determine ultimate development runoff coefficients. In other residential subcatchments without any identified properties likely for development, the directly connected impervious area value was manually increased by up to 5%, based on the likelihood for building extensions and minor development over time.

Allotments classified as heritage properties did not have their runoff coefficients updated, as these are not likely to undergo significant redevelopment. These were located throughout the study area, but predominately in Prospect and Charles Sturt, with far fewer heritage places in the Port Adelaide Enfield region of the study area.

The increased impervious fraction runoff coefficients from the existing fractions are shown in Figure 4-3Figure 4-3, and the resulting runoff coefficients shown in Figure 4-4. Analysis shows the largest increases are likely to occur near the western and southern edges of the Study Area, including the suburbs of Croydon Park, Devon Park, Woodville Gardens and the north-western portion of Prospect. Areas which are zoned commercial and industrial already have a very high impervious fraction, and any redevelopment of these sites is unlikely to result in an increase to the existing impervious fraction. However, undeveloped sites in these zones, if developed, would result in a very large increase in the impervious fraction.

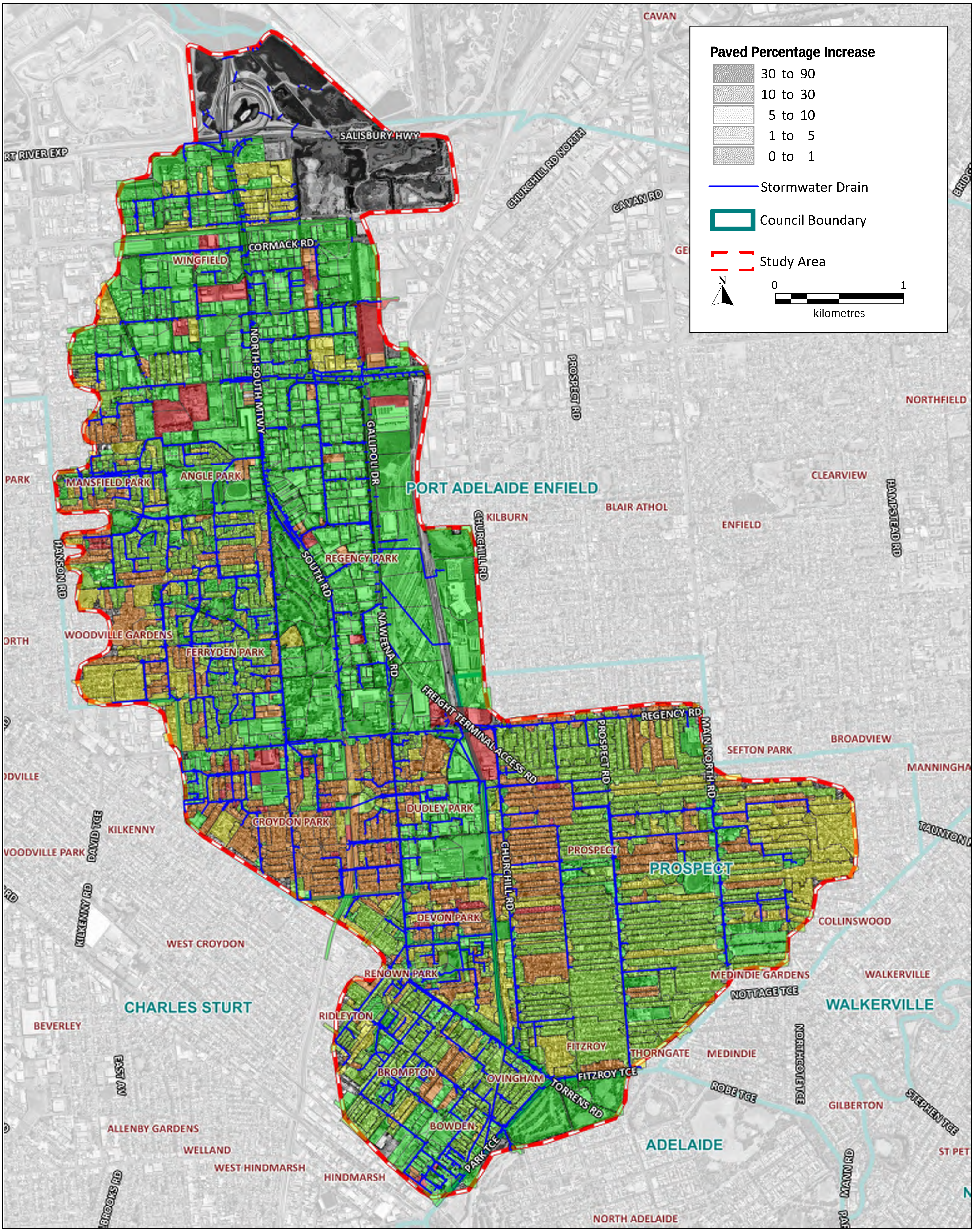


Data Sources:
Southfront (Runoff Coefficients, Subcatchments)
NearMap (Aerial Photograph)
DataSA (Council Boundaries, State Maintained Roads)
City of Port Adelaide Enfield, City of Prospect, City of Charles Sturt (Stormwater Pipes)

southfront

Barker Inlet Central
Stormwater Management Plan

Subcatchment Existing Development Paved Percentage
Figure 4.2

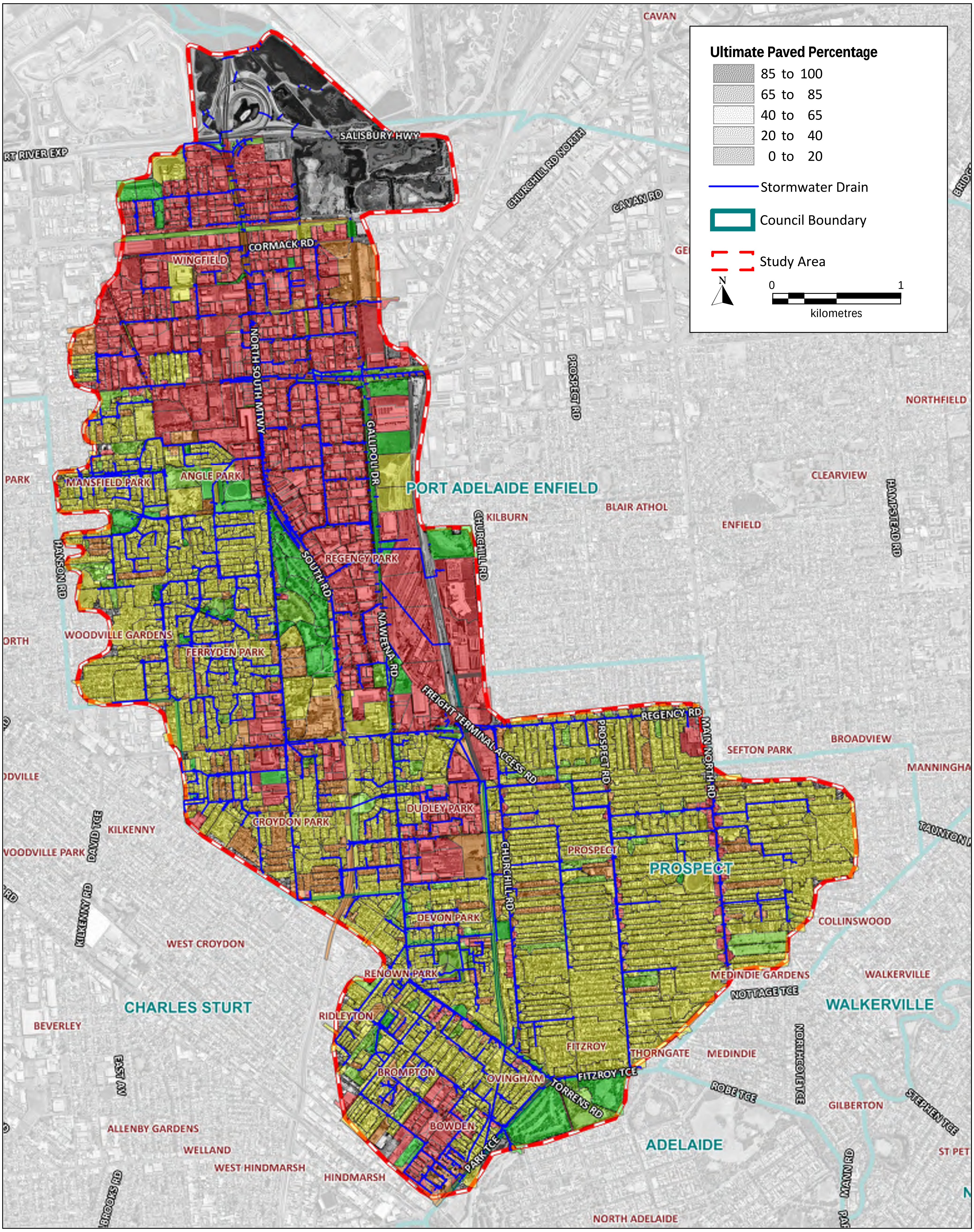


Data Sources:
Southfront (Runoff Coefficients, Subcatchments)
NearMap (Aerial Photograph)
DataSA (Council Boundaries, State Maintained Roads)
City of Port Adelaide Enfield, City of Prospect, City of Charles Sturt (Stormwater Pipes)

Barker Inlet Central
Stormwater Management Plan

southfront

Subcatchment Ultimate Development Paved Percentage Increase
Figure 4.3



Data Sources:
Southfront (Runoff Coefficients, Subcatchments)
NearMap (Aerial Photograph)
DataSA (Council Boundaries, State Maintained Roads)
City of Port Adelaide Enfield, City of Prospect, City of Charles Sturt (Stormwater Pipes)

Barker Inlet Central
Stormwater Management Plan

Subcatchment Ultimate Development Paved Percentage
Figure 4.4

4.4 Floodplain Mapping

Floodplain mapping of the Barker Inlet Central catchment has been undertaken as part of this Stormwater Management Plan to define the flood levels and extents for the 0.2 EY, 5% AEP, 2% AEP and 1% AEP flood events. All rainfall data assumes the ultimate development of the Study Area, as described in Section 4.3.3.

4.4.1 Software Selection

Hydraulic floodplain modelling was carried out using the TUFLOW (and ESTRY) computer program jointly funded and developed by BMT WBM and The University of Queensland in 1990. TUFLOW (Two-dimensional Unsteady FLOW) is specifically oriented towards establishing flow and inundation patterns in coastal waters, estuaries, rivers, floodplains and urban areas where the flow behaviour is essentially 2 dimensional (2D) in nature and cannot or would be awkward to represent using a 1 dimensional (1D) model (BMT WBM, 2010).

A powerful feature of TUFLOW is its ability to dynamically link to 1D networks using the hydrodynamic solutions of ESTRY. The user sets up a model as a combination of 1D network domains inked to 2D domains.

The TUFLOW and ESTRY computational engines use third party software as their interface. These software are typically a text editor (eg. Wordpad), a GIS platform (eg. MapInfo), 3 dimensional (3D) surface modelling software (eg. Global Mapper) and result viewing (eg. SMS).

The TUFLOW model is based on the Stelling (1984) solution scheme, which is a finite difference, alternating direction implicit (ADI) scheme solving the full 2D free surface flow equations. The ESTRY model is based on a numerical solution of the unsteady momentum and continuity fluid flow equations (BMT WBM, 2010).

The model area is divided into fixed rectangular cells that can be either wet or dry during a simulation. The model has the ability to simulate the variation in water level and flow inside each cell once information regarding the ground resistance, topography and boundary conditions are entered.

4.4.2 1D/2D Hydraulic Model Domains

The models were developed so that the underground stormwater drainage system was modelled in 1 dimension (1D), while overland flow paths on the surface were modelled in 2 dimensions (2D) using TUFLOW. The 1D and 2D domains within each model were hydro-dynamically linked, allowing flows in both domains to interact.

4.4.3 2D Cell Size

Determining an appropriate 2D cell size to be used by TUFLOW requires a compromise between the accuracy of modelling necessary to sufficiently reproduce the hydraulic behaviour of the floodplain as well as limitations in computing power and processing time. A detailed understanding of the requirements of the study was also required. In this instance, the study is a broad scale, catchment wide analysis which aims to identify the main flood prone areas and assess the performance of any proposed flood mitigation options at a conceptual level. A cell size of 2 metres was selected for modelling of the Barker Inlet Central area.

4.4.4 Topography

A digital terrain model (DTM) of the model domain area was acquired to define the existing topography of the study area. The DTM was used to assign elevations to individual cells within the 2D domain. These elevations are assigned at the cell centres, corners and mid-sides to enable interaction with surrounding cells. The representation of roads within the DTM was closely inspected to ensure that the kerbs, spoon drains and road crowns were all accurately captured to create a realistic road profile within the 2D domain.

4.4.5 Resistance Parameters

The bed resistance is an essential element used to define the flow and hence the water depth at any location within the 2D model domain. In TUFLOW, bed resistance values for 2D domains are most commonly created by using GIS layers containing polygons with varying 'materials' values. The material values specific in GIS correspond to a user defined Manning's n value described in the materials file. This approach allows for a relatively quick and simple adjustment of Manning's n values, especially if model calibration is possible.

The bed resistance values used in the modelling are specified in Table 4-3.

Table 4-3 – Manning's n Values used in Modelling

Type of Land Use	Manning's Roughness Coefficient
Residential/Commercial/Industrial	0.200
Roads	0.020
Sparsely Vegetated Open Space	0.050
Railway	0.060
Densely Vegetated Open Space	0.080
Golf Course	0.040
Sports Pitch/Reserve	0.060
Vegetated Open Channel	0.035
Concrete Channel	0.018

It should be noted that relatively high values of Manning's n were used for residential, commercial and industrial land to compensate for the lack of building envelopes in the DTM. Where needed, manning's n values used for modelling were revised to suit the characteristics of the Study Area.

The Manning's n value used for modelling underground drains was 0.013.

4.4.6 Boundary Conditions

As part of the modelling, consideration was given to the boundary conditions within the 1D and 2D domains. The 1D boundary conditions consist of the inflows to stormwater pits which allow flows to travel between the 1D domain (underground drainage system) and the 2D domain (ground surface defined by the DTM) as governed by hydraulic conditions that vary over the course of a storm event.

Within the 2D domain, the boundary condition is the edge of the model. A "HQ" (stage-discharge) type boundary condition was applied at the model extent with a water surface slope of 2%. The purpose of this approach was to allow water to "disappear" once flood flows reached the model boundaries and ensure that results in the floodplain were not affected at model edges.

At the downstream end of the model, where the Barker Inlet Wetlands flow out towards the ocean, a tidal boundary condition was configured. This allowed the water level at the interface with the model edge to be raised and lowered with fluctuations of the tide. For the longer duration, larger volume storms (4.5 hour, 6 hour and 9 hour), the tidal curve was timed to coincide with the peak water volume in the wetlands, to exacerbate the impact of the tide.

For all simulations using the 0.2 EY storm event, the 100 year high tide of 2.5 mAHD was applied, whereas for the 5% AEP, 2% AEP and 1% AEP storm events, the MHWS tide of 1.25 mAHD was applied. The adoption of a MHWS tide level boundary condition for infrequent rainfall events is standard practice in the South Australian context where previous analysis such as the *Port Adelaide Seawater Stormwater Flood Risk Study* (Tonkin Consulting, 2005) found no statistical link between heavy rainfall events and storm surges. The chosen tide/rainfall combinations were selected based on the probability of either occurring at the same time. A rare tide event coinciding with a rare rainfall event gives rise to an extremely rare event.

4.4.7 Initial Water Level

Within TUFLOW the initial water level can be specified. An initial water level fills a designated region with water to a given height at the beginning of the model simulation, so that the simulation does not start with these areas devoid of water. This is particularly useful for areas where water pools long term such as basins and wetlands.

This feature was utilised in the Barker Inlet Wetland, with different basins being given different initial water levels. The areas near Gulf St Vincent had initial water levels equal to mean sea level (i.e. 0.0 mAHD), whereas further upstream in the Northern Ephemeral Area and Southern Basin this initial water level was 0.3 and 0.5 mAHD respectively (based on weir overflow levels within the wetland). These initial water levels allowed for a more accurate representation of the behaviour of these basins, and the effect they have on the model.

4.4.8 Inflows

The inflow hydrographs at each inlet were derived from DRAINS modelling. Flows were applied as point source inflows at the invert of each pit within the 1D domain. This approach ensured that the entire inflow hydrograph for each pit was applied to the underground drainage network system.

Due to the hydro-dynamic links between the 1D and 2D domains, this arrangement allowed flows equal to or smaller than the pipe capacity to travel within the underground network, while flows exceeding the pipe capacity spilled onto the surface and travelled overland within the 2D domain.

For catchments which had no existing underground drainage infrastructure, inflow hydrographs were applied directly into the 2D domain. This allowed water to spread along the surface from the outlet of the catchment.

In addition to the open channels within the Barker Inlet Central catchment, the North Arm East catchment also outlets into the Barker Inlet Wetlands. The North Arm East catchment is a very large, primarily urban region with an area of 2,116 hectares, only slightly smaller than the entire Barker Inlet Central catchment. Inflow hydrographs provided by City of Port Adelaide Enfield for this catchment were applied directly into the TUFLOW model in the open channel upstream of the Barker Inlet Wetlands.

Hydrographs for all durations were not available, and in light of this the Project Steering Committee agreed to apply the old North Arm East model hydrographs from the DPTI Barker Inlet Wetland model. This model had 30 hour storm duration hydrographs for the 0.2 EY, 5% AEP and 1% AEP storm events, but not the 2% AEP storm event. The hydrograph for the 2% AEP storm event was created by interpolating between the 1% AEP and 5% AEP hydrographs. These hydrographs, while not completely precise, were considered sufficient to account for inflows from this catchment to reflect higher receiving water levels in the wetlands.

4.5 Minor System Drainage Performance

4.5.1 Existing Development Conditions

The DRAINS model of the existing drainage system under existing development conditions has been executed for the 1 EY, 0.2 EY, 5% AEP, 2% AEP and 1% AEP storm events. Drainage system 'failure' was defined as the hydraulic grade line level within an upstream pit resulting in less than 150 mm of freeboard. The performance standard at drainage nodes (the storm event at which the DRAINS model reported this failure condition to have occurred) is presented in Appendix B. It is desirable for underground stormwater drains to achieve a performance standard of 0.2 EY.

These maps do not necessarily identify areas that require immediate or even any action if the surface overflows from these systems can be appropriately managed, but they do identify locations potentially worthy of further investigation and refinement during the floodplain mapping.

Through the DRAINS modelling, key locations where the existing stormwater drainage network was insufficient were identified. Following the results of the DRAINS modelling, a number of 'hot spots' were identified across the Study Area for further investigation and strategy development.

Looking at the results of the drain and node standard mapping, a number of key flooding hotspots become apparent. There are discussed in further detail below.

- Churchill Road, Prospect

Although the main run of the Churchill Road drain was found to be of good standard (>50 year), the majority of lateral drains were of far lower standard (typically <1EY or 1EY – 0.2EY). While this is the case closer to Regency Road, further South in Prospect the drain standard is far worse, with a long section of main stretching from Boyle Street to Avenue Road having a standard of <1EY, with almost every pit along this run having a similarly bad standard.

- Overland Road, Croydon Park

As with the above hotspot, the downstream main is shown to have a high standard as defined above, however this is a very deep main drain and therefore would be expected. The high HGL in the main results in a low standard in the lateral running back up Overland Road and into

Charron Road and into Berliet Street. This results in a <1EY standard in the lateral drains and side entry pits, and therefore surface flooding would be expected in larger flood events.

- Packard Avenue and Hudson Avenue, Croydon Park

The underground drainage network in these two streets splits off in two directions, one to the north and one to the east. The downstream drain in both systems was found to be a limitation, and there is a cluster of low standard pits and pipes in this region.

Other key locations of note with low drainage standards include:

- Prospect Road, Prospect
- Braund Road, Prospect,
- Durham Terrace, Ferryden Park (as well as upstream lateral systems)
- Wing Street, Wingfield
- Frances Road, Wingfield

4.6 Major System Performance

A1 format floodplain maps have been prepared for each ARI and are presented in Appendix B.

The scope of this Study involved floodplain mapping the 0.5 EY, 0.2 EY, 5%, 2% and 1% AEP storm events for the ultimate development scenario with existing drainage infrastructure.

This report section provides an overview of the floodplain extents for the various AEP events. The purpose of this commentary is to identify areas that are susceptible to inundation from stormwater runoff, and the possible causes.

The commentary also highlights locations where stormwater ingress to private property has been observed on the floodplain maps. It should be noted that stormwater ingress to private property does not necessarily result in above floor inundation, and it is generally expected that depths of inundation of less than 150 mm are unlikely to result in flooding of adjacent buildings or structures.

Storm Duration and Temporal Pattern Selection

Various storm durations were modelled in order to determine which durations were critical for each catchment and event. Storm durations modelled included the 10 minute, 15 minute, 20 minute, 25 minute, 30 minute, 1 hour, 1.5 hour, 2 hour, 3 hour, 4.5 hour, 6 hour, 9 hour and 12 hour storms.

The critical storm durations selected for each AEP event were determined to be the 15 minute, 30 minute, 1 hour, 2 hour, 3 hour, 6 hour and 9 hour.

Under the recommended Australian Rainfall and Runoff 2019 procedures, each storm duration has 10 different associated temporal patterns. Each temporal pattern (1-10) was initially modelled for each of the critical durations for the frequent (0.2 EY) and rare (1% AEP) storm events. Temporal patterns were selected for the remaining storm events based on floodplain analysis of these minor and major storm events.

It should be noted that the variance in flow rates and flood depths between differing temporal patterns was generally very minor, particularly in locations with the deepest flooding.

It was found that the flooding extents in various parts of the catchment differed based on the storm duration that was modelled. Therefore, the results presented in the floodplain maps are based on a combination of critical events and can be assumed to represent the worst case scenario or flood envelope for each AEP.

4.6.1 Major System Performance – Flood Mapping Results

Analysis of the flood mapping results have identified a number of flood prone regions throughout the study area. Below is a description of each flood prone region, the extent of inundation, severity of property inundation and the likely cause of flooding. Flood prone regions were assigned identifiers (F1 – F11).

The below commentary is to be read in conjunction with the attached A1 format flood maps in Appendix B.

F1: Prospect Road, Churchill Road and Regency Road, Prospect (HEP Catchment, City of Prospect)

The flood maps show widespread flooding throughout Prospect in all events modelled. Analysis of model results indicate the capacity of the underground system is exceeded in Prospect Road, Churchill Road and Regency Road from the 0.2EY event, with overflows through many streets and encroaching onto private property.

Flows are shown to surcharge from the Prospect Road drain along almost its full length, resulting in overflows cascading from east to west down the escarpment towards the lower-lying areas of Prospect. Major flow paths through Prospect include Victoria Street, Alexandria Street, Johns Road and Gladstone Road, where flows in all events are shown to travel quickly down the escarpment. Stormwater systems at the bottom of the escarpment, particularly in Churchill Road, are shown to be overwhelmed by these surface flows before breaking out of the road reserve and into private property in a number of low-lying locations.

