City of Port Adelaide Enfield

Lefevre Peninsula Stormwater Management Plan

Final Report

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Final Report

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Executive Summary

This Stormwater Management Plan for the Lefevre Peninsula has been prepared in accordance with the requirements of the Stormwater Management Planning Guidelines (Stormwater Management Authority, 2007).

This document contains:

- A summary of existing information relevant to the 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.

The Stormwater Management Plan area is 2,240 hectares and is not defined by a typical single contributory catchment area, but of numerous individual catchments that all discharge individually to either the Port River or Gulf of St Vincent. The plan boundary area is entirely within the City of Port Adelaide Enfield.

The topography of the Lefevre Peninsula is characterised by undulating coastal dunes to the west and open flat low-lying land to the east. This topography has resulted in a number of low-lying areas and trapped low points that are unable to be serviced by conventional gravity drainage systems, requiring the use of pumped systems and/or soakage (infiltration) systems for stormwater disposal. These low-lying areas and trapped low points do not have a natural overflow path to the Port River or Gulf of St Vincent, and therefore stormwater flows in excess of the pump or infiltration capacity are required to pond in the road carriageway, and the ingress of flows to private property has been known to occur during large rainfall events.

Other key issues identified by this Stormwater Management Plan include:

- Minor (underground) drainage systems that have a lower than desirable performance standard;
- The potential for seawater ingress and projected sea level rise to adversely affect the performance of gravity drainage systems;
- The presence of soil and groundwater conditions that limit the range of stormwater management improvement measures that are feasible at a given location;
- The limited amount of public open space that is able to facilitate catchment-scale stormwater detention, water quality improvement and stormwater harvesting and reuse initiatives; and
- The scope for future development, largely infill, to amplify the issues described above.

Relevant objectives contained within the *City Plan 2010-2016* (City of Port Adelaide Enfield, 2010)*, Strategic Plan for the Adelaide and Mount Lofty Ranges Region 2014-15 to 2023-24*

(Adelaide and Mount Lofty Ranges Natural Resources Management Board, 2013), and *Port Waterways Water Quality Improvement Plan* (Environment Protection Authority, 2008), in addition to the recent documents relating to climate change adaptation were drawn on to develop a set of objectives specific to this Stormwater Management Plan, addressing:

- Provision of an acceptable level of flood protection to the community;
- Provision of an acceptable level of performance in the minor (underground) drainage system;
- Improvements to stormwater quality released to the Port River and Gulf of St Vincent;
- Beneficial harvesting and reuse of stormwater;
- Sustainable management of stormwater infrastructure; and
- Achievement of desirable outcomes associated with new development and management of open space.

The Plan has developed a range of structural and non-structural actions, summarised in the table below and described in this report, by which these objectives can be achieved. The total budget cost for implementation of the proposed structural flood mitigation strategies is $45,665,000. These strategies have been developed with a view to maximising the level of flood protection that can be achieved within practical constraints, such as retaining existing major pump stations that are within their service life, and where possible utilising the existing rising mains to the Port River. In accordance with the Plan's objectives these strategies have aspired to achieve no above floor inundation of properties for all events up to and including the 100 year ARI storm, and where this is not practically achievable, a 20 year ARI standard has been sought.

The strategies include new pump stations to service low-lying catchments with drainage systems that currently do not meet the desired performance standards, including a major new pump station on Victoria Road in the Lulu catchment, and packaged submersible pump stations for Charon Reserve and Midlunga Railway Station in Taperoo. The Semaphore Road East and Jetty Road/Centre Street catchments also require replacement of existing gravity drainage outfalls with new pumped systems to cater for predicted sea level rise and mitigate the impacts of seawater ingress during high tides and storm surge events.

Major underground drainage upgrades are recommended for Semaphore Road, Carlisle Street, Kolapore Avenue, Wills Street, Fletcher Road and Anthony Street. These works will reduce surface ponding and reduce the