Extensive flooding along the full length of Churchill Road and surrounding side streets is evident in all events greater than the 5% AEP. Areas particularly affected by flood waters include Totness Avenue and Vine Avenue (where over 50 properties are affected by flood waters up to 200mm deep in the 1% AEP event) and Charles Street and Princes Street (over 150 properties affected by flood waters up to 800mm deep).

The Charles Street and Princes Street region (east of Churchill Road) is particularly vulnerable to extensive inundation of private property. This area is vulnerable due to a number of reasons:

- The limited capacity of the existing underground drainage network (particularly the Churchill Road drain and the downstream 'HEP' channel);
- Low-lying topography of the area. Charles Street is a trapped low spot which relies entirely on the underground network to drain;
- Extensive volume of overland flows from external/upstream catchments. Flows from catchments east of Prospect Road (up to Main North Road) and southern areas of Churchill Road are shown to flow towards the Charles Street low spot in large events.
- Flat topography immediately downstream of a steep escarpment, resulting in flows breaking out of the road once the velocity of flow reduces;

A small pump station is located within Stan Watson Reserve on Charles Street. This Council operated pump station was designed to manage the local catchment (i.e. the runoff generated from the Charles and Princes Street area) with a rising main that discharges into the Churchill Road drain. Modelling indicates the pump station is quickly overwhelmed by overland flows from the external catchments outside of Charles Street and Princes Street (mainly via overflows from Albert Street to the south), as well as the surcharging Churchill Road drain. The limited capacity of Churchill Road drain to accept any additional flow results in the pump station being relatively ineffective in large (>0.2EY) AEP events.

Ponding within the Charles Street/Princes Street region is also shown to extend to the western side of Churchill Road in events greater than 5% AEP. The vacant allotment on the western corner of the intersection of Regency Road and Churchill Road (currently earmarked for redevelopment) is shown to be inundated by flood waters up to 400mm deep.

The rail line is shown to be affected at two locations in the 1% AEP event. The rail line (consisting of Australian Rail Track Corporation (ARTC) freight line and the Adelaide Metro Gawler line) are shown to be inundated by flood depths of up to 300mm at the Regency Road overpass as well as in the vicinity of Totness Avenue, where flows are spilling into neighbouring Port Adelaide Enfield Council area.

The corner of Regency Road and William Street is also shown to be vulnerable to flood inundation, with widespread stormwater ingress of up to 100 properties in the 1% AEP event. Properties fronting onto Regency Road either side of William Street are flooded up to a maximum water depth of over 500mm.

F2: Overland Road and Sunbeam Road, Croydon Park (HEP Catchment, City of Port Adelaide Enfield)

Stormwater is shown to exceed the capacity of the underground system in the vicinity of Overland Road in events greater than the 2% AEP. Over 20 properties are affected by flood depths of up to 300mm on Overland Road, Sunbeam Road and Charron Road in the 1% AEP flood event. The cause of flooding was determined to be limited capacity of the underground network within the major Harrison Road trunk drain restricting flows and limiting the effectiveness of upstream stormwater systems.

F3: Hudson Avenue and Packard Avenue, Croydon Park (City of Port Adelaide Enfield)

Flood maps indicate flooding of residential properties is likely from the 5% AEP in the vicinity of Hudson Avenue and Packard Avenue, Croydon Park. Analysis of model results indicate flooding is caused by a high Hydraulic Grade Line (HGL) level within the Harrison Road trunk drain relative the ground surface levels in Hudson Avenue. Modelling indicates flows surcharging from the underground system in large events, with up to 30 properties shown to be affected by flood depths of up to 250mm in the 1% AEP at this location.

It should also be noted that surface elevations of Hudson Avenue are approximately 600mm below that of the Harrison Road area. This makes the Hudson Avenue area vulnerable to flooding when water levels within the Harrison Road drain are high, as demonstrated by the flood model results.

F4: Laurel Avenue, Croydon Park (City of Port Adelaide Enfield)

Properties at the corner of Laurel Avenue and Margititch Street, Croydon Park are shown to be flood affected from the 2% AEP event. These properties are located east of a new housing development between Ena Street and Regency Road. Up to 15 properties are shown to be affected by flood waters up to 300mm deep in the 1% AEP event. The cause of flooding is due to the limited capacity of the underground network and the location in the vicinity of Laurel

Avenue and Margitich Street being a trapped low-spot without adequate overland flow paths to the downstream system to the east.

F5: Nairn Street, Ferryden Park (City of Port Adelaide Enfield)
Nairn Street is cul-de-sac with a trapped low spot at the northern end. Inflows exceed the capacity of the underground system in events greater than the 5% AEP. While flood maps indicate only two allotments affected in the 1% AEP at this location, the allotment consists of high density unit block (19 units) which are flood affected by depths of up to 300mm.

F6: Longford Crescent, Ferryden Park (City of Port Adelaide Enfield)
Minor stormwater ingress within private property is evident at Longford Crescent from the 2% AEP event. Up to 15 properties are shown to be affected by flood depths of over 250 mm in the 1% AEP event. Analysis of model results indicates the Warren Street trunk drain (2100 x 900 mm RCBC) is at capacity in the 2% AEP, resulting in localised flooding of Longford Crescent properties.

It should be noted that this area has been subject to recent infill development. Newer properties sited at higher elevations are shown not to be as flood affected as the older housing stock.

F7: Ridley Grove and Essex Street, Woodville Gardens (City of Port Adelaide Enfield)
Flood maps indicate flooding of residential properties is likely from the 5% AEP in the vicinity of Ridley Grove and Essex Street.

Modelling indicates that the Mikawomma Reserve detention basin (corner of Liberty Grove, upstream of Rudely Grove) and the Reg Robinson Reserve detention basin (downstream of Ridley Road) both reach capacity during the 5% AEP event. This is shown to result in up to 30 properties are flood affected by flood levels of up to 350mm in the 1% AEP event (particularly at the intersection with Humphries Terrace, which is a low spot in Ridley Grove).

F8: Short Street, Clara Street and John Street, Mansfield Park (NAW Catchment, City of Port Adelaide Enfield)
Ponding in Short Street, Clara Street and John Street is evident from the 0.2EY event as the underground system reaches its capacity to convey flows to the downstream North Arm West channel, to the east. Stormwater is shown to encroach onto private property from the 5% AEP event, particularly in Short Street and Clara Street which are both trapped low spots according to the Digital Terrain Model (DTM). Up to 17 residential properties are shown to be flood affected in the 1% AEP event.

F9: North Arm West Channel – Grand Junction Road to Cormack Road, Wingfield (NAW Catchment, City of Port Adelaide Enfield)
Modelling indicates the North Arm West Channel between Grand Junction Road and Cormack Road reaches its capacity from approximately the 5% to 2% AEP events. This is evident by minor channel break-outs at Francis Road and Havelock Street where a number of industrial properties are shown to be flood affected in the 5%, 2% and 1% AEP's. Modelling also indicates that flood levels within the channel are relatively high compared to surround ground surface levels, resulting in localised flooding in some industrial allotments (generally those sited lower than the top bank of the channel). This is particularly true for a number of industrial properties in the vicinity of Francis Street which have private systems discharging into the NAW channel. Water levels within NAW result in the allotments being unable to drain and, in some cases, water surcharging into the allotment via the private drainage system.

Other streets susceptible to flooding as a result of high water levels in this section of NAW channel include Morgan Street, Davis Street and Albion Street from the 5% AEP event.

F10: Wing Street, Wingfield (City of Port Adelaide Enfield)
Minor property flooding is evident in the vicinity of Wing Street, Wingfield from the 5% AEP event. This low-lying area at the bottom of the catchment was found to be vulnerable to water levels within NAW channel and the Barker Inlet Wetlands (BIW). The allotment at the top of Millers Road is also shown to be flood affected with considerable inundation from the BIW in the 1% AEP event.

F11: Napier Street, Renown Park (City of Charles Sturt)
Flood model results indicate flooding is relatively minor within The City of Charles Sturt compared to Prospect and Port Adelaide Enfield Council areas, with flooding mainly confined to the road network in all events up to the 1% AEP. The exception to this is in the vicinity of Napier Street and St Johns Avenue, Renown Park, where stormwater ingress within private property is evident from the 5% AEP event. Up to approximately 20 properties are shown to be flood affected in the 1% AEP at this location, with the underground system shown to be running at capacity from the 0.2EY event.

Property Inundation Summary

A catchment summary of the number of properties subject to inundation of depths greater than 50 mm for each storm event is shown in Table 4-4. Note that the number of properties inundated by depth greater than 50 mm is to be used as an indication of regions which are most at risk of flooding, however is not used in the damages assessment in Section 4.7.

Table 4-4 – Property Inundation by Catchment, Ultimate Development / Existing Drainage

Catchment	Number of Properties Inundated > 50 mm			
	0.2 EY	5% AEP	2% AEP	1% AEP
Hindmarsh Enfield Prospect	243	637	934	1272
North Arm West	15	69	143	230
Dunstan Road	2	3	13	17
Total	**260**	**709**	**1090**	**1519**

A Council-based summary of the number of inundated properties is also provided in Table 4-5.

Table 4-5 – Property Inundation by Council, Ultimate Development / Existing Drainage

Council	Number of Properties Inundated > 50 mm			
	0.2 EY	5% AEP	2% AEP	1% AEP
City of Prospect	233	587	802	981
City of Port Adelaide Enfield	25	97	216	372
City of Charles Sturt	2	25	72	166
Total	**260**	**709**	**1090**	**1519**

A summary of the flooding hotspots identified above as well (as some other minor locations) is summarised in Table 4-6. The referenced critical AEP threshold indicates the AEP in which the capacity of both the 'minor' (underground drainage) system and 'major' (above ground storage/overflow) systems are exceeded and stormwater inundation occurs within nearby private property.

Table 4-6 – Summary of Flooding Hotspots by Catchment

Observed Surface Inundation Location	Critical AEP Threshold	Approx. Maximum Flood Depth in 1% AEP Storm (mm)
Hindmarsh Enfield Prospect Catchment		
Charles Street / Princes Street	< 0.2 EY	1150
Regency Road / William Street	< 0.2 EY	600
Victoria Street / Alexandra Street / Albert Street	< 0.2 EY	650
Churchill Road / Devonport Terrace	< 0.2 EY	1300
Muriel Street / Lillian Street / Doreen Street	< 0.2 EY	350
Emilie Street / Jones Street / Davies Terrace	< 0.2 EY	250
Chevalier Street / Alpha Road / Peel Street	0.2 EY – 5%	1250
Audley Avenue / Clifton Street	< 0.2 EY	300
Azalea Street / Daphne Street	< 0.2 EY	550
Olive Street / Staples Court / Gladstone Road	< 0.2 EY	350
Overland Road / Sunbeam Road / Charron Road	0.2 EY – 5%	350
Auburn Crescent	< 0.2 EY	250
Exeter Terrace / Simpson Avenue	5% – 2%	350
Torrington Avenue / Cavendish Avenue / Plymouth Avenue / Belford Avenue	0.2 EY – 5%	250
Reo Road / Chrysler Road	0.2 EY – 5%	250
Regency Road / Naweena Road	< 0.2 EY	550
Napier Street / Gosport Street / St Johns Avenue	< 0.2 EY	300
Park Terrace / Telford Street / Gilbert Street	< 0.2 EY	200
Chief Street / Wattle Street / Mais Street / Coglin Street / Torrens Road	0.2 EY – 5%	600
Hudson Avenue / Packard Avenue	< 0.2 EY	400
North Arm West Catchment		
Laurel Avenue / Margitich Street	0.2 EY – 5%	450
Durham Terrace	< 0.2 EY	300
Liberty Grove / Fourth Avenue	< 0.2 EY	300
Nairn Street	0.2 EY – 5%	450
Longford Crescent / Murray Street	0.2 EY – 5%	400
Ridley Grove / Essex Street	0.2 EY – 5%	400
Short Street / Clara Street / Frederick Street	< 0.2 EY	300
Morgan Street	0.2 EY – 5%	350
Francis Road / Davis Street	< 0.2 EY	400
Albion Street / Clyde Street / Havelock Street	< 0.2 EY	600

Observed Surface Inundation Location	Critical AEP Threshold	Approx. Maximum Flood Depth in 1% AEP Storm (mm)
Wingfield Road / Production Road	< 0.2 EY	250
Grand Junction Road / South Road	< 0.2 EY	400
South Terrace	< 0.2 EY	300
Wing Street / Miller Road / Perth Street / Tolley Street	0.2 EY – 5%	350
Dunstan Road Catchment		
TAFE SA Campus	0.2 EY – 5%	300
Aruma Street / South Road	< 0.2 EY	600
Taminga Street	< 0.2 EY	350
Kateena Street	0.2 EY – 5%	400

4.7 Existing Flood Damages Estimation

4.7.1 Background

Estimates of flood damages provide important information that can be used to prioritise flood mitigation works. The estimates indicate the magnitude of damages caused by a design flood event of a given AEP.

Flood damages can be classified into two categories:

- 'Tangible' damages represent the financial cost of recovering from flooding. These include 'direct tangible' costs arising from loss or damage to property and physical assets, and 'indirect tangible' costs associated with interruptions to business and the flood response by property owners and emergency services; and
- 'Intangible' damages relate to the effect on the physical and mental health of individuals who are impacted by flooding. Intangible damages are difficult to quantify in monetary terms, however similar studies have noted that these damages may match or even exceed the tangible damage cost.

This Study has included an assessment of the 'direct tangible' damages from flooding on the Barker Inlet Central study area, using the floodplain mapping results for the ultimate development scenario with the existing stormwater drainage infrastructure. The magnitude of flood damages is dependent upon a number of factors including land use, property values, depth of inundation and the preparedness of the community to respond to the threat of flooding. These factors (and others) are included in the damages assessment calculations and are detailed in the following sections.

4.7.2 Evaluation Approach

Properties within the floodplain have been assessed according to their land use type, and categorised as either Residential, Commercial – Office, Commercial – Retail or Industrial. No capital or 'improved value' data for individual properties has been made available for this Study. Therefore an assumed improved value has been assigned to each property category, which represents the value of the structures or infrastructure that are susceptible to damages as a result of inundation, as shown in Table 4-7.

Table 4-7 – Assumed 'Improved Values' of Flood Affected Properties

Property Category	Improved Value
Residential	$195,000
Commercial – Office	$276,000
Commercial – Retail	$330,500
Industrial	$621,500

The flood depth at each property was determined for the 0.2 EY, 5% AEP, 2% AEP and 1% AEP flood events, and categorised into the following ranges:

- 0 – 0.1m;
- 0.1 – 0.15m;
- 0.15 – 0.25m;

- 0.5 – 1.0m;
- 1.0 – 1.5m; and
- 1.5 – 2.5m.

In the absence of surveyed floor level data, an assumption was made of the typical floor level of residential and commercial/industrial buildings (relative to the ground level determined by the DTM). This is required to ensure that the damage estimates consider that building floor levels are often situated at higher elevations than the ground levels as determined by the DTM, particularly in the case of residential dwellings. These assumptions are:

- Residential – Floor level 150 mm above the property DTM level; and
- Commercial/Industrial – Floor level at the property DTM level.

Damage multiplier curves from the *Brown Hill Keswick Creek Stormwater Management Plan* (2016) were used to assign flood damage costs by inundation depth for each property category, as summarised in Table 4-8.

Table 4-8 – Flood Damage Cost by Property Type and Inundation Depth

Property Category	Flood Damage Cost by Inundation Depth					
	0 – 0.1	0.1 – 0.15	0.15 – 0.25	0.25 – 0.5	0.5 – 1.0	1.0 – 1.5
Residential	$4,095	$6,240	$53,820	$65,520	$80,730	$108,225
Commercial – Office	$91,080	$114,264	$114,264	$139,104	$171,396	$228,528
Commercial – Retail	$144,759	$182,436	$182,436	$618,696	$1,007,034	$1,750,328
Industrial	$226,226	$303,914	$303,914	$650,089	$917,334	$1,357,978

4.7.3 Damages to Residential Properties

The number of residential properties that are at risk of inundation during various storm events was estimated by overlaying the flood inundation maps for these events over the cadastral layer and aerial photography. The results of the analysis for each AEP and depth range are shown in Table 4-9.

Table 4-9 – Residential Damages, Ultimate Development / Existing Drainage

AEP	No. of Residential Properties Inundated at each Depth Range						Damage Estimate
	0 – 0.1	0.1 – 0.15	0.15 – 0.25	0.25 – 0.5	0.5 – 1.0	1.0 – 1.5	
0.2 EY	148	45	31	7	2	1	$3,283,605
5% AEP	335	111	120	64	15	1	$14,035,320
2% AEP	436	242	159	13	23	2	$21,329,880
1% AEP	367	548	184	202	48	3	$32,260,020

4.7.4 Damages to Commercial and Industrial Properties

The number of commercial and industrial buildings that would potentially become inundated during various storm events was estimated by overlaying the flood inundation maps for these events over the cadastral layer and aerial photography. The results of the analysis for each AEP and depth range are shown in Table 4-10, Table 4-11 and Table 4-12.

Table 4-10 – Commercial - Office Damages, Ultimate Development / Existing Drainage

AEP	No. of Office Properties Inundated at each Depth Range						Damage Estimate
	0 – 0.1	0.1 – 0.15	0.15 – 0.25	0.25 – 0.5	0.5 – 1.0	1.0 – 1.5	
0.2 EY	10	4	0	0	0	0	$1,367,856
5% AEP	14	8	4	2	0	0	$2,924,496
2% AEP	36	15	10	2	0	0	$6,413,688
1% AEP	22	37	19	8	1	0	$9,686,772

Table 4-11 – Commercial - Retail Damages, Ultimate Development / Existing Drainage

AEP	No. of Retail Properties Inundated at each Depth Range						Damage Estimate
	0 – 0.1	0.1 – 0.15	0.15 – 0.25	0.25 – 0.5	0.5 – 1.0	1.0 – 1.5	
0.2 EY	5	1	1	0	0	0	$1,088,667
5% AEP	14	2	3	1	0	0	$3,557,502
2% AEP	15	7	1	4	0	0	$6,105,657
1% AEP	14	17	3	4	0	0	$8,150,130

Table 4-12 – Industrial Damages, Ultimate Development / Existing Drainage

AEP	No. of Industrial Properties Inundated at each Depth Range						Damage Estimate
	0 – 0.1	0.1 – 0.15	0.15 – 0.25	0.25 – 0.5	0.5 – 1.0	1.0 – 1.5	
0.2 EY	1	3	1	0	0	0	$1,441,880
5% AEP	7	4	2	2	0	0	$4,707,241
2% AEP	8	8	6	3	0	0	$8,014,864
1% AEP	12	10	14	5	1	0	$14,176,415

4.7.5 Summary of Total Damages

The total damages for the ultimate development scenario with existing drainage infrastructure are summarised in Table 4-13, and have been presented on a per catchment basis in Table 4-14, and on a per Council basis in Table 4-15.

Table 4-13 – Total Damages, Ultimate Development / Existing Drainage

AEP	Residential	Commercial – Office	Commercial – Retail	Industrial	Total
0.2 EY	$3,283,605	$1,367,856	$1,088,667	$1,441,880	$7,182,008
5% AEP	$14,035,320	$2,924,496	$3,557,502	$4,707,241	$25,224,559
2% AEP	$21,329,880	$6,413,688	$6,105,657	$8,014,864	$41,864,089
1% AEP	$32,260,020	$9,686,772	$8,150,130	$14,176,415	$64,273,337

Table 4-14 – Total Damages per Catchment, Ultimate Development / Existing Drainage

Catchment	Total Damages Estimate per Catchment			
	0.2 EY	5% AEP	2% AEP	1% AEP
North Arm West	$1,066,231	$4,180,070	$7,365,374	$12,247,493
Dunstan Road	$530,140	$1,102,541	$2,698,210	$4,116,346
Hindmarsh Enfield Prospect	$5,585,637	$19,941,948	$31,800,505	$47,909,498
Total	$7,182,008	$25,224,559	$41,864,089	$64,273,337

Table 4-15 – Total Damages per Council, Ultimate Development / Existing Drainage

LGA	Total Damages Estimate per Council			
	0.2 EY	5% AEP	2% AEP	1% AEP
City of Port Adelaide Enfield	$1,716,116	$6,184,157	$12,163,505	$21,647,520
City of Prospect	$5,407,977	$18,542,498	$28,171,471	$37,568,715
City of Charles Sturt	$57,915	$497,904	$1,529,113	$5,057,102
Total	$7,182,008	$25,224,559	$41,864,089	$64,273,337

4.7.6 Average Annual Damages

Average Annual Damage (AAD) value was calculated for the catchment area and broken down by Council area in Table 4-16. The AAD value is based on flood damage results for each AEP modelled (i.e. 0.2 EY to 1% AEP). It should be noted that the 1:500 year AEP event or Probable Maximum Flood (PMF) were not within the scope of this project, and as such are excluded from the AAD calculation.

The Average Annual Damage value for the full catchment area was calculated to be approximately $5.2m. A breakdown for each Council area is presented in the Table below.

Table 4-16 – Average Annual Damages By LGA

LGA	Average Annual Damage (AAD) Value
City of Port Adelaide Enfield	$1.3 m
City of Prospect	$3.7 m
City of Charles Sturt	$0.2 m
Total	**$5.2 m**

4.8 Flood Mitigation Strategies

Flood mitigation strategies are outlined in this section. These strategies have been developed with a view to maximising the level of flood protection that can be achieved within practical constraints, for example where providing the desired 1% AEP (100 year ARI) flood protection standard would be infeasible or cost prohibitive.

In accordance with the Plan's objectives outlined in Section 3, these strategies have aspired to achieve no above floor inundation of private property for all events up to and including the 1% AEP storm. However where this was not practically achievable, a 5% AEP standard has instead been sought. Floor level survey (outside of the scope of this study) would be required to confirm whether these performance standards have been achieved for all properties.

An overview of all upgrades is presented in Figure 4-15 and concept designs are presented in Appendix D. Each of the proposed upgrades has been assigned a Project ID for reference. A1 format floodplain maps have been prepared for each AEP event to demonstrate the performance of the flood mitigation strategies, and are presented in Appendix E.

Budget cost estimates have been prepared for the proposed flood mitigation works. The budget cost estimates are exclusive of GST and include allowances of:

- 10% for design;
- 5% for modification to existing services;
- 15% for construction preliminaries;
- 20% for contingencies on construction; and
- 13% for Council admin contingencies (on the grand total cost).

These cost estimates are based upon historical cost information and experience, and do not allow for latent or market conditions (i.e. competition, escalation) or land acquisition.

It is expected that floor level survey will be undertaken to inform the design development phase, and this has been allowed for in the cost estimates.

Budget pricing has been sought from supplies for proprietary items such as gross pollutant traps.

The potential cost of soil remediation and/or disposal of contaminated material has not been considered in preparing these cost estimates, and it is recommended that Council undertake environmental testing of project sites during the design development phase to assist in managing this risk.

The cost of ancillary landscaping works to be undertaken at the project sites has also not been considered, with the exception of re-seeding turf areas and the establishment of riparian plantings associated with WSUD elements.

4.8.1 Hindmarsh Enfield Prospect Catchment

D1: City of Prospect Flood Mitigation Strategy

An upgrade to the stormwater drainage network and outfall channel of the City of Prospect is recommended to alleviate flooding throughout the low areas surrounding Charles Street and William Street in the 0.2 EY and greater storm events. This upgrade consists of four components, labelled D1-A through D1-D as described in detail below, and the resulting reduction in flooding in the worst affected area is illustrated in Figure 4-5 below.

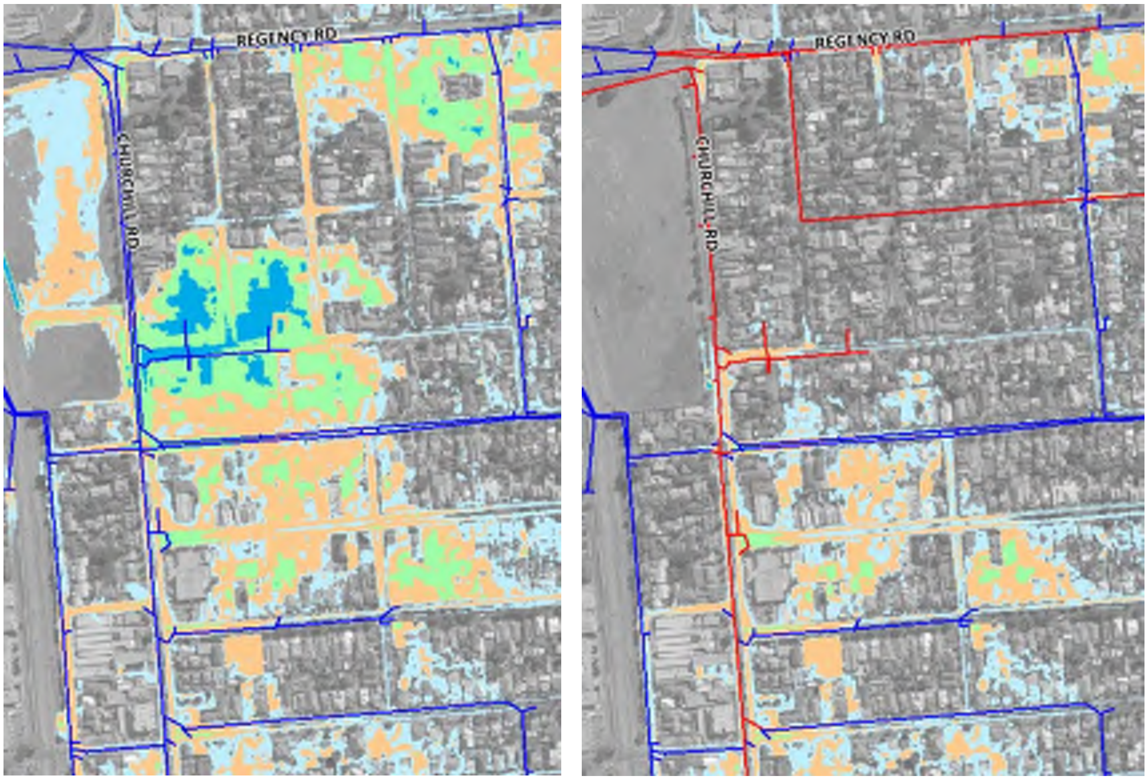


Figure 4-5 – D1 Existing (left) and Upgrade (right) 5% AEP Flood Maps

D1-A: Prospect Road / Redin Street / Regency Road – Drainage (Objectives O1 and O2)
A diversion drain is recommended through Prospect, connecting into the existing downstream outfall drain. The drain is to extend from Barker Street (located between Main North Road and Prospect Road) to the existing twin 1500mm RCPs at the intersection of Churchill Road and Regency Road. An upgrade of the low-lying part of the Regency Road drain is also proposed.

This drain is designed to intercept relatively large overland flows within Barker Road, Johns Road and Farrant Street, redirecting them into the underground system. This upgrade would also redirect the main trunk drain in Prospect Road from the Victoria Street / Albert Street / Churchill Road system, taking water further north via Redin Street, Princes Street and Regency Road. The upgraded drain in Regency Road is designed to provide relief to properties along Regency Road and William Street.

The drain ranges in size from 1050mm at the upstream end to 1650mm at the downstream end. The existing twin 1050mm diameter drains within Prospect Road would be directed into a new 1500mm diameter drain at the intersection of Prospect Road and Victoria Street. This drain will then increase to a 1650mm diameter drain at the intersection of Prospect Road and Farrant Street, which continues along Prospect Road until Redin Street. Within Redin Street the drain will transition from a relatively steep gradient (5 – 7%) in the escarpment zone to a relatively flat gradient (0.2 – 0.5%) in the western zone. This sudden gradient change will require the lower end of the Redin Street drain to act as an express drain down to the intersection of Regency Road and Churchill Road where the pipe size increases to twin 1500 mm pipes. This may require modifications to the existing drainage in William Street crossing perpendicularly to the proposed drain, depending on the inverts of the existing system.

The proposed drain in Regency Road is recommended to be upgraded to a 3.0 x 1.2m box culvert. This additional capacity will allow water arriving at the local low spot on Regency Road and William Street to drain far more effectively, reducing the extent of flooding in all modelled flood events.

The proposed drain alignments are shown in Figure 4-6. The total catchment area diverted from the Victoria Road / Churchill Road system is approximately 300 hectares.

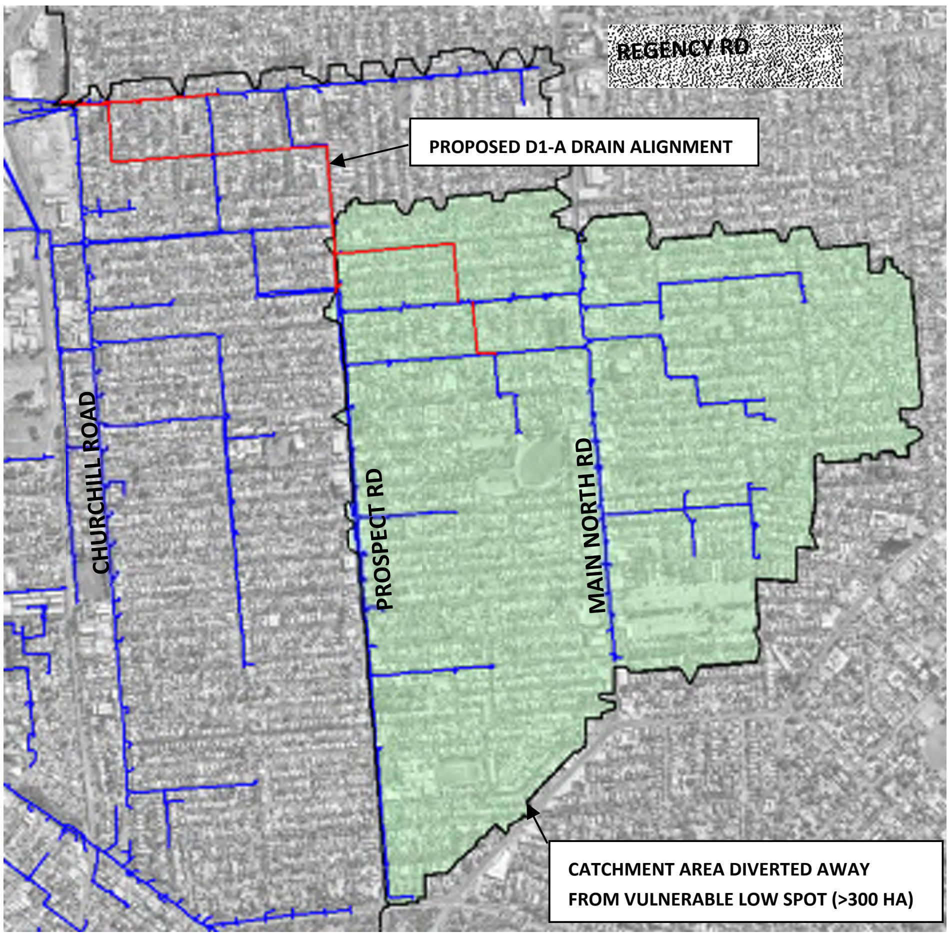


Figure 4-6 – Proposed Diversion Drain, Diverted Catchment Area

The cost for these drainage works is estimated to be $9,630,000.

D1-B: Churchill Road – Drainage (Objectives O1 and O2)
An upgrade of the drain within Churchill Road is recommended, extending from Avenue Road to Regency Road, then diverting across the railway tracks beneath Regency Road and connecting into an upgraded Pedder Crescent drain before terminating at the HEP channel.

This upgraded drain was found to capture far more of the water flowing down the steep escarpment from Prospect Road to Churchill Road, and prevent water spilling across Churchill

Road through private property to Devonport Terrace. The larger capacity also enabled the low spot at Charles Street to drain more effectively, resulting in less flooding.

The new trunk main along Churchill Road is proposed to range from 600mm diameter RCP at the upstream end, to 2400mm x 1200mm RCBC between Charles Street and Regency Road, to 3000mm x 1800mm RCBC downstream of the connection with the existing Pedder Crescent trunk drains.

Due to the low-lying area around Charles Street, a box culvert was required in order to achieve a suitable grade while maintaining safe cover from the top of the box to the road surface. The drain was graded back from the HEP channel inlet at a very gradual slope of 0.2% in order to keep the invert low in Churchill Road until the drain passed Charles Street. As a result, the downstream end of the trunk drain is quite flat.

The cost for these drainage works is estimated to be $11,530,000.

D1-C: HEP Open Channel – Drainage (Objectives O1 and O2)
The existing HEP open channel between Pedder Crescent and Narweena Road (refer Figure 4-7) was found to be undersized and a bottleneck for flows discharging from the Prospect drainage network. As a result, water cannot leave the low-lying parts of Prospect as quickly as it arrives, and there is widespread above-surface inundation in all storm events modelled.

Figure 4-7 – Existing HEP Channel adjacent to Freight Rail Terminal, Regency Park

Any works to upgrade the existing upstream stormwater network without a significant upgrade to the HEP open channel will likely exacerbate flooding in the low-lying reaches of the catchment, particularly in the vicinity of Charles Street and Princes Street. As a result, the upgrade of the HEP open channel is an essential prerequisite for flood mitigation strategies D1-A and D1-B.

An upgrade of the HEP open channel from its existing capacity of approximately 14 m^3/s to 25 m^3/s is recommended. Modelling indicates this channel capacity (in conjunction with the associated upgrades specified in strategies D1-A and D1-B) will generally achieve a 5% AEP (20 year ARI) flood standard in the low-lying area centred on Charles Street and Princes Street, and a moderate reduction to property inundation in the larger 2% and 1% AEP storm events.

The culvert beneath the railway alongside Freight Terminal Access Road will also need to be upgraded, from its current size of 2100mm x 1800mm to 4200 mm x 1800 mm (or an equivalent box culvert configuration). Modelling indicated that the existing box culvert between the HEP open channel and Naweena Road was of sufficient size and capacity and could be preserved.

To achieve a 1% AEP flood protection standard in the upstream catchment, a much larger channel capacity would be required. Instead, a 5% AEP flood protection standard was chosen, and the upgraded open channel flow rate specified to suit this reduced requirement.

The cost for these drainage works is estimated to be $3,890,000.

D1-D: HEP Channel Grand Junction Road Upgrade – Drainage (Objectives O1 and O2)
The upgrades detailed in D1-A, D1-B and D1-C result in a much greater flow rate through the HEP open channel all the way through to the wetlands.

It was found that applying these upgrades further upstream exacerbated a bottleneck within the HEP channel at Grand Junction Road crossing. The additional flow caused flows to break out of the channel upstream of Grand Junction Road and spill across adjacent Indama Street and Birralee Road (including surrounding industrial properties).

An upgrade to the Grand Junction Road culverts is required to ensure HEP channel can accommodate this increase in flows. The existing Grand Junction Road culverts (3 x 3000 x 1800 mm RCBC) were found to be a bottleneck within the HEP channel, with culvert crossings at upstream at Aruma Street consisting of 5 x 3300 x 1800 mm RCBC and downstream at Schumacher Road, consisting of 7 x 3000 x 2400 mm box culverts.

Two options could be considered in order to achieve increased capacity at the Grand Junction Road crossing; (1) an upgrade of the culverts under the Grand Junction Road or (2) a flood levee surrounding the banks of HEP channel upstream of Grand Junction Road.

The culvert upgrade option would require at least two additional 3000 x 1800 mm RCBC cells under Grand Junction Road/ Gallipoli Drive intersection (a length of approximately 150 metres) for a total of 5 x 3000 x 1800 mm RCBC. This would provide adequate capacity to convey the full 1% AEP post-development/post-upstream upgrade flow of 25 m^3/s.

The cost for the culvert option is estimated to be $2,600,000.

The levee option would require construction of a levee around both sides of the channel from Grand Junction Road to approximately Myuna Street, 470 metres to the south. The levee (likely a combination of earthen embankment and concrete wall) would create a greater headwater depth on the upstream side of the Grand Junction Road culverts, allowing more flow to pass through the existing culvert system. This option was considered as an alternative to the additional culverts due to the cost and construction difficulties involved in building large culverts through a busy intersection.

The levee is required to be constructed to a level of 5.3 mAHD, approximately 1.5 metres above the lowest point, with an average height above natural of 800mm with an assumed 1:3 batter and 1 metre top width. Modelling of the flood levee was found to contain water in all flood events up to and including the 1% AEP event, and provide over 300 mm freeboard to the highest water level observed in the channel.

As a result of the raised water level in the channel following the inclusion of the levee into the model, a number of non-return valves are required to prevent water flowing up stormwater pipes and causing water to spill through private property. These are required at the Grand Junction Road crossing, but also further upstream in order to protect private property from inundation.

The levee is a less desirable option due to the residual flood risk to surrounding properties associated with the backwater effect within HEP channel, potential levee failure or blockage of the culverts.

The cost of the levee option is estimated to be $920,000.

The four upgrades (D1-A, B, C and D) above were found to substantially reduce the extent and depth of flooding in all modelled storm frequencies. In the 0.2 EY storm event, almost all ponding through private property in the low spot, on the corner of Regency Road and William Street, and in the surrounding streets is removed by the upgrades. In the 5% AEP (20 year ARI) storm event, there is less improvement in surrounding streets, however there is practically no flooding impact on private property along Charles Street. In the larger storm events, the impact of the upgrades is less prominent, but there is still a substantial improvement.

The total cost for these drainage works (D1-A to D1-D) is estimated to be approximately $25 million (levee option).

These four components aim to address Objectives O1 (flood protection) and O2 (underground drainage performance) as per the Objectives outlined in Table 3-2.

D2: Talbot Road / Overland Road – Drainage (Objectives O1 and O2)

A new drain is recommended on Overland Road, Talbot Road and connecting into the large trunk drain at Cowley Avenue. This drain ranges from a 600mm diameter RCP at the upstream end to a 1500mm diameter RCP before connecting into the existing twin 1950mm diameter RCPs running north.

The existing drainage on Charron Road and Berliet Street connects into the drain in Overland Road before joining into the large downstream trunk drains. In all modelled storm events from 0.2 EY to 1% AEP, the Hydraulic Grade Line (HGL) in the downstream trunk drain is very high, preventing the lateral systems within Overland Road, Charron Road and Berliet Street from draining effectively and resulting in above surface ponding and spill through private property.

Modelling indicates that the new drain will achieve a 1% AEP (100 year ARI) flood protection standard, with only very minor residual property inundation occurring along Charron Road, Overland Road, Sunbeam Road and Berliet Street. Figure 4-9 shows a before and after for this upgrade, displaying the impact of the works.

The cost for these drainage works is estimated to be $2,550,000.

These works aim to address Objectives O1 (flood protection) and O2 (underground drainage performance) as per the Objectives outlined in Table 3-2.

4.8.2 North Arm West Catchment

D3: Laurel Avenue / Hudson Avenue – Drainage, Detention (Objectives O1 and O2)
Properties on and around Laurel Avenue and Hudson Avenue were found to be vulnerable to widespread ponding in events as frequent as the 5% AEP (20 year ARI) storm. As shown in the existing scenario flood maps, the ponding in this area is quite significant even in the 5% AEP storm, with a much larger impact in less frequent storm events.

To reduce flooding in these areas, it is proposed to construct a new storage basin on a vacant plot of land on Days Road, opposite Gray Street (refer Figure 4-8). It is proposed to upgrade the drainage in Laurel Avenue and direct it into this new basin. Additionally, it is recommended that the Hudson Avenue system be upgraded and redirected such that it drains to Days Road (rather than the Harrison Road drain to the east). At the Days Road connection, the basin is to act as both a detention storage and surcharge system in large events, allowing the Days Road trunk to surcharge in large events. The basin is to have a volume of 18,000 m³.

Figure 4-8 – Proposed Site of Detention Basin

The drainage in Laurel Avenue ranged from a 900mm diameter RCP to a 2400mm x 1200mm RCBC at the inlet to the basin, with a box culvert being used due to the limited vertical space in the road. It is proposed that the Hudson Avenue drain be split off from the drain beneath South Road and directed into the basin via a new pipe ranging in size from 750mm at the upstream end to 1350mm at the inlet to the basin.

The upgrade also includes an upgrade of the Packard Avenue system and the pits on the corner of Gray Street and Standard Avenue, which are both to be disconnected from the small, local drainage system and redirected into the detention basin.

The proposed upgrades were found to provide a 1% AEP (100 year ARI) flood protection standard along Hudson Avenue, Packard Avenue, Rugby Avenue and Gray Street. The extent of water ingress along Laurel Street, Margitich Street and Hardy Street is also substantially reduced in the 1% AEP storm, with very little residual ponding through private property. Figure 4-10 and Figure 4-11 show the existing and upgrade flood maps, demonstrating the effectiveness of the solution.

In order to proceed with this upgrade, the site of the recommended basin would need to be purchased. This cost has been excluded from the provided cost estimate. The cost for these drainage works is estimated to be $4,930,000.

These works aim to address Objectives O1 (flood protection) and O2 (underground drainage performance) as per the Objectives outlined in Table 3-2.

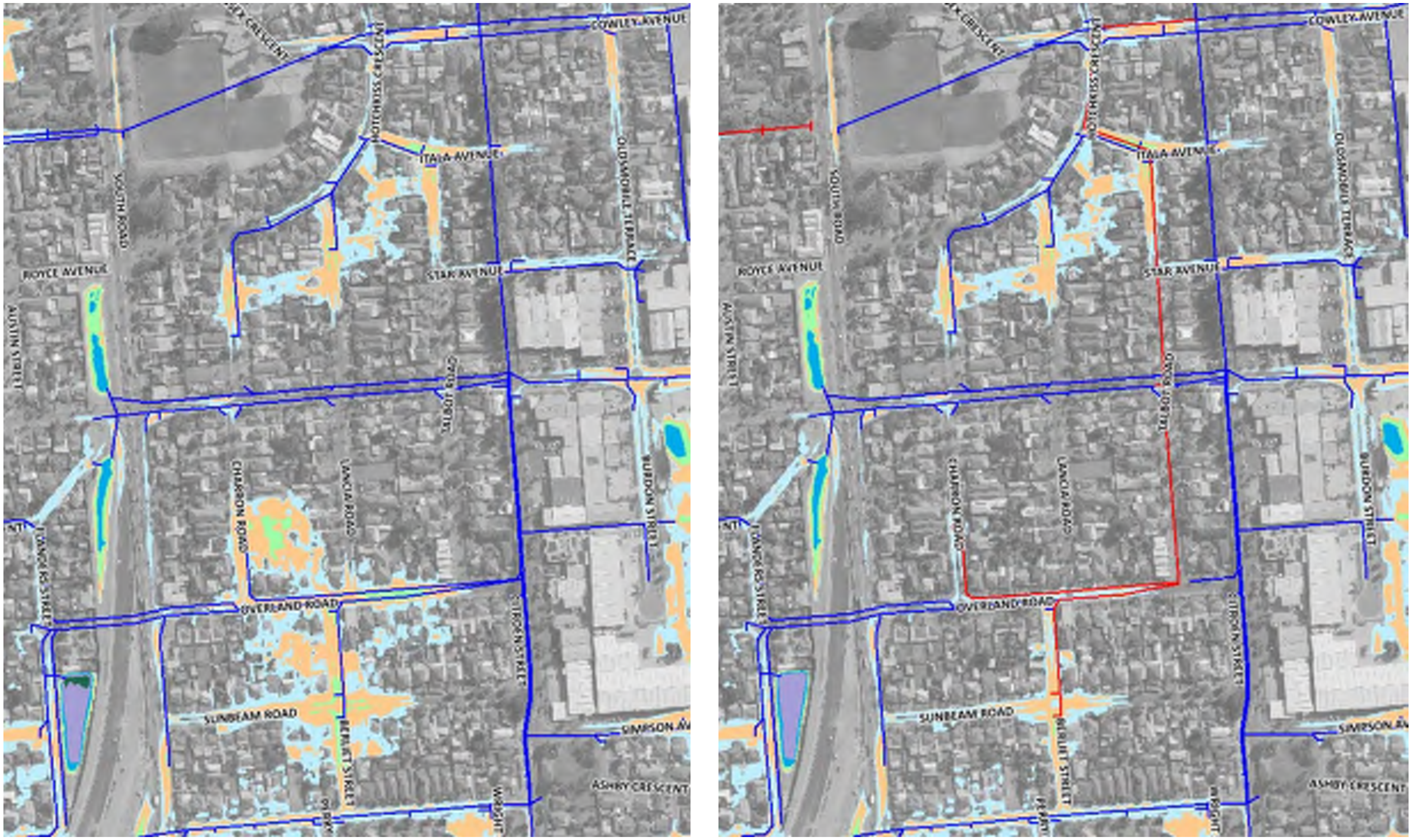


Figure 4-9 – D2 Existing (left) and Upgrade (right) 1% AEP Flood Map

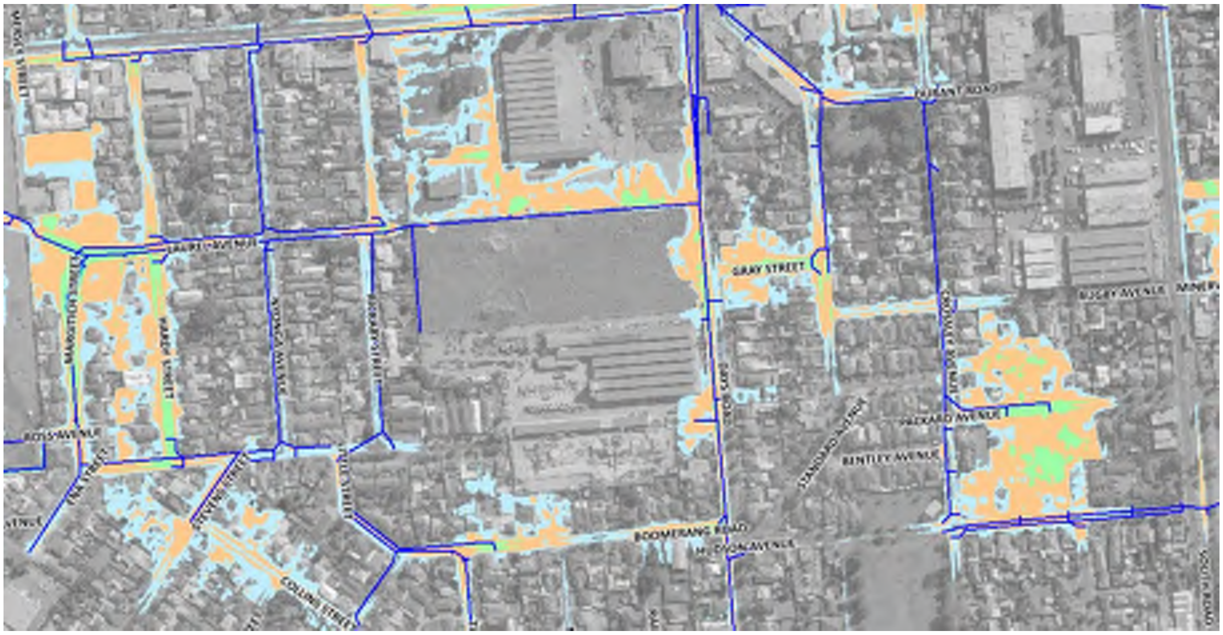


Figure 4-10 – D3 Existing 1% AEP Flood Map

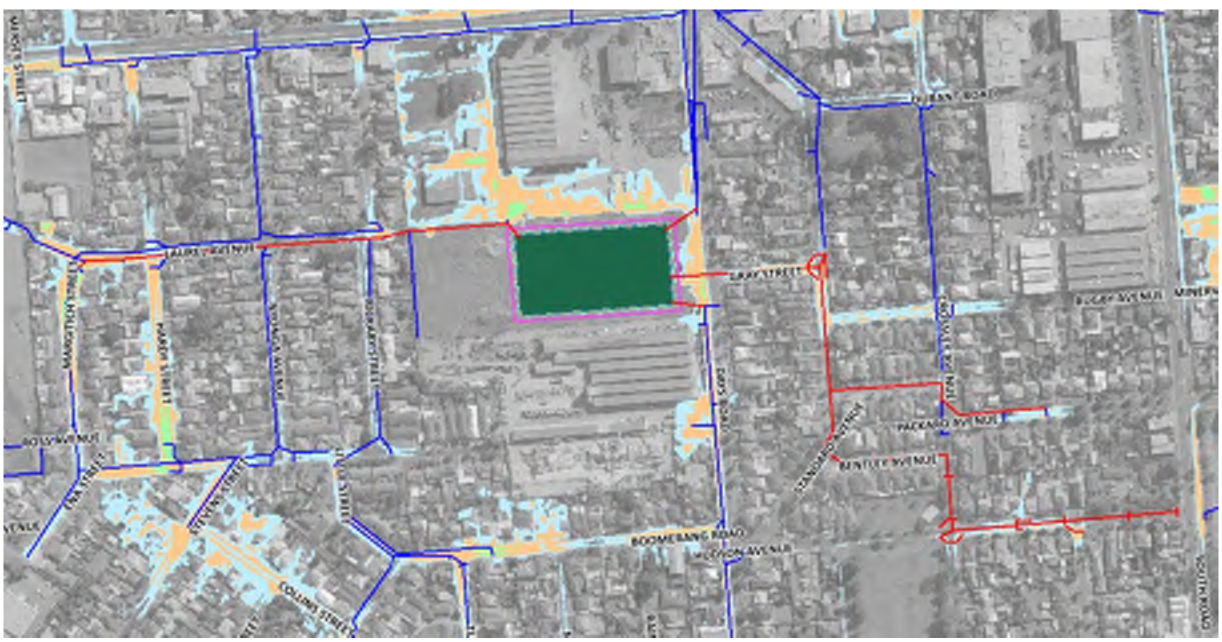


Figure 4-11 – D3 Upgrade 1% AEP Flood Map

D4: Ridley Grove – Detention (Objectives O1, O9)
An upgrade to the detention storage volume within Mikawomma Reserve (refer Figure 4-12) on the corner of Ridley Grove and Liberty Grove is proposed, increasing the available detention volume for larger storms. For the purposes of flood modelling, this has been achieved by erecting a levee along the perimeter of the reserve, however the same result could be achieved alternatively through earthworks or lifting the perimeter footpath levels.

Figure 4-12 – Mikawomma Reserve

In the 1% AEP (100 year ARI) storm event, there is widespread flooding through properties between Ridley Grove and Essex Street, as the capacity of the basin is exceeded. It was not found practical to provide a 1% AEP flood protection standard in this location, as the level of earthworks required within the basin would be very substantial, vastly diminishing the amenity value of Mikawomma Reserve. As a result, a 5% AEP flood protection standard was chosen as the desired level of service.

The existing detention volume within the reserve was estimated at approximately 2200 m^3, and an upgraded volume of approximately 3800 m^3 was assumed within the model. In order to achieve this volume, the levee/footpath would require to be lifted by a maximum of 300 mm above natural (to the 6.2mAHD contour level. This increased capacity was found to provide a 5% AEP flood protection standard for almost every property between Ridley Grove and Essex Street, with shallow ponding observed through just a handful of properties.

The cost for these drainage works is estimated to be $280,000.

These works aim to address Objectives O1 (flood protection) and O9 (multi-objective outcomes) as per the Objectives outlined in Table 3-2.

D5: Short Street / Frederick Street / John Street – Drainage (Objectives O1 and O2)
Replacement of the existing underground drains from Short Street to Clara Street, along John Street, discharging into the NAW open channel is recommended. Short Street and Clara Street are problem areas with significant roadway ponding and property inundation in the larger storm events (5% AEP and greater). A new box culvert is proposed, ranging in size from 1800mm x

600mm at the outlet from John Street, to 900mm x 450mm on Short Street. Due to the low ground surface elevations at the intersection of Clara Street and Frederick Street, a wide box culvert with a low height was required to provide the desired flow rate.

The upgrades recommended are effective at protecting properties in events up to and including the 1% AEP storm, with water instead breaking out of the NAW grassed open channel further downstream and ponding through the carpark of an industrial property. This new ponding caused by the upstream drainage upgrades could likely be mitigated with an upgrade to the NAW open channel, such as increasing its capacity or constructing a raised levee in this location.

The cost for these drainage works is estimated to be $1,780,000.

These works aim to address Objectives O1 (flood protection) and O2 (underground drainage performance) as per the Objectives outlined in Table 3-2.

D6: Wing Street / Miller Road – Drainage, Detention (Objectives O1 and O2)
In the downstream, industrial area of Wingfield, properties to the west of South Road were found vulnerable to ponding in storm events as frequent as the 0.2 EY (5 year ARI). The high water level in the open channel beneath the South Road Superway acts as a restriction for the surrounding stormwater drainage networks, preventing water from draining and causing surface ponding.

It is recommended to construct a detention basin in the open space between East Terrace and Phillis Street (refer Figure 4-13), in order to reduce the extent and depth of ponding through industrial properties. The existing 825mm diameter pipe through this land is to be removed and replaced with a basin inlet and outlet. A maximum detention depth of 1.5 metres below the natural surface was assumed.

Despite the basin being quite low-lying, regions of far lower elevation in the Barker Inlet Wetlands appear to be above the level of the groundwater table, so it is not anticipated that groundwater would impact on the function of the basin.

Figure 4-13 – Location of Proposed Detention Basin

It is also recommended to upgrade the pipe leaving the northern end of Millers Road, adding a non-return valve, to prevent water backing up this system and spilling through the adjacent industrial properties.

The proposed upgrades were found to reduce the amount of ponding on roads and property inundation in up to the 1% AEP (100 year ARI) storm event. The non-return valve was found to reduce the flooding in the industrial properties on Millers Road, however there was still some residual ponding in the 1% AEP flood.

The cost for these drainage works is estimated to be $340,000.

These works aim to address Objectives O1 (flood protection) and O2 (underground drainage performance) as per the Objectives outlined in Table 3-2.

D7: Napier Street and St Johns Avenue – Drainage, Detention (Objectives O1, O2 and O9)
An upgrade of the existing underground drainage system in Napier Street and St Johns Avenue is recommended. The upgrade is to extend from Napier Street to the Sam Johnson Sportsground and aims to resolve flooding of multiple properties in the Napier Street trapped low spot and St Johns Avenue catchments.

To ensure the upgrades do not diminish the capacity of the downstream stormwater system, a detention storage is recommended within the open space/soccer pitch area of the Sam Johnson Sportsground. An underground detention storage could be considered for detention such that ongoing use of the soccer pitch is possible (i.e. not converted to an open air detention basin). A detention storage of 1500 m^3 was assumed within the stormwater models. This could be achieved by use of reinforced concrete box culverts, pipes or detention storage cells (i.e. Humes StormTrap or equivalent).

Underground detention can also potentially incorporate 'leaky' floors which reduce the overall volume of water flowing through to downstream systems with potential water quality benefits. Underground detention was demonstrated recently within City of Charles Sturt as part of the Port Road Stage 3 Stormwater Upgrade, as shown below.

Figure 4-14 – Example of underground detention storage – during construction (left) and post-construction (right), (Port Road, Southfront 2019)

Modelling indicates these upgrades could provide an underground drainage capacity and property protection standard up to the 5% AEP event. It should be noted that with larger detention storage (and further upgrade of underground pipes) a 1% AEP drainage standard could potentially be achieved, however modelling shows that the capacity of downstream trunk drainage within Harris Road will form a limitation on the drainage capacity at this location.

The cost for these drainage works is estimated to be $2,170,000.

These works aim to address Objectives O1 (flood protection), O2 (underground drainage performance), and O9 (multi-objective outcomes) as per the Objectives outlined in Table 3-2.

D8: Barker Inlet Wetland Floodgate Outlet Structures (Objectives O1, O5, O6 and O9)
As part of stormwater modelling for this study, it was assumed all tidal gates were operating as intended, preventing sea water intrusion through the wetland and further upstream into the catchment. In reality however, the major outlet gates from Barker Inlet Wetland through the seawall are known to be in disrepair, corroded and in need of replacement.

Tidal gate replacements are recommended to ensure ongoing protection of the wetlands from excessive tidal inflows (particularly into the freshwater zone of the wetland) and protection of upstream catchments from high tides and to reduce the risk of diminishing the capacity of upstream stormwater systems.

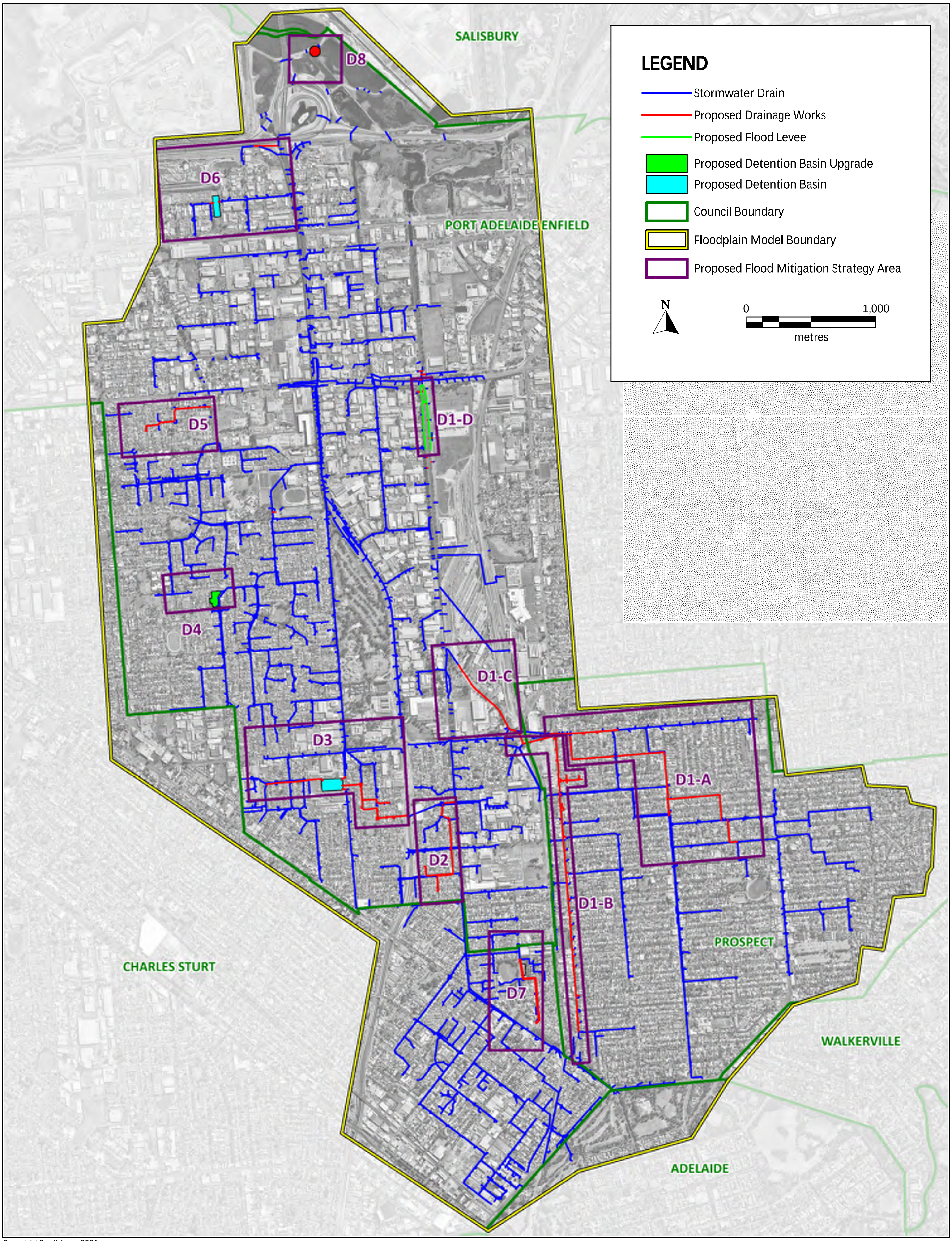
The following tidal gates will require repair or replacement:

- 3 x 2700 mm x 1200 mm box culvert - penstock tidal gates only;
- 4 x 750 mm RCPs - flap gates and penstock tidal gates;
- 3 x 1050 mm RCPs - flap gates and penstock tidal gates; and
- 2 sets of 2 x 1500 mm x 600 mm box culverts - penstock tidal gates only.

See Figure 2-6 for the outlet structure arrangement.

The cost for these works is estimated to be $1,400,000 (supplied by Council). This cost includes installation of actuators for automated operation of all penstock gates.

These works aim to address Objectives O1 (flood protection), O5 (improved end state values for receiving waterways) and O6 (sustainable management) as per the Objectives outlined in Table 3-2.



Data Sources:
Southfront (Flood Strategies)
NearMap (Aerial Photograph)
City of Port Adelaide Enfield, City of Prospect and City of Charles Sturt (Stormwater Data)

Barker Inlet Central
Stormwater Management Plan
Proposed Flood Mitigation Works - Overview Plan
Figure 4-15

southfront

4.8.3 Non-structural Measures

To complement the proposed structural options, a number of non-structural flood mitigation options are also recommended. Non-structural options are typically low cost (relative to structural measures) and hence are extremely cost effective with respect to the flood damage reductions that they achieve.

D9: Community Flood Response and Preparedness – SES Community FloodSafe Program (Objective O8)
The State Emergency Service (SES) deliver their FloodSafe and StormSafe program in schools and the community throughout the area, to help build community resilience and understanding about flood risk. Community FloodSafe is a partnership between local Councils and State and Federal governments. The FloodSafe program uses existing SES volunteers, as well as new community volunteers with good presentation skills, to reach into communities to raise awareness in flood-prone areas. Initiatives include articles in Council newsletters, street corner meetings, community group meetings, internet sites, brochures and school education.

The volunteers talk to community groups, local residents, businesses and schools about what they can do to reduce the risk of flood damage and improve the resilience of their community if a flood should occur. FloodSafe volunteers typically address communities on:

- Local risks and historic flooding in the area;
- Having a flood plan to reduce the risk to business equipment, stock and staff;
- Protecting family and property;
- Understanding BOM Flood Watch and Flood warnings;
- Having a home emergency kit; and
- How to call for SES response.

Since its inception in 2009, many metropolitan and regional South Australian councils have joined the FloodSafe program. Councils may also elect to make the floodplain mapping of the Barker Inlet Central catchment available via their websites, along with advice to residents on measures they can take to reduce their flood risk and steps to preparing a Personal Flood Action Plan.

These recommendations aim to address Objective O8 (community awareness) as per the Objectives outlined in Table 3-2.

D10: Community Flood Response and Preparedness – Council's Community Emergency Management Plan (Objective O8)
The Cities of Port Adelaide Enfield and Prospect have produced Community Emergency Management Plans, and the City of Charles Sturt has produced a Community Emergency Management Policy, all with the purpose of collectively developing skills which provide the community with:

- Knowledge of the emergency risks that exist in the local area;
- Information to support the role that each member of the community can have in an emergency;
- A platform to connect with each other and council before, during and after an emergency; and

- The ability to support each to become resilient in an emergency event or disaster.

The Community Emergency Management documents are currently available on the websites of all three Councils. The sections of the documents focussed on flooding provide information on how the community should **prevent, prepare, respond** and **recover** from a flood emergency arising from either storm activity or sea water intrusion. Councils may also elect to make the floodplain mapping for Barker Inlet Central publicly available via their websites, along with advice to residents on measures they can take to reduce their flood risk and steps to take to prepare a Personal Flood Action Plan.

These recommendations aim to address Objective O8 (community awareness) as per the Objectives outlined in Table 3-2.

D11: Development Controls – Floor Levels (Objective O7)
It is recommended that Councils continue to ensure that all new development in the Barker Inlet Central area has a floor level that provides at least 200 mm freeboard to the 1% AEP floodplain, as depicted on the floodplain maps of the area. The finished floor level of existing properties that have been shown to be at risk of flooding will be surveyed during the design development phase of flood mitigation works.

It should be noted that at a number of locations throughout the study area, flood modelling indicates ponding would within a small number of residential properties would occur during the 1% AEP event. Flood mitigation works would be required to resolve these issues. However, due to the type and age of affected properties, the high likelihood of redevelopment and the likely cost involved in providing structural mitigation works, it was decided that floor level development control would be preferable in these locations. This approach was undertaken in consultation with the Project Steering Committee.

Locations where development controls were preferable to flood mitigations works included:

- Durham Terrace, Ferryden Park (5 properties affected by the 1% AEP, 3 vacant, 2 older stock)
- Fourth Avenue, Woodville Gardens (6 properties of older stock)
- Longford Crescent, Ferryden Park (7 properties of older stock)
- Nairn Street, Ferryden Park (4 properties of older stock)

This recommendation aims to address Objective O7 (planning controls) as per the Objectives outlined in Table 3-2.

D12: Ongoing Maintenance and Monitoring of Council Assets (Objective O6)
All three Councils have developed various Asset Management Plans for managing their stormwater infrastructure. The goal of these plans is to ensure processes are in place for the required maintenance, monitoring and capital renewal of Council assets and to ensure it is done in a financially sustainable way. The Councils also keep records of all of their stormwater assets in GIS form. It is recommended that the Councils maintain the Asset Management Plans as live documents, continually updating them when required as issues are identified. It is also recommended that the Councils' GIS systems are continually updated with any new infrastructure as it is constructed, and filled in where gaps may exist.

These recommendations aim to address Objective O6 (monitoring and management plans) as per the Objectives outlined in Table 3-2.

4.9 Flood Mitigation Benefits Evaluation

The residual flood damages associated with the ultimate development scenario and proposed upgrades have been evaluated, consistent with the methodology outlined in Section 4.7, as summarised in the tables below.

Table 4-17 – Residential Damages, Ultimate Development / Upgraded Drainage

AEP	No. of Residential Properties Inundated at each Depth Range						Damage Estimate
	0 – 0.1	0.1 – 0.15	0.15 – 0.25	0.25 – 0.5	0.5 – 1.0	1.0 – 1.5	
0.2 EY	127	20	7	1	0	0	$1,087,125
5% AEP	285	98	50	8	4	1	$5,424,900
2% AEP	404	204	128	26	7	1	$12,193,155
1% AEP	425	408	180	117	17	1	$23,120,370

Table 4-18 – Commercial - Office Damages, Ultimate Development / Upgraded Drainage

AEP	No. of Office Properties Inundated at each Depth Range						Damage Estimate
	0 – 0.1	0.1 – 0.15	0.15 – 0.25	0.25 – 0.5	0.5 – 1.0	1.0 – 1.5	
0.2 EY	9	3	0	0	0	0	$1,162,512
5% AEP	15	8	2	0	0	0	$2,508,840
2% AEP	28	13	8	0	0	0	$4,949,784
1% AEP	25	28	17	4	1	0	$8,146,692

Table 4-19 – Commercial - Retail Damages, Ultimate Development / Upgraded Drainage

AEP	No. of Retail Properties Inundated at each Depth Range						Damage Estimate
	0 – 0.1	0.1 – 0.15	0.15 – 0.25	0.25 – 0.5	0.5 – 1.0	1.0 – 1.5	
0.2 EY	5	1	0	0	0	0	$906,231
5% AEP	15	2	0	0	0	0	$2,536,257
2% AEP	16	7	3	0	0	0	$4,140,504
1% AEP	15	15	4	2	0	0	$6,875,061

Table 4-20 – Industrial Damages, Ultimate Development / Upgraded Drainage

AEP	No. of Industrial Properties Inundated at each Depth Range						Damage Estimate
	0 – 0.1	0.1 – 0.15	0.15 – 0.25	0.25 – 0.5	0.5 – 1.0	1.0 – 1.5	
0.2 EY	1	2	1	0	0	0	$1,137,967

5% AEP	6	3	2	1	0	0	$3,527,013
2% AEP	7	9	5	2	0	0	$7,138,549
1% AEP	11	9	14	2	1	0	$11,696,009

Table 4-21 – Total Damages, Ultimate Development / Upgraded Drainage

AEP	Residential	Commercial – Office	Commercial – Retail	Industrial	Total
0.2 EY	$1,087,125	$1,162,512	$906,231	$1,137,967	$4,293,835
5% AEP	$5,424,900	$2,508,840	$2,536,257	$3,527,013	$13,997,010
2% AEP	$12,193,155	$4,949,784	$4,140,504	$7,138,549	$28,421,992
1% AEP	$23,120,370	$8,146,692	$6,875,061	$11,696,009	$49,838,132

The total reduction in direct tangible damages when comparing the upgraded drainage scenario to the existing drainage scenario is shown in Table 4-22.

Table 4-22 – Potential Reduction to Damages

AEP	Existing Damages	Upgraded Damages	Reduction in Damages	Reduction in Damages (%)
0.2 EY	$7,182,008	$4,293,835	$2,888,173	40%
5% AEP	$25,224,559	$13,997,010	$11,227,549	44%
2% AEP	$41,864,089	$28,421,992	$13,442,067	32%
1% AEP	$64,273,337	$49,838,132	$14,435,205	22%

Due to the large extent of ponding through private property in even frequent events such as the 0.2 EY storm, particularly throughout Prospect, achieving a much greater reduction in damages would require an impractical amount of works. Instead, upgrades were focussed on the worst-affected areas, intending to substantially improve these.

A breakdown of the reduction in damages by catchment is shown in Table 4-23, and by Council in Table 4-24.

Table 4-23 – Reduction in Damages by Catchment

Catchment	Total Damages Estimate and Reduction per Catchment ($000)							
	0.2 EY		5% AEP		2% AEP		1% AEP	
	Est.	Red.	Est.	Red.	Est.	Red.	Est.	Red.
NAW	$1,066	$-	$3,178	$1,002	$5,850	$1,515	$9,414	$2,833
Dunstan Rd	$530	$-	$1,103	$-	$2,698	$-	$4,116	$-
HEP	$2,697	$2,888	$9,717	$10,225	$19,874	$11,927	$36,307	$11,602

Table 4-24 – Reduction in Damages by Council

Council	Total Damages Estimate and Reduction per Council ($000)							
	0.2 EY		5% AEP		2% AEP		1% AEP	
	Est.	Red.	Est.	Red.	Est.	Red.	Est.	Red.
PAE	$1,708	$8	$4,988	$1,197	$10,029	$2,135	$17,047	$4,600
COP	$2,528	$2,880	$8,600	$9,942	$16,969	$8,202	$28,171	$9,398
CCS	$58	$-	$409	$89	$1,424	$105	$4,620	$437

The number of properties shown to experience inundation of more than 50 mm in the upgrade scenario is presented by catchment in Table 4-25 and by council in Table 4-26. A direct comparison with the existing drainage scenario can be made by catchment in Table 4-4, and by council in Table 4-5, demonstrating the benefits of the proposed works in terms of property inundation. Floor level survey of properties that have been identified as vulnerable to stormwater ingress in the upgrade scenario would be required to confirm that the minimum performance standard has been achieved for flooding up to and including the 5% AEP storm event.

Table 4-25 – Property Inundation by Catchment, Ultimate Development / Upgraded Drainage

Catchment	Number of properties inundated > 50 mm			
	0.2 EY	5% AEP	2% AEP	1% AEP
Hindmarsh Enfield Prospect	160	458	771	1123
North Arm West	15	39	84	156
Dunstan Road	2	3	13	17
Total (Proposed) (% Reduction)	**177 (32%)**	**500 (30%)**	**868 (20%)**	**1296 (15%)**
Total (Existing)	**260**	**709**	**1090**	**1519**

Table 4-26 – Property Inundation by Council, Ultimate Development / Upgraded Drainage

Council	Number of properties inundated > 50 mm			
	0.2 EY	5% AEP	2% AEP	1% AEP
Prospect	152	428	670	885
Port Adelaide Enfield	23	56	139	252
Charles Sturt	2	16	59	159
Total (Proposed) (% Reduction)	**177 (32%)**	**500 (30%)**	**868 (20%)**	**1296 (15%)**
Total (Existing)	**260**	**709**	**1090**	**1519**

4.9.1 Average Annual Damages Reduction

The Average Annual Damage for the upgrades scenario was calculated based on the damage values above. The total AAD reduction as a result of the flood mitigation works was calculated to be $2.9m, an AAD reduction of $2.3m. AAD reductions for each LGA is shown in the table below.

LGA	Average Annual Damage (AAD) Value ($000)	Reduction amount Value ($000)
City of Port Adelaide Enfield	$1.1	$0.35
City of Prospect	$1.7	$1.90
City of Charles Sturt	$0.1	$0.05
Total	$2.9	$2.3

4.10 Flood Mitigation Strategy Action Summary

A consolidated summary of flood mitigation strategies across the Study Area is presented in Table 4-27. Each of the strategies listed below were developed in order to address the flooding issues identified in Section 4. The objectives addressed (as outlined in Table 3-2) column identifies the objective(s) for which the proposed works is addressing.

Table 4-27 – Flood Mitigation Strategy Action Summary

Project ID	Project Location / Type of Works	Flood ID Addressed	LGA/ Catchment	App D Sheet	Related WSUD Action	Budget Estimate	Design AEP	Objectives Addressed
D1-A	Prospect Road, Redin Street and Regency Road – Drainage	F1	CoP/HEP	01 - 03	Nil	$9,630,000	5% AEP (20 year ARI)	O1, O2
D1-B	Churchill Road – Drainage	F1	CoP/HEP	04 -07	Nil	$11,530,000	5% AEP (20 year ARI)	O1, O2
D1-C	HEP Upgrade, Pedder Cres to Narweena Rd – Drainage	F1	CoP/HEP	08	Nil	$3,890,000*	5% AEP (20 year ARI)	O1, O2
D1-D	HEP Upgrade, Grand Junction Road – Drainage	F1	CoP/HEP	09	Nil	940,000	1% AEP (100 year ARI)	O1, O2
D2	Talbot Road and Overland Road – Drainage	F2	PAE/HEP	10 – 11	Nil	$2,550,000	1% AEP (100 year ARI)	O1, O2
D3	Hudson Avenue and Laurel Avenue – Drainage and Detention	F3, F4	HEP/NAW	12 – 13	Multi-objective WSUD	$4,930,000*	1% AEP (100 year ARI)	O1, O2
D4	Ridley Grove – Detention	F7	PAE/NAW	14	Multi-objective WSUD	280,000	5% AEP (20 year ARI)	O1, O9
D5	Short Street, Frederick Street and John Street - Drainage	F8	PAE/NAW	15	Nil	$1,780,000	1% AEP (100 year ARI)	O1, O2
D6	Wing Street and Miller Road – Drainage and Detention	F10	PAE/NAW	16	Multi-objective WSUD	$340,000	1% AEP (100 year ARI)	O1, O2
D7	Napier Street – Drainage Upgrade and Detention	F11	CoCS/HEP	17	Multi-objective WSUD	2,170,000	5% AEP (20 year ARI)	O1, O2, O9

Project ID	Project Location / Type of Works	Flood ID Addressed	LGA/ Catchment	App D Sheet	Related WSUD Action	Budget Estimate	Design AEP	Objectives Addressed
D8	Barker Inlet Wetland Tidal Gate Replacement	-	PAE/ALL	N/A	Multi-objective WSUD	$1,400,000	1% AEP (100 year ARI)	O1, O5, O6
D9	Community Flood Response and Preparedness – FloodSafe Program	N/A	N/A	N/A	N/A	N/A	N/A	O8
D10	Community Emergency Management Plan	N/A	N/A	N/A	N/A	N/A	N/A	O8
D11	Development Controls – Floor Levels	F5, F6, F9	N/A	N/A	N/A	N/A	N/A	O7
D12	Ongoing Maintenance and Monitoring of Council Assets	N/A	N/A	N/A	N/A	N/A	N/A	O6
					TOTAL	39,100,000		

Note: * The budget estimate for this strategy does not include the cost of land acquisition necessary for construction of the infrastructure.

5 Water Sensitive Urban Design

5.1 Receiving Waters

Stormwater runoff from the Barker Inlet Central catchments discharges into the Barker Inlet Wetlands followed by North Arm Creek and ultimately the Gulf of St Vincent.

The Barker Inlet Wetland is situated at the downstream end of each major catchment being assessed in the SMP. These wetlands play an import role in improving the water quality before it is discharged into the North Arm Creek. The Barker Inlet Wetland is a constructed wetland designed to use vegetation, enhanced sedimentation, fine filtration and biological pollutant uptake processes to improve water quality.

The wetlands also provide habitats to numerous native birds with over 130 different bird species recorded in the area. The wetlands provide habitat for other native fauna such as replies, frogs and fish.

The habitats most likely to be impacted by water discharged from the wetlands are those along the North Arm Creek, Eastern Passage, Angus Channel and minor channels surrounding Torrens Island. Stormwater dilution away from outfalls will vary greatly over the area due to hydrodynamics, also affecting the load and concentration of contaminants reaching different areas.

5.2 Potential Risks from Stormwater Outflows

Potential risks from stormwater are increased suspended sediments, which have impacts through light reduction (turbidity) and sedimentation, nutrients, other contaminants such as metals, pesticides, hydrocarbons, and emerging organic contaminants, and reduced salinity due to freshwater inputs (Gaylard 2009b). The ACWS and other investigations on the Adelaide coast have demonstrated negative impacts to reef and seagrass habitats, particularly from sediments and nutrients (Gorgula and Connell 2004; Turner 2004; Fox *et al.* 2007; Gorman *et al.* 2009).

5.2.1 Risks to habitats in the vicinity of stormwater outfalls

In the case of the Barker Inlet Central catchments, all stormwater outfalls are directed to the Barker Inlet Wetlands. As stated these wetlands are designed to treat the stormwater before it eventually reaches the Barker Inlet and St Vincent Gulf. While the wetlands provide this water quality improvement function, they also provide key habitat for a number of flora and fauna species. Hence, it is important that the wetlands are able to manage the amount of pollutants being discharged into them and ensure they are not degraded.

If the wetlands are not functioning correctly and taking on a pollutant load that is too great, then there is an increased risk to habitats further downstream of the wetlands. Habitats in the immediate vicinity of wetlands outfalls would be at most risk. The load and concentration of pollutants reaching marine environments away from these outfalls will be determined by local hydrodynamics, but it is likely that contaminants will be rapidly diluted away from outfalls.

In addition to contributing to chronic nutrient effects on a wider scale, local impacts from stormwater nutrients, such as blooms of harmful dinoflagellates (red tides), or increased growth of opportunistic (*Ulva* spp.) or invasive (*Caulerpa* and *Codium* spp) green algae, could occur in the vicinity of outfalls to the Barker Inlet Wetlands and the Barker Inlet more generally if nutrient levels are too high. The expansion of *Zostera* seagrass in the Port River and Barker Inlet could be threatened or potentially reversed by elevated nutrients, and the mangrove and saltmarsh habitats of southern Barker Inlet and Mangrove Cove would be at risk from nutrient inputs from the Barker Inlet Central catchments. In particular, mangroves may be impacted by *Ulva* through reduced recruitment of new trees and smothering of pneumatophores (Edyvane 1999; Harbison 2008). Saltmarshes can also be negatively impacted by stormwater contaminants, including nutrients and metals, with effects including shifts in community composition, reduced saltmarsh cover, or increased incidence of introduced species (Geedicke et al. 2018). Although phosphorus is not noted as being of concern currently in Adelaide waters, phosphorus inputs can promote algal blooms where nitrogen is not limiting (EPA 2008; McDowell and Pfennig 2011).

Stormwater is likely to be major contributor to local turbidity, and, given the correlation between TSS and other contaminants (Mills and Williamson 2008), habitats surrounding outfalls could be at risk of impacts from these pollutants, particularly metals. Mangrove habitats are at greatest risk due to the propensity of metals to accumulate in mangrove muds, while *Zostera* would be at risk from turbidity and sedimentation.

5.3 Water Quality Modelling Approach

An estimation of the pollutant loads and concentrations within stormwater discharges from the urban catchment to the receiving waterbodies has been undertaken. The MUSIC (Model for Urban Stormwater Improvement Conceptualisation) computer software package developed by the Cooperative Research Centre for Catchment Hydrology has been used for this purpose.

MUSIC can be used to simulate the quantity and quality of runoff from stormwater catchments, and predict the performance of stormwater quality management systems. The MUSIC model requires user defined meteorological and catchment data to estimate the quantity and quality of stormwater runoff for a given catchment, as described below.

5.3.1 Meteorological Data

The meteorological data templates used for this project were compiled using average monthly potential evapo-transpiration (PET) values for Adelaide, and 6 minute rainfall data from a gauge at Adelaide Airport for the years 1996-2001. The average annual rainfall for this period was 485 mm (compared to the annual average rainfall of 482 mm for the Barker Inlet Central area for the years 1876 - 2019).

It is noted that the average annual rainfall for the Barker Inlet Central Catchment area varies from north to south due to the large area the study area covers. Average annual rainfall at the northern end closer to the coast is in the low 400s (mm) while towards the southeast of the study area, average annual rainfall is in the low 500s (mm). The chosen value of 484 mm is for the central region of the study area and the best representation of the whole area.

5.3.2 Catchment Area and 'Effective Impervious' Fraction

The 'effective impervious' fraction adopted in MUSIC should correspond to the 'directly connected paved' (DCP) portion of the catchment area. The stormwater runoff volumes estimated by MUSIC are highly sensitive to this value.

The MUSIC models compiled for the Barker Inlet Central catchments are based on the ultimate development scenario, and the typical 'effective impervious' fractions for development in the Study Area were estimated to be:

- 0.2 to 0.3 for low density residential development;
- 0.4 to 0.6 for high density residential development; and
- 0.6 to 0.8 for high density commercial and industrial developments.

These values were adjusted for individual subcatchments based on the relative proportions of urban development and open space within the subcatchment area under the ultimate development scenario; hence the 'effective impervious' fractions for the MUSIC subcatchments varied from 0.01 to 0.9.

5.3.3 Rainfall-runoff Parameters

A 'rainfall threshold' of 1 mm has been adopted for the impervious areas (commonly referred to as the initial loss), which is consistent with the industry standard approach to hydrological modelling of urban catchments.

A 'soil storage capacity' of 40 mm and 'field capacity' of 30 mm have been adopted for the pervious areas, which is consistent with MUSIC's recommended values for the Adelaide region. The stormwater runoff volumes estimated by MUSIC are not sensitive to variation in parameters defining the pervious area response to rainfall (except where impervious fractions are low).

5.3.4 Pollutant Load Parameters

MUSIC's default pollutant load parameters have been adopted for Total Suspended Solids (TSS), Total Nitrogen (TN) and Total Phosphorus (TP), which are based on a comprehensive review of worldwide stormwater quality in urban catchments undertaken by Duncan (1999), supplemented by local data specific to regional applications.

MUSIC's default pollutant load parameters have also been adopted for Gross Pollutants (GP), which are based on field monitoring data of Allison et al (1997) for 12 storm events in an inner city suburb.

The above parameters are consistent with those recommended for use in *Chapter 15 - Modelling Process and Tools, Water Sensitive Urban Design Technical Manual for the Greater Adelaide Region* (Department of Planning and Local Government, 2010).

5.3.5 Model Structure and Output

The individual pit level subcatchments from the DRAINS model described in Section 4 were aggregated into larger catchments, based on areas of similar land use and/or to reflect the contributing area to specific points of interest in the stormwater management system (i.e. outfalls, location of treatment measures). This approach enables estimates to be obtained of the quantity and quality of runoff at these points of interest, and guides the development of the water quality improvement strategy for the catchment.

MUSIC can provide summary results for each point of interest as follows:

- Sources – the annual pollutant loadings and quantity of water that arrive at outlet under no treatment;
- Residual – the annual pollutant loadings and quantity of water that arrive at outlet with the included treatment devices; and
- Percent reduction – the percentage reduction in pollutant loadings as a result of the included treatment devices (ie. between the Sources and Residual loadings).

The MUSIC models for the Barker Inlet Central catchments have been structured to enable results to be reported for each major catchment discharging into the Barker Inlet Wetlands.

5.3.6 Barker Inlet Wetlands MUSIC Model – Northern Connector

The Barker Inlet Wetlands (BIW) is designed to treat stormwater runoff from the whole Barker Inlet Central Study Area before it enters North Arm Creek. Hence it is an important treatment node to include in the MUSIC model.

The northern basin of the BIW has gone under significant change due to the Northern Connector project which was completed early 2020. Figure 5-1 provides an overview of the changes made to the northern basin of the BIW. Details of the changes to the wetland are described in documentation provided by the 'Jacobs-Arup Joint Venture' (JAJV), *DP-0206 Annexure F2 Wetland Water Treatment - Modelling Report (August, 2017)*. A requirement of the new wetland design was that the water treatment performance is maintained or improved. The report states that the proposed wetland configuration maintains the existing stormwater treatment effectiveness and is more effective than the guideline targets.

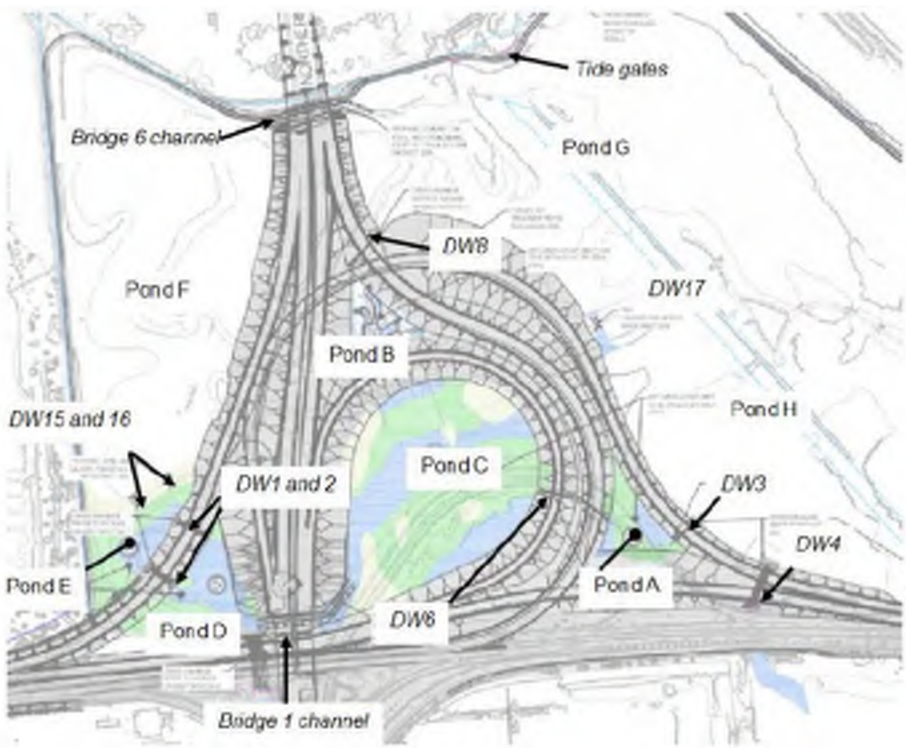


Figure 5-1 – BIW layout and concept sketch (taken from the *Northern Connector Project Detailed Design, Jacobs Arup Joint Venture, DP-0206 Annexure F2 Wetland Water Treatment - Modelling Report*)

A MUSIC model of the proposed wetlands was created by JAJV, with its catchment and treatment node arrangement shown in Figure 5-2. Model parameters and inputs were outlined with the report and were able to be replicated as part of the MUSIC model developed for this SMP. Incorporating the wetland model into the BIC MUSIC model allows for an assessment of the wetland's ability to improve the water quality of stormwater runoff from the BIC catchments and provide an estimate of the water quality discharging into Barker Inlet. For modelling purposes, the North Arm East catchment (outside of the scope of this study) was also incorporated into the model based on catchment input values obtained from the modelling report.

Note that the BIW treatment nodes were not included in the baseline model, described in the following section.

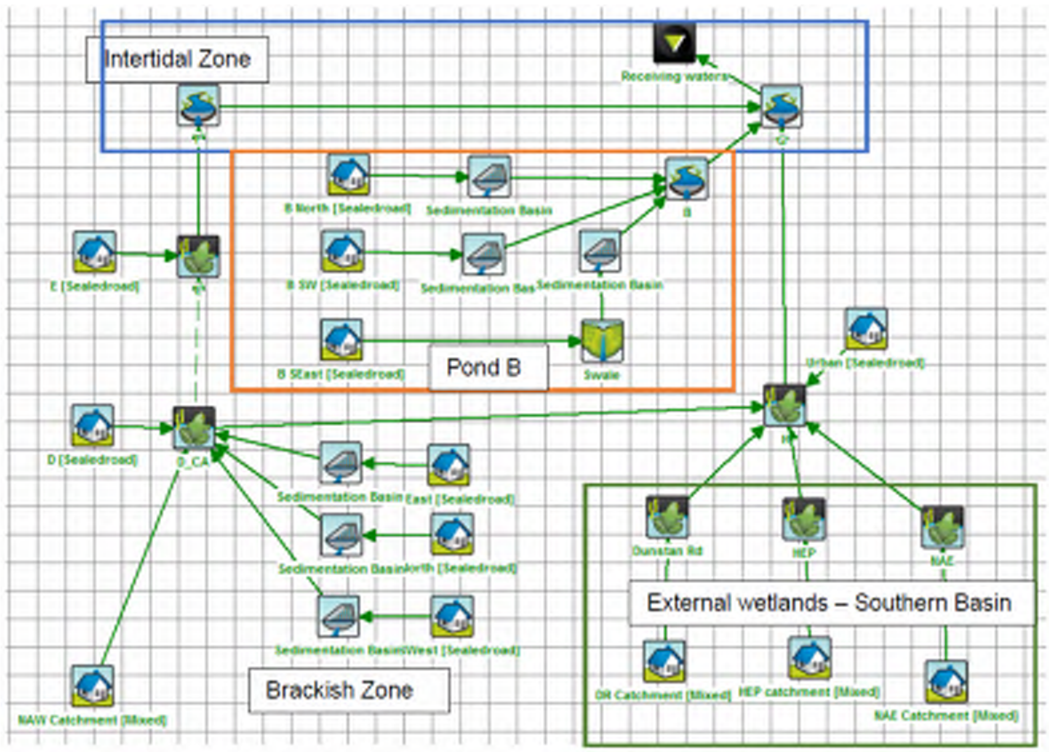


Figure 5-2 – Proposed BIW arrangement MUSIC model layout (extract from the *Northern Connector Project Detailed Design, Jacobs Arup Joint Venture, DP-0206 Annexure F2 Wetland Water Treatment - Modelling Report*)

5.4 Baseline Scenario MUSIC Model

A MUSIC model was compiled for the Barker Inlet Central catchments using the input parameters described above, to represent the 'baseline' scenario, whereby all stormwater runoff generated within the Study Area is discharged to the receiving environment (North Arm Creek) with no pre-treatment. Figure 5-3 provides a screenshot of the downstream layout. The whole baseline scenario MUSIC model layout is shown in Appendix C. The purpose of the baseline MUSIC model is to estimate the pollutant loads generated by the catchment under ultimate development conditions and to facilitate an assessment of the water quality improvement performance of existing and proposed treatment measures.

Figure 5-3 – Baseline MUSIC Model, Screenshot of Downstream Layout

A summary of the average annual pollutant loadings and quantity of stormwater runoff generated by the whole Study Area and individual catchments are provided in the following tables.

Table 5-1—MUSIC Model Results; Baseline Scenario, Total BIC Study Area discharging into North Arm Creek

Parameter	Source Load
Flow (ML/yr)	5,270
Total Suspended Solids (kg/yr)	1,050,000
Total Phosphorous (kg/yr)	2,160
Total Nitrogen (kg/yr)	15,100
Gross Pollutants (kg/yr)	225,000

Table 5-2—MUSIC Model Results; Baseline Scenario, Total BIC/NAE Catchment Area discharging into North Arm Creek

Parameter	Source Load
Flow (ML/yr)	9,300
Total Suspended Solids (kg/yr)	1,830,000
Total Phosphorous (kg/yr)	3,740
Total Nitrogen (kg/yr)	26,600
Gross Pollutants (kg/yr)	402,000

Table 5-3—MUSIC Model Results; Baseline Scenario, NAW Catchment discharging into Barker Inlet Wetlands

Parameter	Source Load
Flow (ML/yr)	1,880
Total Suspended Solids (kg/yr)	377,000
Total Phosphorous (kg/yr)	772
Total Nitrogen (kg/yr)	5,390
Gross Pollutants (kg/yr)	79,800

Table 5-4—MUSIC Model Results; Baseline Scenario, Dunstan Road Catchment discharging into Barker Inlet Wetlands

Parameter	Source Load
Flow (ML/yr)	523
Total Suspended Solids (kg/yr)	106,000
Total Phosphorous (kg/yr)	216
Total Nitrogen (kg/yr)	1,500
Gross Pollutants (kg/yr)	21,500

Table 5-5—MUSIC Model Results; Baseline Scenario, HEP Catchment discharging into Barker Inlet Wetlands

Parameter	Source Load
Flow (ML/yr)	2,830
Total Suspended Solids (kg/yr)	561,000
Total Phosphorous (kg/yr)	1,150
Total Nitrogen (kg/yr)	8,080
Gross Pollutants (kg/yr)	122,000

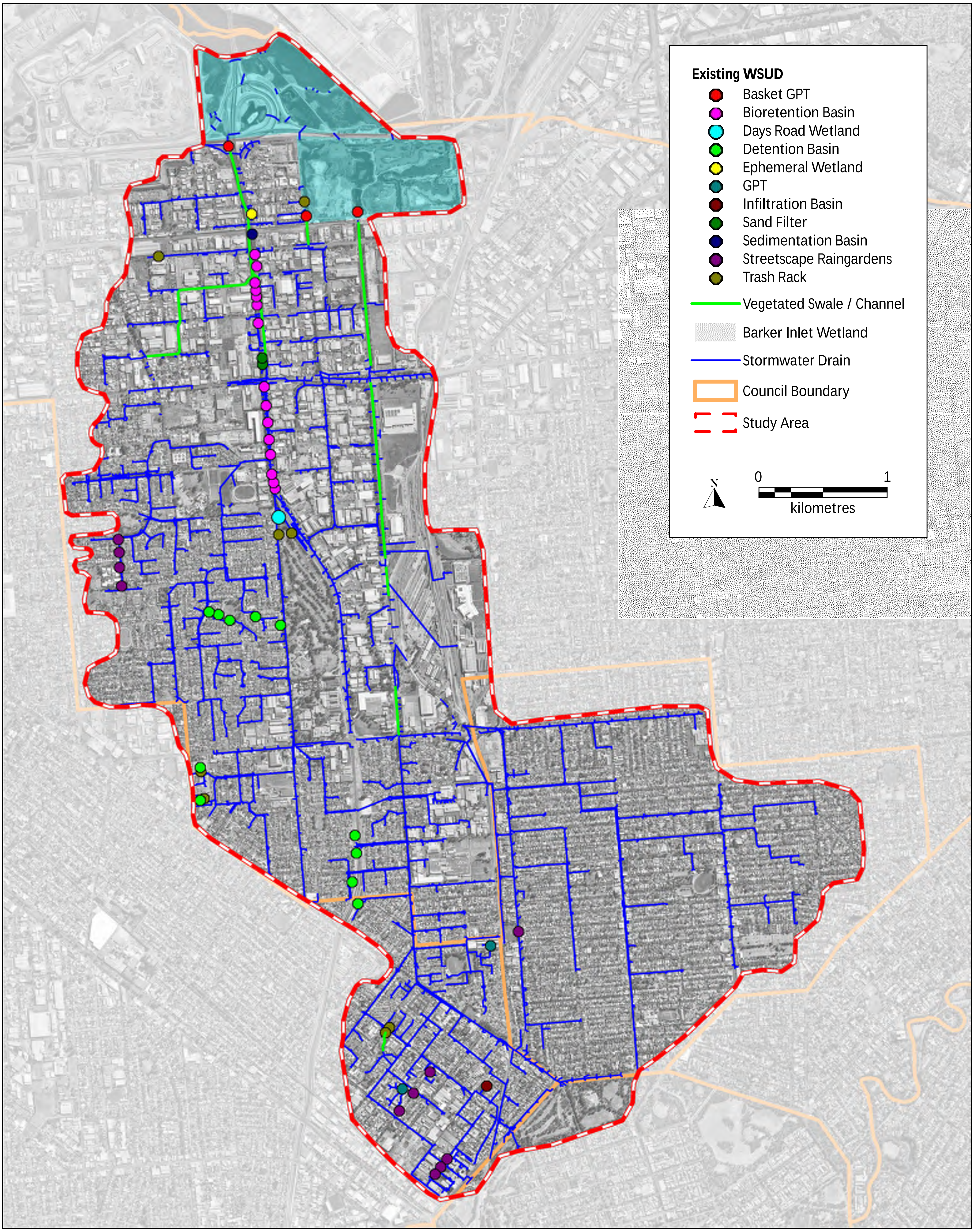
5.5 Existing Water Sensitive Urban Design

An existing scenario MUSIC model of the BIC study area was created which included WSUD measures already existing within the catchment. The creation of this model was necessary to understand the impact the existing treatment measures have on water quality and to what extent they reach the required water quality improvement targets outlined in Section 3.8. The existing MUSIC model will ultimately be used to create the future MUSIC model which will include proposed WSUD measures.

Existing WSUD measures present in the study area were identified through the following sources:

- Council supplied data and reports
- WSUD Interactive Map – watersensitivesa.com.au
- Site inspections
- GIS measurements

The following sections describe the identified WSUD measures that were included in the existing MUSIC model. An overview of all the existing WSUD measures present in the Barker Inlet Central Study Area is provided in Figure 5-4.



Data Sources:
City of Port Adelaide Enfield (Drainage Data, Existing WSUD)
City of Prospect (Drainage Data)
City of Charles Sturt (Drainage Data, Existing WSUD)
Southfront (Drainage Data, Existing WSUD)

southfront

Barker Inlet Central
Stormwater Management Plan

Existing Water Sensitive Urban Design - Location Plan
Figure 5.4

5.5.1 Barker Inlet Wetlands

The Barker Inlet constructed wetlands are located at the downstream end of the Study Area. Constructed wetlands are artificial versions of a natural wetland system that use vegetation, enhanced sedimentation, fine filtration and biological pollutant uptake processes to improve water quality.

Wetlands function to improve water quality by:

- Removing sediments and suspended solids, together with their attached pollutants
- Removing a range of dissolved nutrients and contaminants.

Wetlands also reduce peak flows from frequent rainfall events and thus reduce downstream erosion potential and can facilitate stormwater harvesting.

For the existing MUSIC model, the BIW was assumed to be working optimally. This is a critical assumption as the BIW are the major treatment measure for the BIC Catchment. MUSIC model inputs and parameters were taken from the Northern Connector Detailed Design report (DP-0206 Annexure F2 Wetland Water Treatment - Modelling Report, JAJAV, 2017).

5.5.2 Open Earth Channels/Swales

The three major channels including the NAW, Dustan Road and HEP, are unlined in some sections with extensive plant growth. These channels act as vegetated swales, providing water quality improvements. Modelling parameters were determined by site inspections and GIS measurements. A section of the unlined HEP channel looking upstream from Grand Junction Road is shown in Figure 5-5.

Figure 5-5—HEP open channel, Grand Junction Road

5.5.3 Detention Basins and Infiltration Systems

Detention Basins are a common stormwater management technique to mitigate stormwater flows to a level that ensures that the performance of the downstream drainage systems and associated flood risk are not adversely affected.

There are several online detention basins throughout the Barker Inlet Central Study Area which provide some water quality improvement for base flows. A number of these basins have also been designed as infiltration systems, providing further water quality improvements.

Infiltration systems generally consist of a shallow excavated trench or ‘tank’, designed to detain (and retain) a certain volume of runoff and subsequently infiltrate the stored water to the surrounding soils. They reduce runoff volumes by providing a pathway for treated runoff to recharge local groundwater aquifers. Infiltration systems are designed to infiltrate runoff on site, thereby reducing the overall volume of water that runs off a site to the urban drainage network. This also reduces the impact of development on peak flow volumes. Infiltration systems also cleanse runoff via a variety of processes, primarily filtration, which improves the quality of water leaving the system.

Modelling parameters for the various online detention basins and infiltration systems were determined by site inspections and GIS measurements.

5.5.4 Bioretention Systems (Raingardens)

Bioretention systems, also known as raingardens, are landscaped basins that facilitate treatment of stormwater by vegetation prior to the filtration of runoff through soil media. Percolated runoff is typically collected at the base of the filter media using perforated underdrains for subsequent harvesting and reuse or discharge to receiving waterways.

The system can be lined to prevent infiltration to the surrounding soil profile, and a submerged zone is often incorporated beneath the underdrain to improve the potential for denitrification and provide a moisture storage to support the vegetation during prolonged periods without rainfall.

Maintenance of bioretention systems is primarily about promoting healthy vegetation, removing excess collected sediments, ensuring the surface remains free draining and removing any material that blocks hydraulic structures. A simple schematic showing how stormwater is passed through a bioretention system is shown Figure 5-6.

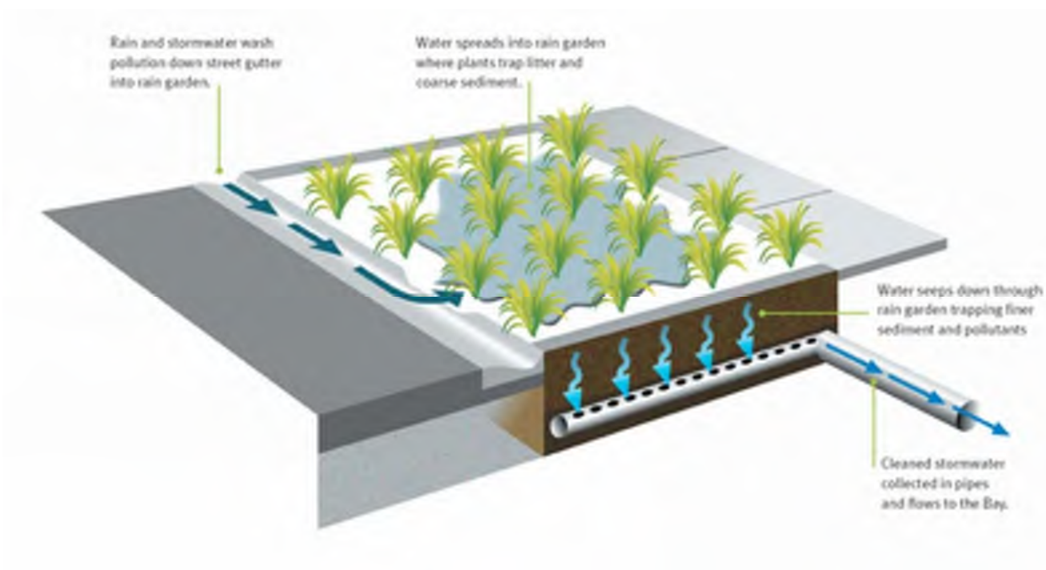


Figure 5-6—Bioretention System Schematic (City of Kingston)

There are several existing streetscape raingarden systems present throughout the catchment. Modelling parameters were determined by site inspections and GIS measurements.

An example of a streetscape bioretention system, in its establishment phase, is shown in Figure 5-7.

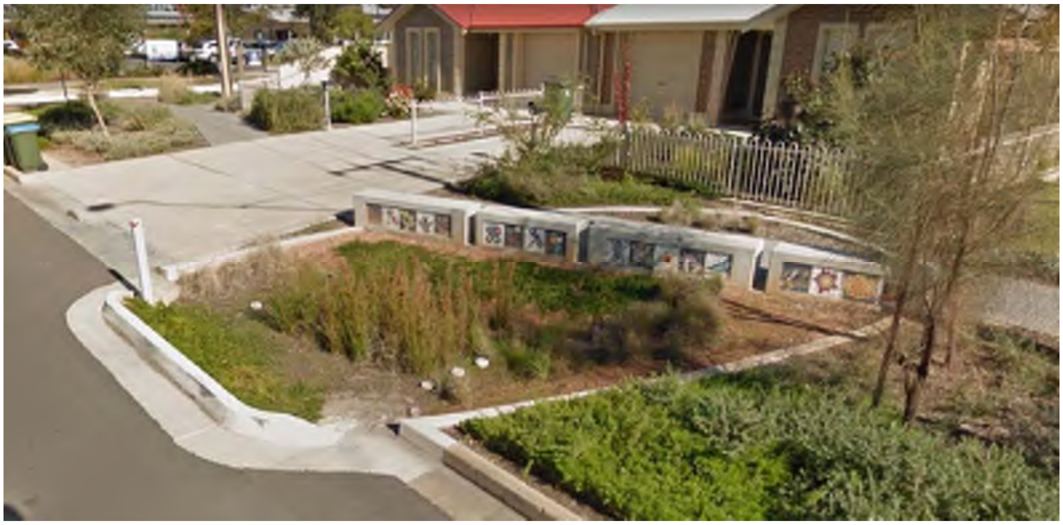


Figure 5-7—Bioretention System (Raingarden), Murchison Street, Woodville Gardens

5.5.5 Gross Pollutant Traps

Gross Pollutant Traps (GPTs) are primary treatment devices that are designed to remove anthropogenic waste, organic matter and coarse sediment from stormwater flows. There are many different proprietary makes and models of GPT, ranging from below ground 'wet sump' devices to above ground trash racks and capture nets on pipe outlets.

Large trash racks are located at the end of each major channel just upstream of the Barker Inlet Wetland. There are several smaller trash racks and ECOSOL GPTs located within the Study Area. Standard GPT and trash rack modelling parameters were assumed as shown in Table 5-6.

Table 5-6—Assumed Gross Pollutant Trap Annual Pollutant Removal Efficiency

Pollutant	Trash Rack or Basket Type	ECOSOL SF4300[1]
Total Suspended Solids	0%	80%
Total Phosphorous	0%	70%
Total Nitrogen	0%	10%
Gross Pollutants	50%	90%

1 Values taken from Ecosol™ Sand Filter Technical Specification

5.5.6 South Road Superway WSUD

A number of WSUD measures were constructed as a part of the South Road Superway Upgrade. Details of these measures were taken from various DPTI reports and design drawings. The WSUD measures identified included the upgraded NAW open earth channel, Days Road wetland, an ephemeral wetland, 17 bioretention basins and 2 sand infiltration basins. The majority of modelling parameters for these measures were provided in the *South Road Superway Project, FINAL DESIGN REPORT, TRUNK DRAINAGE NORTH 2011 – Appendix D1 Ecological Assessment* (South Road Superway Project, 2011).

5.5.7 Assessed Performance

The MUSIC model was executed to assess the overall water quality performance in the scenario with assumed future land development (as described in Section 4.3.3), existing WSUD infrastructure and existing climate conditions, as summarised in Table 5-7.

Table 5-7—MUSIC Model Results; Existing Scenario, Total BIC/NAE Catchment Area discharging into North Arm Creek

Parameter	Sources[1]	Residual	Reduction	Objective
Flow (ML/yr)	9,300	8,510	8%	-
Total Suspended Solids (kg/yr)	1,830,000	143,000	92%	80%
Total Phosphorous (kg/yr)	3,740	835	78%	60%
Total Nitrogen (kg/yr)	26,600	12,900	52%	45%
Gross Pollutants (kg/yr)	402,000	0	100%	90%

1 From Baseline Scenario model.

As shown from the results above, the existing WSUD scenario meets all of the objective water quality improvement targets. The Barker Inlet Wetlands were shown to play a major role in achieving the above reductions. If the wetlands are not performing optimally (or as modelled), some additional reduction targets may not be met, such as the total nitrogen reduction, which was 52% compared to a target of 45%.

Given the importance of the Barker Inlet Wetlands in the treatment of stormwater runoff from the catchment, a sensitivity analysis was carried out by removing the wetland components from the MUSIC model. This allowed for the WSUD upstream of the wetlands alone to be considered, to determine the improvement in water quality prior to water reaching the wetlands. The results of this analysis are summarised in Table 5-8 below.

Table 5-8 – MUSIC Model Results; Existing Scenario without Wetlands, Total BIC/NAE Catchment Area discharging into North Arm Creek

Parameter	Sources[1]	Residual	Reduction	Objective
Flow (ML/yr)	9,300	9,260	0.4%	-
Total Suspended Solids (kg/yr)	1,830,000	971,000	47%	80%
Total Phosphorous (kg/yr)	3,740	2,520	33%	60%
Total Nitrogen (kg/yr)	26,600	23,000	14%	45%
Gross Pollutants (kg/yr)	402,000	181,000	55%	90%

1 From Baseline Scenario model.

As seen in Table 5-8, the Barker Inlet Wetlands are a large component of the water quality treatment within the Barker Inlet Central catchment, and without them the pollutant reductions are substantially reduced across the board. These results stress the importance of maintaining the health and functionality of the wetlands as the catchment continues to develop, as they play a key role in improving the quality of the water being discharged out into the gulf.

The water quality at the site of the SA Water MAR scheme was also of interest, as the scheme is currently inactive, citing excessive total suspended solids due to carp infestation as one of the main causes. Table 5-9 below shows the MUSIC model results at the approximate location of the MAR scheme offtake. It should be noted that the poor water quality issues currently plaguing the MAR scheme are not accounted for in this MUSIC model and are not reflected in the results below.

Table 5-9 – MUSIC Model Results; Existing Scenario, at Approximate Location of SA Water MAR Scheme

Parameter	Sources[1]	Residual	Reduction	Objective
Flow (ML/yr)	2,790	2,780	0.4%	-
Total Suspended Solids (kg/yr)	557,000	80,000	86%	80%
Total Phosphorous (kg/yr)	1,130	429	62%	60%
Total Nitrogen (kg/yr)	7,980	5,950	25%	45%
Gross Pollutants (kg/yr)	121,000	0	100%	90%

The results of the above table consider the treatment provided by all upstream WSUD infrastructure, and the full length of the HEP catchment open earth swale, which serves to treat the stormwater while it moves towards the wetlands. They do not consider the impact of the GPTs between the open earth swale and the wetlands, as it is understood that the offtake is prior to this component of the treatment train. It can be seen that at the approximate location of the MAR scheme offtake, the total suspended solids, total phosphorus and gross pollutants have all been treated to above the reduction targets, but total nitrogen was far short of the target.

5.6 WSUD Strategy

A Water Sensitive Urban Design (WSUD) strategy has been developed for the Barker Inlet Central Study Area in order to reduce the volume and increase the quality of stormwater discharging into the Barker Inlet Wetlands. Although the existing WSUD in the catchment was found to achieve the target water pollutant reductions according to the MUSIC modelling, it was considered important continue to recommend WSUD measures within the Study Area to:

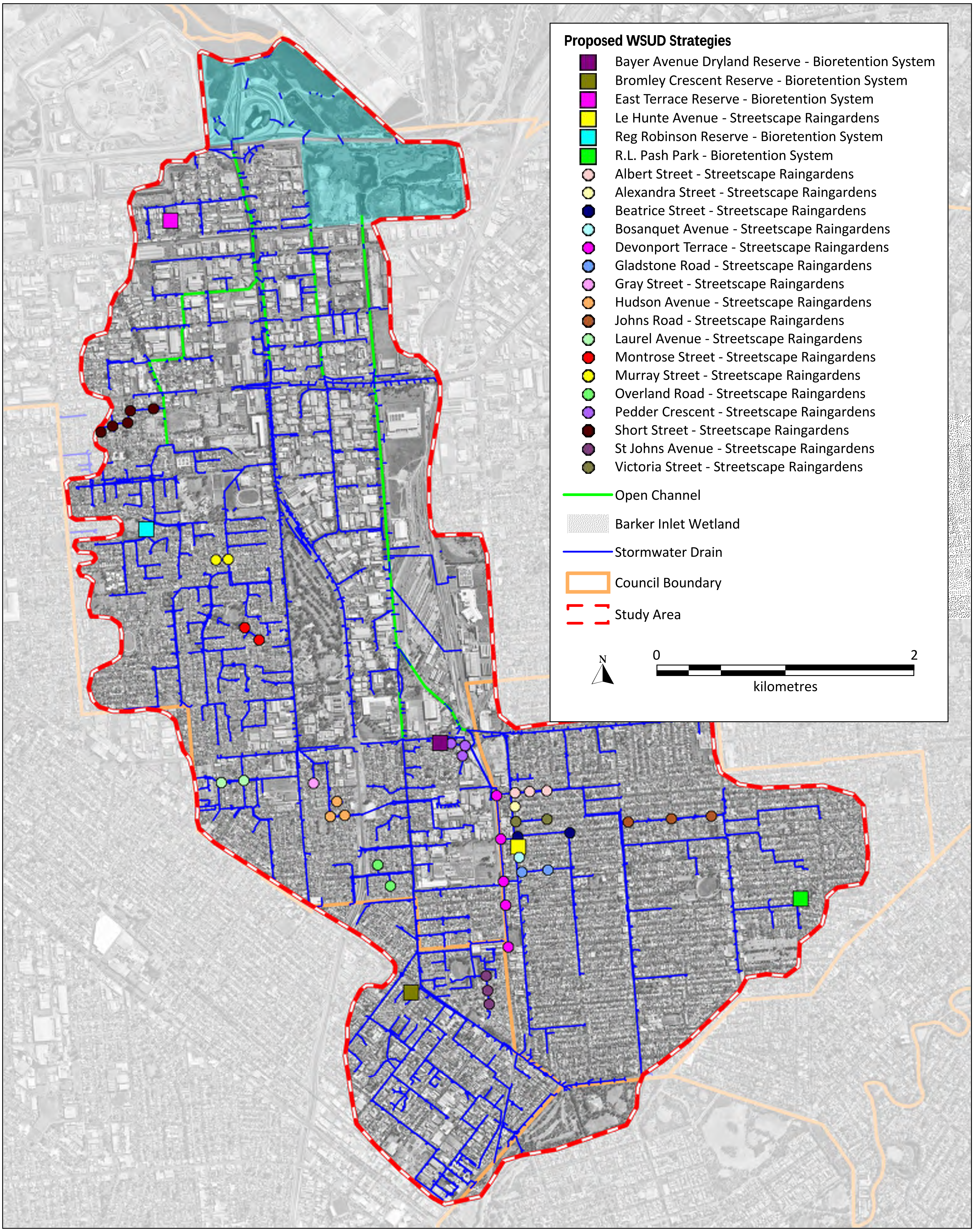
- Ensure the continuing functionality of the wetlands to achieve the water quality objectives;
- Ensure wetland resilience and adaptation with ongoing development within the upstream catchment;
- Mitigate against future impacts of climate change (reduced rainfall volumes, increased temperatures and heat island effect) for residents and environments within the catchment area; and
- Reduce the reliance of mains water supply for irrigation and other processes.

A WSUD strategy MUSIC model has been compiled to enable comparison to the baseline (future land development, existing climate, existing WSUD infrastructure) scenario MUSIC model, enabling preliminary sizing of WSUD elements and budget cost estimation.

The range of WSUD measures that are proposed across the Barker Inlet Central Study Area includes streetscape raingardens, bioretention/detention basins as well as activation of the existing MAR system.

The WSUD strategy has also identified allotment-level opportunities for beneficial reuse of stormwater, which will reduce the overall volume of stormwater that is discharged to receiving waters. This includes the provision of rainwater tanks for new developments.

An overview of all proposed WSUD upgrades is shown in Figure 5-8, and each of the proposed works packages has been assigned a Project ID which corresponds to action summary tables.



Data Sources:
Southfront (Proposed WSUD)
NearMap (Aerial Photograph)
DataSa (Council Boundaries)
City of Port Adelaide Enfield, City of Prospect and City of Charles Sturt (Stormwater Data)

Barker Inlet Central
Stormwater Management Plan

southfront

Proposed Water Sensitive Urban Design Strategies - Location Plan
Figure 5.8

5.6.1 Barker Inlet Wetlands Rehabilitation, Monitoring and Management (Q1)

The Barker Inlet Wetlands are integral to the peak flow detention and water quality treatment of the Barker Inlet Central and North Arm East stormwater catchments. For water quality modelling purposes, the assumption has been made that the Wetlands are working optimally in terms of their treatment of water. In reality, this assumption may not necessarily be the case, and therefore a number of rehabilitation and management related strategies are recommended to ensure the Barker Inlet Wetlands remain healthy and functional into the future.

European Carp can be found throughout the Barker Inlet Wetlands, and they are an introduced pest species. The presence of carp poses a risk to the ecology of the wetlands, due to their potential for disrupting the physical environment. When feeding, these carp disrupt the channel bed, resulting in increased water turbidity, and can produce more than a million eggs while spawning, leading to a very large population. This is one of the factors preventing the SA Water aquifer recharge scheme from operating. It is recommended that the current carp control program, which involves removing the carp every 2 years, is continued, and that the carp population is monitored to ensure the control program is working effectively.

Further to the above, it is recommended to conduct an investigation into the function, performance and health of the Barker Inlet Wetlands. An ongoing water monitoring program at the upper and lower reaches of the wetland would allow Council to determine the effectiveness at treating stormwater discharging from the upstream catchments, ensure adequate water quality is achieved for Managed Aquifer Recharge to occur (see Section 5.6.2 below) and control carp populations before they get out of control. As shown in Table 5-8, the level of water treatment is heavily reliant on the Barker Inlet Wetlands, and therefore it is important to have a deep understanding of their operation.

5.6.2 BIW SA Water MAR Scheme Activation (Q2)

As described in Section 2.5.4, the Managed Aquifer Recharge (MAR) scheme in the Barker Inlet Wetlands is currently inactive. Following the previous recommendation relating to the carp population control and implementation of a consistent monitoring program, provided that the turbidity returns to a suitable level for aquifer injection, it is recommended to reinstate operations in the aquifer recharge scheme. In order for this to happen, it would first be required to repair the vandalism and fix the collapsed well, at an estimated cost of $100,000 (*Barker Inlet Central SMP Hydrogeological Assessment*, WGA 2019).

Once the scheme is recommissioned the scheme will supply an alternative water main that runs south into the City of Port Adelaide Enfield with a design harvest capacity of around 400 ML/y.

5.6.3 Reserve / Detention Basin Bioretention Systems (Q3 – Q8)

Bioretention systems are proposed to be incorporated into a number of existing reserves or integrated with proposed flood mitigation works outlined in the Section 4.8. These bioretention systems are to be fully lined and include a submerged zone that will provide moisture storage to support the vegetation during prolonged periods without rainfall. These bioretention systems will provide an opportunity for high quality landscaping and integration with the surrounding reserves. The size of the filter area was determined using the MUSIC model, and ensuring that water leaving a bioretention node meets the required water quality improvement targets.

Bayer Avenue Dryland Reserve (Dudley Park)
Bayer Avenue Dryland Reserve is an existing area of open space, located on the corner of Regency Road and Bayer Avenue. A small bioretention basin is proposed at this location to treat

water from the local catchment prior to discharging into the Regency Road drainage network. Modifications to the kerb and gutter of Bayer Avenue to allow surface waters into the reserve is recommended. This bioretention system is to have a filter area of 100 m² and an extended detention depth of 0.3 metres. The bioretention outlet is to discharge directly into the existing Regency Road drainage system.

The estimated cost for these works is $220,000.

Bromley Close (Brompton)
The small reserve between Bromley Close and Doughty Street is the site of a proposed bioretention system. It is proposed that the 450mm diameter stormwater pipe in Bromley Close be diverted into the reserve and allowed to discharge into the proposed bioretention basin. This site will treat water from the local catchment and is to have a filter area of 150 m² and an extended detention depth of 0.3 metres.

The estimate cost for these works is $350,000.

Reg Robinson Reserve (Mansfield Park)
The existing Reg Robinson Reserve detention basin is proposed to be modified in order to incorporate low-flow swale and bioretention and water quality improving features. Currently the reserve acts as a surcharge basin, only receiving inundation during large storm events. It is proposed to slightly lower a small portion of the reserve and modify the upstream stormwater drain inverts (900mm x 300mm RCBC), to allow low flows to be sent into the basin to be treated in the bioretention system. A GPT is also recommended on the drain outlet into the basin to remove any gross pollutants prior to discharge into the This bioretention system is to have a filter area of 700 m² and be elevated above the floor of the detention basin such that the maximum depth of submergence is 0.3 metres.

The estimated cost for these works is $550,000 (including $270,000 for the wet-sump GPT device).

Existing Basins on Montrose Street (Ferryden Park)
Along Montrose Street there are a number of interconnected on-line detention basins, taking flows from the local catchments and directing them into larger downstream mains. It is recommended that a bioretention component is added to each of these basins, to further treat stormwater before it enters the downstream drainage network and ultimately flows into the Barker Inlet Wetlands. The two directly connected basins are to have bioretention systems with a filter area of 50 m² each, and the basin further east will have a filter area of 100m² for a total filter area of 200 m², and each is to have a maximum depth of submergence of 0.3 metres.

The estimated cost for these works is $150,000.

R.L. Pash Park (Collinswood)
At the upstream end of the HEP catchment, situated between Collins Street and Ellen Street is a small reserve, sitting atop a stormwater drain which takes water from Collins Street and part of Howard Street. It is proposed divert surface gutter flows from Collins Street into the reserve and construct a small bioretention system to treat stormwater. Removal of kerb and gutter to allow surface flows into the reserve would be required. The bioretention basin would require a filter area of 50 m² and an extended detention depth of 0.3 metres.

The estimated cost for these works is $220,000.

Days Road Detention Basin (Croydon Park)

Upgrade D3 in Table 4-27 includes a new detention basin in land adjacent to Days Road. It is proposed that a low-flow bioretention swale system be incorporated into the design to treat base flows from the proposed upgraded Laurel Avenue system. A filter area in the bottom of the detention basin of 500 m² and an extended detention depth of 0.3 metres is recommended.

The cost of these works is included in the cost estimate for flood mitigation works (D3).

East Terrace Reserve (Wingfield)

In line with upgrade D6 from Table 4-27, the proposed detention basin between East Terrace and Phillis Street is to incorporate a low-flow bioretention swale at the basin invert. This bioretention system is to have a filter area of 500 m² with an extended detention depth of 0.3 metres.

The cost of these works is included in the cost estimate for flood mitigation works (D6).

These recommendations aim to address Objectives O3 (reduce pollutant loads), O5 (environmental values, reducing urban runoff) and O9 (multi-objective outcomes) as per the Objectives outlined in Table 3-2.

5.6.4 Streetscape Raingardens (Q9)

It is proposed to construct lined bioretention systems at strategic locations throughout the Barker Inlet Central Study Area, primarily within residential and commercial regions.

The locations of proposed streetscape bioretention systems include road reserves that may become the sites of stormwater drainage upgrades, and that have sufficient width to accommodate bioretention systems without adversely impacting on other streetscape features such as parking provisions. In these cases, bioretention systems are proposed to be used in lieu of traditional side entry pits, to treat the flows from small contributing catchments. In addition to bioretention systems being constructed where new stormwater works have been proposed, it is recommended that bioretention systems be retrofitted to existing stormwater systems in order to maximise the water quality improvement performance of this Plan.

Two sizes of bioretention systems were used for MUSIC modelling. Smaller 15 m² systems were used for areas with less available space, such as retrofitting into existing streetscapes with narrow road reserves. Larger 30 m² bioretention systems were used where possible, such as wide road reserves or medians, to service larger catchments and to achieve greater pollutant reductions. MUSIC modelling parameters for the proposed streetscape bioretention systems are included in Table 5-10.

Table 5-10 – Streetscape Bioretention System Properties

Parameter	Small Bioretention System	Large Bioretention System
Filter Area (m²)	15	30
Extended Detention Depth (m)	0.15	0.15
High Flow Bypass (L/s)	125	250
Filter Depth (m)	0.5	0.5

Streetscape bioretention systems are suitable for widespread implementation across the Study Area, and would ideally be delivered in conjunction with the road reconstruction and open space upgrade programs of the Councils.

A more widespread adoption of streetscape bioretention systems would result in enhanced water quality improvement and amenity outcomes. The estimated cost of constructing each bioretention system is $50,000 (assuming a footprint of 30 m²).

Table 5-11 – Streetscape Bioretention System per Catchment

Catchment	No. of Raingardens (Included in Proposed Stormwater Upgrades)	No. of Raingardens (Retrofit to Existing Stormwater Systems)	Total No. of Raingardens
HEP	14	77	91
NAW	56	6	62
Dunstan Road	-	-	-
Total	**70**	**83**	**153**

Key roads throughout the Study Area have been identified as suitable for bioretention systems, particularly where new stormwater works are proposed and/or retrofitting into an existing drainage system where the road reserve is able to accommodate the required footprint. These have been incorporated into the MUSIC model and are summarised below.

Where new stormwater works are proposed:

- Overland Road / Charron Road / Berliet Street, Croydon Park, HEP Catchment
- Hudson Avenue / Packard Avenue, Croydon Park, NAW Catchment
- Gray Street / Standard Avenue, Croydon Park, NAW Catchment
- Laurel Avenue, Croydon Park, NAW Catchment
- Short Street / Clara Street / Frederick Street, Mansfield Park, NAW Catchment
- St Johns Avenue, Renown Park, HEP Catchment
- Churchill Road, Prospect, HEP Catchment

Retrofitting to an existing drainage system:

- Devonport Terrace, Prospect, HEP Catchment
- Pedder Crescent, Dudley Park, HEP Catchment
- Gladstone Road, Prospect, HEP Catchment
- Bosanquet Avenue, Prospect, HEP Catchment
- Le Hunte Avenue, Prospect, HEP Catchment
- Beatrice Street, Prospect, HEP Catchment
- Victoria Street, Prospect, HEP Catchment
- Alexandra Street, Prospect, HEP Catchment
- Albert Street, Prospect, HEP Catchment

- Johns Road, Prospect, HEP Catchment
- Montrose Street / Westwood Boulevard / Lachlan Street, Ferryden Park, NAW Catchment
- Murray Street, Ferryden Park, NAW Catchment

Implementation of streetscape raingardens aims to address Objectives O3 (reduce pollutant loads) and O5 (environmental values, reducing urban runoff) as per the Objectives in Table 3-2.

5.6.5 Rainwater Tanks (Q10)

The installation of rainwater tanks into new residential development was mandated by the State Government a number of years ago. Prior to 2021, this stipulation required that new development provide a minimum 1 kL tank to receive site-generated stormwater runoff, with the tank plumbed into any combination of toilet, laundry or hot water system demand nodes.

The new South Australian Planning and Design Code (released in March 2021) currently requires rainwater tanks for new dwellings based on allotment size, as outlined in the table below.

Table 5-12 – Rainwater Tank Requirement by allotment size (Planning and Design Code - 19 March - Version 2021.2)

Allotment Size (m^2)	Minimum Rainwater Tank Volume (kL)
<200	2
201 – 400	3
401 – 500	5

Based minimum site perviousness – see planning code document for details.

As stated in Section 4.3.3, Infraplan investigated the development potential of the Barker Inlet Central area and identified a midrange value of 3058 new residential sub-divided allotments. Based on this assessment (with allotments having an average size of 780 m^2) rainwater tanks of 3kL in size were modelled for each property pegged for redevelopment/subdivision. Assuming each tank is connected to a roof area of 200m^2, this storage is equivalent to the runoff volume generated by a 15 mm rainfall event (for comparison a 1EY, 2 hour duration event produces 15.5 mm of rainfall).

This policy is considered to be appropriate given that:

- Capture of stormwater would reduce the pollutant load discharged to receiving waters;
- Capture of stormwater would reduce the volume of runoff directed into the Council stormwater system;
- Greater storage capacities would achieve a greater reduction in residential mains water usage; and
- Rainwater tank prices have become more competitive in recent years, and therefore the payback period of providing a greater storage capacity has been reduced.

The MUSIC modelling has assumed that the rainwater tanks for new dwellings shall supply a daily demand of 200 L/day. This allowance includes watering gardens, flushing of toilets and washing machines, for example. The cost of rainwater tanks shall be borne by the homeowner.

This policy addresses Objectives O4 (allotment level reuse) and O7 (development requirements) as per the Objectives outlined in Table 3-2.

5.6.6 Assessed Performance

The baseline MUSIC model was modified to incorporate the various WSUD features described above. The MUSIC model was run to assess the overall performance of the proposed WSUD strategy, as summarised in Table 5-13 for the overall catchment plus the NAE catchment.

Table 5-13 – MUSIC Model Results; Upgrade Scenario, Total BIC/NAE Catchment Area discharging into North Arm Creek

Parameter	Sources	Residual	Reduction	Objective
Flow (ML/yr)	9,300	7,980	14%	-
Total Suspended Solids (kg/yr)	1,830,000	137,000	93%	80%
Total Phosphorous (kg/yr)	3,740	789	79%	60%
Total Nitrogen (kg/yr)	26,600	12,000	55%	45%
Gross Pollutants (kg/yr)	402,000	0	100%	90%

Compared to the results of the existing WSUD in Table 5-7, the additional improvement in water quality from the proposed upgrades is relatively minor, amounting to a couple of percent across the board. It must be noted that the model used to determine these reductions did not consider any WSUD upstream of the wetlands for the NAE catchment. In reality, there would be some level of water treatment occurring throughout the NAE catchment, even if it is just from the length of open earth channel leading to the wetlands, however the water is arriving unmitigated at the wetlands. In effect, this means that the improvements provided by the proposed WSUD strategy, if considering purely the Barker Inlet Central Study Area, would likely be slightly greater than those of Table 5-13 which includes the NAE catchment.

Although the resulting improvement to water quality was found to be relatively minor, the benefits of WSUD are not limited to water treatment. Table 5-14 below summarises the potential benefits of WSUD in a general sense, as described in *Water Sensitive Urban Design* (Department of Environment, Water and Natural Resources, 2013).

Table 5-14 – Potential Benefits of WSUD

Economic	Environmental	Social
Capital cost savings – Reduced sizing of off-site pipe work, drains and stormwater infrastructure	*Hydrological balance* – maintains the hydrological balance by using natural processes of storage, infiltration and evaporation.	*Amenable urban and residential landscapes.*
Construction cost savings – grading and tree clearing.	*Sensitive area protection* – can contribute to protecting environmentally sensitive areas from urban development.	*High visual amenity.*
Water quality cost savings – reducing the costs of water	*Waterways restoration* – supports restorations and	*Linking* – opportunities to link community

quality improvement by maintaining existing waterways.	enhancement of urban waterways.	nodes through open space.
Developer cost savings – reduced developer contributions to downstream drainage capacities and open space requirements.	*Impact reduction* – minimises the impact of urban development on the environment.	*Ameliorating urban heat island effects.*
Improved market value – making such developments more desirable and marketable.	*Natural habitats enhancement* – can enhance the diversity of natural habitats/landscapes.	
Improved resource utilisation – offers cost benefits where areas are unsuitable for residential development, but are suitable for passive recreation and contribute to required public space allocation.	*Groundwater recharge.*	

In addition to the benefits described in Table 5-14, given the importance of the Barker Inlet Wetlands in treating urban stormwater runoff, it is desirable to improve the water quality as much as practicable upstream of the wetlands, so that the risks of the wetlands not performing as they did in the model are somewhat mitigated. Furthermore, constructing additional WSUD infrastructure upstream will help safeguard the catchment from the impacts of climate change.

Table 5-15 below provides the model results for each of the three major catchments. Note that the outlet point for these catchments is located upstream of part of the Barker Inlet Wetlands, and therefore there are further water quality improvements than what is shown in the table further downstream.

Table 5-15 – MUSIC Model Results; Upgrade Scenario, Major Catchments discharging into Barker Inlet Wetlands

Parameter	NAW Catchment			Dunstan Road Catchment			HEP Catchment		
	Source	Residual	Reduction	Source	Residual	Reduction	Source	Residual	Reduction
Flow (ML/yr)	1,880	1,770	6%	523	473	10%	2,830	2,400	15%
Total Suspended Solids (kg/yr)	377,000	46,900	88%	106,000	6,060	94%	561,000	27,500	95%
Total Phosphorous (kg/yr)	772	268	65%	216	37	83%	1,150	190	83%
Total Nitrogen (kg/yr)	5,390	3,530	35%	1,500	654	56%	8,080	3,590	56%
Gross Pollutants (kg/yr)	79,800	0	100%	21,500	0	100%	122,000	0	100%

The results of Table 5-15 show that on a per-catchment basis, the NAW catchment performed the worst, falling 10% short of meeting the total nitrogen concentration reduction target (however this was measured prior to discharge into the Barker Inlet Wetlands). The Dunstan Road and HEP catchments performed much more effectively, with reductions far above the targets across the board, in large part thanks to vegetated open channels through these catchments.

The baseline and upgrade MUSIC models were also executed to assess the overall performance of the proposed WSUD strategy under projected climate conditions, based on predictions of a 5% reduction to the current mean annual rainfall (average annual rainfall for the period 1996-2001 was 485 mm). The period 2000-2005, with an average annual rainfall of 455 mm, was used for modelling climate change, with results summarised in Table 5-16.

Table 5-16 – MUSIC Model Results; Climate Change Upgrade Scenario, Total BIC/NAE Catchment Area discharging into North Arm Creek

Parameter	Sources	Residual	Reduction	Objective
Flow (ML/yr)	9,270	7,910	15%	-
Total Suspended Solids (kg/yr)	1,820,000	125,000	93%	80%
Total Phosphorous (kg/yr)	3,750	756	80%	60%
Total Nitrogen (kg/yr)	26,400	11,700	56%	45%
Gross Pollutants (kg/yr)	409,000	0	100%	90%

After changing the rainfall data time series, the reductions in pollutant concentrations were somewhat negligible compared to those of the non-climate change model, as shown in Table 5-13. This suggests that climate change will not have a substantial impact on the ability of the WSUD infrastructure to treat the stormwater discharged from the catchment.

5.6.7 Non-structural Measures

Q11: Maintaining Existing Vegetated Swales/Open Channels
It is recommended that the three major open channels (HEP, Dunstan and NAW) are retained as vegetated earthen swales (where they exist) as the contributing catchments continue to develop and evolve. Water quality modelling results indicate they are key drainage and water treatment infrastructure in addition to the Barker Inlet Wetland. While concrete lined channels are more hydraulically efficient, they do not assist in treatment of stormwater runoff, as well as having low amenity value. Maintaining and enhancing these channels will ensure that both water quality and the extent of flooding are not significantly worsened as future infill development results in an increased stormwater load. Further to this, Council may consider converting some section of paved/concrete open channel (particularly sections of Dunstan Road and NAW channels) to earthen swale over time as those assets degrade (provided adequate hydraulic capacity can be achieved).

Q12: Integration with Council Business Plans
A goal identified from this Stormwater Management Plan is for the Councils to ensure that there is ongoing integration between the proposed stormwater upgrade works and other capital programs (roads, open space) in the annual Business Plan. It is recommended that the Councils actively identify viable WSUD projects suitable for integration with other capital works as set out in the Business Plan.

This recommendation aims to address Objective O9 (multi-use objectives) as per the Objectives outlined in Table 3-2.

Q13: Community Education and WSUD Promotion
It is recommended that the Councils seek to maximise the uptake of WSUD measures on private property through community education and the promotion of WSUD demonstration sites.

Council staff and volunteers should seek to educate community groups, local residents, businesses and schools about what they can do to manage the stormwater runoff generated by their property in an environmentally responsible manner, including the use of rainwater tanks, passive irrigation systems and raingardens.

Initiatives may include articles in Council newsletters, street corner meetings, community group meetings, website updated, brochures and school education.

It is recommended to utilise and share the Water Sensitive SA website with the community. WSSA have a page on their website, 'Smart water solutions for your home & backyard', which provides information and instructions on how to integrate WSUD into a homeowner's property. Information is provided on rainwater tanks, permeable paving and reducing hard surfaces outside the house, raingardens for the backyard and general ideas for a new home. This website has many other resources that can be utilised for community education on WSUD and related issues.

This recommendation aims to address Objective O5 (environmental values, reducing urban runoff) and Objective 8 (community awareness) as per the Objectives outlined in Table 3-2.

5.7 WSUD Strategy Action Summary

A consolidated summary of the WSUD strategies across the study area is presented in Table 5-17. The costs of establishing the proposed detention basins were included as part of the flood mitigation strategy cost estimates in Section 0. In other cases where WSUD elements are to be integrated with flood mitigation works at a single project site, the costs below are representative of the WSUD elements only.

SMP objectives that have been addressed by a particular WSUD strategy action are shown in Table XX using the objective reference IDs from Table 3-2.

A number of the WSUD strategies proposed incur ongoing maintenance costs which have been included in Table 5-17. These estimates are based on historical knowledge and industry sources.

Table 5-17 – WSUD Strategy Action Summary

Project ID	Project Location / Type of Works	LGA & Catchment	Precursor Project	Budget Estimate	Annual Maintenance Cost	Description	Objectives Addressed
Q1	Wetland Rehabilitation and Monitoring	PAE/All	N/A	N/A	$50,000	Carp removal and monitoring of water quality within the wetland to ensure water quality benefits are achieved	
Q2	SA Water MAR Scheme Reactivation	PAE/HEP	Q1	$500,000	20,000	Repair vandalised equipment and Reactivate the SA Water MAR Scheme at BIW Wetland	O4, O5
Q3	Bayer Avenue Dryland Reserve bioretention	PAE/HEP	N/A	$220,000	$2,000	Bioretention within Bayer Avenue Dryland Reserve	O3, O5, O9
Q4	Bromley Close bioretention	CS/HEP	N/A	$350,000	$2,000	Bioretention within Bromley Close reserve	O3, O5, O9
Q5	Reg Robinson reserve bioretention	PAE/NAW	N/A	$550,000	$2,000	Bioretention within Reg Robinson reserve	O3, O5, O9
Q6	Montrose Street bioretention	PAE/NAW	N/A	$150,000	$2,000	Bioretention within basins along Montrose Street	O3, O5, O9
Q7	R.L. Pash Park bioretention	CoP/HEP	N/A	$220,000	$2,000	Bioretention within R.L. Pash Park	O3, O5, O9
Q8	Days Road reserve bioretention	PAE/NAW	D3	Included	$2,000	Bioretention within proposed Days Road detention basin	O3, O5, O9

Project ID	Project Location / Type of Works	LGA & Catchment	Precursor Project	Budget Estimate	Annual Maintenance Cost	Description	Objectives Addressed
Q9	East Terrace reserve bioretention	PAE/NAW	D8	Included	$2,000	Bioretention with proposed East Terrace detention basin	O3, O5, O9
Q10	Streetscape raingardens / bioretention	Various	Various	$6,230,000	$700 per raingarden	153 streetscape raingardens, each with a filter zone footprint of 30 m^2	O3, O5
Q10	Rainwater Tanks	Various	N/A	N/A	N/A	A requirement for installing a 3kL rainwater tank for new dwellings	O4, O7
Q11	Maintenance of existing vegetated open channels and swales (HEP, Dunstan, NAW)	PAE	N/A	N/A	N/A	Ensure vegetated swales are maintained as development occurs within the catchment to continue achieving water quality benefits to the lower catchment	O3
Q11	Integration with Council Business Plans	Various	N/A	N/A	N/A	Councils to ensure that there is ongoing integration between proposed stormwater upgrade works and other capital programs in the annual Business Plan	O9
Q13	Community Education and WSUD Promotion	Various	N/A	N/A	N/A	Council staff and volunteers should seek to educate community groups, local residents, businesses and schools about how to manage stormwater runoff generated by their property in an environmentally responsible manner, including the use of rainwater tanks, passive irrigation systems and raingardens	O5, O8

Project ID	Project Location / Type of Works	LGA & Catchment	Precursor Project	Budget Estimate	Annual Maintenance Cost	Description	Objectives Addressed
			TOTAL	$8,220,000			

6 Stakeholder and Community Consultation

6.1 Project Steering Committee

This Stormwater Management Plan was undertaken under the guidance and instruction of a Steering Committee comprised of staff representing:

- City of Port Adelaide Enfield;
- City of Prospect;
- Adelaide and Mount Lofty Ranges Natural Resources Management Board (represented in a technical review capacity by staff from Natural Resources Adelaide and Mount Lofty Ranges); and
- Stormwater Management Authority.

The Steering Committee met with the Consultant Team at key intervals during the preparation of the Stormwater Management Plan to plan, review and approve the work undertaken.

6.2 Initial Community Consultation

Open house sessions were held on 14 and 15 March 2020 as part of the investigation phase of the Plan. The purpose of the open house sessions was to outline the goals of the Plan, explain the process for preparing the Plan, provide general information on the environs and stormwater management practices in the Barker Inlet Central catchment area, and provide opportunities for interested parties to share their local knowledge and experiences.

A summary brochure was made available on Council's website and to attendees of the open house sessions. The outcomes of these sessions are summarised as follows:

- Five people attended;
- Key points of interest with attendees included long term solutions to flooding and seawater ingress issues, water quality issues in the Barker Inlet (particularly the impact on marine wildlife) and allotment level stormwater management (benefits of rainwater tanks and retaining stormwater onsite);
- The key take home message was that a range of stormwater management techniques will be required for different locations across the Study Area.

6.3 Consultation on the Draft Stormwater management Plan

This section to be completed upon consultation of the Draft Plan.

7 Draft Stormwater Management Plan

7.1 Prioritisation and Timeframes

The actions outlined in this draft Stormwater Management Plan will require implementation to be scheduled across many years, in order to be accommodated sustainably within the respective Council budgets and the budgets of other potential funding partners.

Each of the actions within the Plan has been assigned one of three priority levels, which has an associated anticipated timeframe for the strategy action to be completed as follows:

- High (0 - 5 years);
- Medium (5 - 10 years); and
- Low (10+ years).

A methodology has been developed to enable relative priorities to be assigned to all identified future stormwater works which takes into account financial, environmental and social variables. In order to account for benefits across a range of categories, a Multi-Criteria Analysis (MCA) approach has been used. The criteria and weightings adopted for the MCA have been developed in response to the stormwater management objectives that have been identified from meeting with the project steering committee, and the overarching strategic directions summarised in Section 3 that influence Council’s approach to stormwater management.

A diverse range of stormwater management strategies have been recommended in this Plan to cater for the unique requirements of each of the Barker Inlet Central catchments. Having regard to the diversity of these strategies and the need for a flexible and optimal decision making framework for this Plan, a separate MCA approach has been applied to the Flood Mitigation and Water Sensitive Urban Design (WSUD) strategies.

The two MCA approaches are linked through the inclusion of a criteria that recognises flood mitigation projects that are required as a precursor to the implementation of WSUD actions. Consolidation of scores from the two MCA approaches has also been undertaken to inform the prioritisation of works and reinforce the value of achieving multiple objectives for stormwater management projects on the Barker Inlet Central study area.

The priority rating of actions is flexible and subject to change over time, and it is expected that some actions will be ‘brought forward’, particularly when opportunities for external grant funding arise. A number of flood mitigation projects have been identified that are eligible for Stormwater Management Authority funding support. It is recommended that respective Councils liaise with the Stormwater Management Authority to identify a timeframe for the delivery of these projects that meets the forward budget limitations of both parties.

Projects not identified as eligible for Stormwater Management Authority funding support may still be eligible for other external funding opportunities.

7.1.1 Flood Mitigation Strategies Multi-Criteria Analysis

The criteria and weightings used in the MCA to prioritise the flood mitigation strategies are summarised in Table 7-1.

Table 7-1—Flood Mitigation Strategies MCA Criteria Performance Score

Criteria	Weighting	Performance Score				
		5	4	3	2	1
Financial	*$33\frac{1}{3}$*					
Flood Damages Reduction Ratio (1% AEP)	25	>1	0.75-1	0.5-0.75	0.25-0.5	<0.25
Maintenance Cost	$8\frac{1}{3}$	<$5k	$5-20k	$20-50k	$50-100k	>$100k
Environmental	*$33\frac{1}{3}$*					
Precursor to Implementation of WSUD Strategy	$16\frac{2}{3}$	Multi-objective WSUD	-	Water Quality Only	-	None
Offers Improved Protection Against Sea Level Rise and Seawater Ingress	$16\frac{2}{3}$	Yes	-	-	-	No
Social	*$33\frac{1}{3}$*					
Community Acceptance	$6\frac{2}{3}$	Very High	High	Moderate	Low	Very Low
Change to Workplace and Public Safety	$3\frac{1}{3}$	None	Negligible	Low	Moderate	Significant
Reduced Property Inundation	$16\frac{2}{3}$	>40	30-40	20-30	10-20	<10
Reduced Street Drainage Nuisance	$6\frac{2}{3}$	Very High	High	Moderate	Low	Very Low
Total	*100*					

Performance values used in the assessment of flood mitigation strategies have been derived as follows:

- Flood Damages Reduction Ratio

The flood mitigation strategies for each catchment have been grouped together and prioritised based on a ratio of estimated reduction in flood damages against the budget estimate for the corresponding capital works. The ratio has been considered for the 1% AEP. All projects within a single catchment have been assigned the same value.

- Maintenance Cost

Gravity drainage systems were assigned the highest value, with detention basins and minor pump stations assigned slightly lesser values, and major pump stations assigned the lowest values.

- Precursor to Implementation of WSUD Strategy

The project is required as a precursor to, or directly facilitates, the implementation of a Water Sensitive Urban Design strategy. Projects that facilitate multi-objective WSUD outcomes have been assigned higher values than projects that facilitate water quality improvement only (eg. Gross Pollutant Traps).

- Community Acceptance

All projects were assigned a default maximum value against this criteria, with values revised down for projects that (1) require acquisition of land or easements over private property, and (2) result in changes or impacts to the existing use of public open space. Projects that result in changes or impacts to existing sites that have high recreational value and/or support organised sport were assigned the lowest values.

- Change Workplace and Public Safety

A Safety in Design (SiD) approach was adopted in the development of all flood mitigation strategies. Notwithstanding, those strategies that create water storages or open channels were assigned a lower value against this criteria, as they were viewed to be creating assets with inherent risks that did not previously exist at a given location. Continued application of SiD principles would serve to mitigate some of these risks throughout the design and construction phase, and residual risks would be required to be managed on an ongoing basis in accordance with Council's established policies and procedures for the operation and maintenance of similar assets.

- Reduced Property Inundation

These values (number of properties) were obtained through reference to the 1% AEP floodplain mapping of the ultimate scenario.

- Street Nuisance

This value was assigned based on judgement of the improvements demonstrated by the 0.2EY (5 year ARI) floodplain mapping of the ultimate scenario. Projects that limit roadway ponding in the vicinity to a depth of less than 0.1 metres were assigned the highest value, with projects that limit roadway ponding to greater depths assigned progressively lower values.

Performance scores have been allocated for consideration by the Project Steering Committee (refer Appendix F) and a summary of the weighted score for each flood mitigation strategy/project is presented in Table 7-2 (note that each project can achieve a maximum score of 5).

Table 7-2—Flood Mitigation Strategies MCA Results

ID	Strategy / Project	Weighted Score
D1-A*	Prospect Drainage Upgrade Scheme - Prospect Road to Redin Street	3.97
D1-B*	Prospect Drainage Upgrade Scheme - Churchill Road	3.97
D8	Barker Inlet Wetland Outlet Gate Replacement	3.40
D2	Talbot Road / Overland Road – Drainage	2.92
D3	Laurel Avenue / Hudson Avenue – Drainage, Detention, Bioretention	2.87
D7	Nairn Street to Sam Johnson Sportsground Soccer Pitch	2.83
D4	Ridley Grove – Detention	2.47
D5	Short Street / Frederick Street / John Street – Drainage	2.47
D6	Wing Street / Miller Road – Drainage, Detention	2.28

* D1-C and D1-D are both precursors for completion of D1-A and D1-B. Therefore the cost and benefits of these works have been equally divided and incorporated into the MCA Scores above.

7.1.2 WSUD Strategies Multi-Criteria Analysis

The criteria and weightings used in the MCA to prioritise the WSUD strategies are summarised in Table 7-3.

Table 7-3—WSUD Strategies MCA Criteria Performance Score

Criteria	Weighting	Performance Score				
		5	4	3	2	1
Financial	$33\frac{1}{3}$					
Capital Cost	$16\frac{2}{3}$	<$50k	$50-300k	$300-600k	$600k-1.2m	>$1.2m
Maintenance Cost	$16\frac{2}{3}$	<$10k	$10-20k	$20-30k	$30-40k	>$40k
Environmental	$33\frac{1}{3}$					
Pollutant (TSS) Reduction to Port River (annual average)	$13\frac{1}{3}$	>10 tonnes	5-10 tonnes	2-5 tonnes	1-2 tonnes	<1 tonne
Volume Reduction (annual average)	$13\frac{1}{3}$	>40 ML	10-40 ML	1-10 ML	<1 ML	0 ML
Habitat and Ecosystems	$6\frac{2}{3}$	Create new and restore / improve existing infrastructure	Create new	Improve existing	Restore existing infrastructure	No change
Social	$33\frac{1}{3}$					
Community Acceptance	$13\frac{1}{3}$	Very High	High	Moderate	Low	Very Low
Change to Workplace and Public Safety	$6\frac{2}{3}$	None	Negligible	Low	Moderate	Significant
Public Open Space	$13\frac{1}{3}$	Provide new	Improve existing	No change	Negative impact on existing users	Excludes public
Total	*100*					

- Capital Cost

Reference has been made to the construction cost estimates outlined in this Plan to determine this value. Where the WSUD project is to be integrated with a flood mitigation project, this value represents the "extra-over" cost associated with the WSUD component of the works.

- Maintenance Cost

Values were assigned based on maintenance cost estimates from historical experience and industry sources.

- Pollutant (TSS) Reduction

Projects have been assigned a value that is commensurate with their expected pollutant removal performance, as defined by the average annual load reduction of Total Suspended Solids reported by the MUSIC model.

- Stormwater Reuse or Volume Reduction

Projects have been assigned a value that is commensurate with their expected stormwater reuse or volume reduction performance, as defined by the average annual harvesting yield or volume reduction reported by the MUSIC model.

- Habitat and Ecosystems

Projects have been assigned a qualitative value that reflects (1) their expected impact on existing habitats and ecosystems, and (2) their potential to create new habitats and ecosystems.

- Community Acceptance

Consideration was given to feedback received during the community consultation phase of the draft Plan in determining the values assigned for this criteria.

- Workplace and Public Safety

A Safety in Design (SiD) approach was adopted in the development of all WSUD strategies. Notwithstanding, those strategies that create water storages or pump stations were assigned a lower value against this criteria, as they were viewed to be creating assets with inherent risks that did not previously exist at a given location. Continued application of SiD principles would serve to mitigate some of these risks throughout the design and construction phase, and residual risks would be required to be managed on an ongoing basis in accordance with Council's established policies and procedures for the operation and maintenance of similar assets.

- Public Open Space

Projects have been assigned a qualitative value that reflects (1) their expected impact on existing public open space, and (2) their potential to create new public open space. Projects that result in changes or impacts to existing sites that have high recreational value and/or support organised sport, or result in the exclusion of the public access, were assigned the lowest values.

Performance scores have been allocated for consideration by the Project Steering Committee (refer Appendix F) and a summary of the weighted score for each WSUD strategy/project is presented in Table 7-4 (note that each project can achieve a maximum score of 5).

Table 7-4—WSUD Strategies MCA Results

ID	Strategy / Project	Weighted Score
Q1, Q2*	Wetland Rehabilitation, Monitoring and MAR activation	3.70
Q10	Streetscape raingardens / bioretention	3.67
Q8	Days Road reserve bioretention	3.40
Q3	Bayer Avenue Dryland Reserve bioretention	3.03
Q4	Bromley Close bioretention	3.03
Q5	Reg Robinson reserve bioretention	3.03
Q6	Montrose Street bioretention	3.03
Q7	R.L. Pash Park bioretention	3.03
Q9	East Terrace reserve bioretention	3.03

7.2 Strategy Action Costs, Benefits, Objectives and Priority Summary

A consolidated list of prioritised actions is presented in Table 7-5, together with a brief description of the benefits realised and objectives addressed through implementation of each action. Actions that are potentially eligible for Stormwater Management Authority funding support (typically co-funding on a 50/50 basis with Local Government for projects with a contributing catchment area greater than 40 hectares) have been highlighted. Note that the Authority has the discretion to contribute more or less than 50% of the cost of certain works and may elect to contribute to the cost of works in a catchment of less than 40 hectares, provided that those works form part of an approved Stormwater Management Plan.

7.3 Responsibilities for Implementation and Funding Opportunities

Each Council is responsible for implementation of all activities identified within this Plan. It is expected that Councils will continue to liaise with one another (where necessary), relevant State and Federal Government departments and agencies to satisfy a variety of regulatory requirements.

Council may be able to secure funding from the Green Adelaide and Department for Environment and Water particularly in relation to water quality improvement works outlined in 5. The South Australia Environmental Protection Authority (EPA) also occasionally provide grants for WSUD projects, such as the Rain Garden 500 programme which was held in 2017.

Potential contribution from the Stormwater Management Authority has been highlighted for a number of projects in Table 7-5. It should be noted that funding is at the discretion of the SMA that may contribute more or less than 50%. The Commonwealth government also occasionally offers grants for the purpose of flood disaster planning and relief.

7.3.1 Inter-Council Cost Split

The majority of proposed stormwater works within this Plan are contained within individual Council areas for the benefit of the subject Council. The exception to this is items DB1-C and DB1-D (HEP channel upgrades). Both project sites are located within the City of Port Adelaide Enfield Council area, however, are prompted by the requirement of upstream flood mitigation works within the City of Prospect (i.e. would not immediately be required without upgrades D1-A and D1-B within City of Prospect).

South Australia has a long and well established practice in developing cost sharing agreements in order to deliver flood mitigation works within catchments that span across multiple Council areas. Examples include:

- Brown Hill - Keswick Creeks (Adelaide, Burnside, Mitcham, Unley and West Torrens)
- Port Road (Charles Sturt, Port Adelaide Enfield)
- Holdfast - Marion Coastal Catchments (Marion, Holdfast Bay)
- Torrens Road (Charles Sturt, Port Adelaide Enfield)
- Hindmarsh - Enfield - Prospect (Prospect, Port Adelaide Enfield, Charles Sturt)
- Cobbler Creek (Salisbury, Tea Tree Gully)
- South West Suburbs Drainage Scheme (Marion, Mitcham, Unley, West Torrens, Holdfast Bay)

While the funding agreement for any flood mitigation scheme is ultimately a matter for agreement amongst the catchment Councils, guidance on principles for cost sharing to support this process is available in *Metropolitan Adelaide Stormwater Management Study Part C: Apportionment of Council Costs* (KBR, 2004). This document is referenced by the Stormwater Management Authority in its *Stormwater Management Planning Guidelines* for this purpose.

This document recommends adoption of a model that distributes costs on two guiding principles:

- The extent to which each Council area causes the cost/damage (the 'cost cause')
- The extent to which each Council area avoids future flooding costs on completion of the mitigation works (the 'future costs avoided')

The 'cost cause' component is suggested to primarily take into account the contributing catchment area.

The 'future costs avoided' component can be determined by taking into account the number of properties removed from the flood plain (simple approach), or evaluation of reduction in flood damages (which takes into account varying damage value rates arising from different types of land use).

The relative weightings of these 2 components is not prescribed, however in two recent urban examples (Brown Hill - Keswick Creeks, Holdfast – Marion Coastal Catchments), a 50/50 split was assigned to these components.

Table 7-5—SMP Strategy Actions

Priority	Project Location	Activities	LGA/ Catchment	Project ID	App D Sheet	Flood Mitigation Benefit	Water Quality Benefit	Sea Level Protection Benefit	Capital Cost	Annual Costs	SMA Eligible	Objectives Addressed
High	D1-A Prospect Road, Redin Street and Regency Road	Drainage	CoP/HEP	D1-A	01 - 03	✓			$9,630,000		✓	O1, O2
High	Churchill Road	Drainage	CoP/HEP	D1-B	04 -07	✓			$11,530,000		✓	O1, O2
High	HEP Upgrade, Pedder Cres to Narweena Rd	Drainage	CoP/HEP	D1-C	08	✓			$3,890,000		✓	O1, O2
High	HEP Upgrade, Grand Junction Road	Drainage	CoP/HEP	D1-D	09	✓			$940,000		✓	O1, O2
High	Barker Inlet Wetland Tidal Gate Replacement	Drainage, Sea level Rise Protection, Wetland Maintenance	PAE/ALL	D8	N/A	✓	✓	✓	$1,400,000		✓	
High	Community Flood Response and Preparedness – FloodSafe Program	N/A	ALL	D9	N/A				-	-		O8
High	Community Emergency Management Plan	N/A	ALL	D10	N/A				-	-		O8
High	Development Controls – Floor Levels	N/A	ALL	D11	N/A				-	-		O7
High	Ongoing Maintenance and Monitoring of Council Assets	N/A	ALL	D12	N/A				-	-		O6
High	Wetland Rehabilitation and Monitoring	Wetland Maintenance	PAE/ALL	Q1	N/A		✓		-	$50,000		

Priority	Project Location	Activities	LGA/ Catchment	Project ID	App D Sheet	Flood Mitigation Benefit	Water Quality Benefit	Sea Level Protection Benefit	Capital Cost	Annual Costs	SMA Eligible	Objectives Addressed
High	Streetscape raingardens / bioretention	Bioretention	Various	Q10	N/A		✓		$6,230,000	$700 per raingarden		O3, O5
High	Rainwater Tanks		Various	Q10	N/A		✓		N/A	N/A		O4, O7
High	Maintenance of existing vegetated open channels and swales (HEP, Dunstan, NAW)		PAE	Q11	N/A		✓		N/A	N/A		O3
High	Integration with Council Business Plans		Various	Q11	N/A		✓		N/A	N/A		O9
High	Community Education and WSUD Promotion		Various	Q13	N/A		✓		N/A	N/A		O5, O8
Medium	Talbot Road and Overland Road –	Drainage	PAE/HEP	D2	10 – 11	✓			$2,550,000	-		O1, O2
Medium	Hudson Avenue and Laurel Avenue –	Drainage Detention and bioretention	HEP/NAW	D3	12 – 13	✓	✓		$4,930,000	-		O1, O2
Medium	Short Street, Frederick Street and John Street -	Drainage	PAE/NAW	D5	15	✓			$1,780,000	-		O1, O2
Medium	Napier Street	Drainage Upgrade and Detention	CoCS/HEP	D7	17	✓	✓		2,170,000	-		O1, O2, O9
Medium	SA Water MAR Scheme Reactivation	Water Harvesting	PAE/HEP	Q2	N/A		✓		$500,000	$20,000		O4, O5
Medium	Bayer Avenue Dryland Reserve	Bioretention	PAE/HEP	Q3	N/A		✓		$220,000	$2,000		O3, O5, O9
Medium	Bromley Close	Bioretention	CS/HEP	Q4	N/A		✓		$350,000	$2,000		O3, O5, O9
Medium	Reg Robinson reserve	Bioretention	PAE/NAW	Q5	N/A		✓		$550,000	$2,000		O3, O5, O9

Priority	Project Location	Activities	LGA/ Catchment	Project ID	App D Sheet	Flood Mitigation Benefit	Water Quality Benefit	Sea Level Protection Benefit	Capital Cost	Annual Costs	SMA Eligible	Objectives Addressed
Medium	Montrose Street	Bioretention	PAE/NAW	Q6	N/A		✓		$150,000	$2,000		O3, O5, O9
Medium	R.L. Pash Park	Bioretention	CoP/HEP	Q7	N/A		✓		$220,000	$2,000		O3, O5, O9
Low	Ridley Grove	Drainage and Detention	PAE/NAW	D4	14	✓	✓		280,000			O1, O9
Low	Wing Street and Miller Road	Drainage Detention and bioretention	PAE/NAW	D6	16	✓	✓		$340,000			O1, O2
TOTAL									**$47,320,000**			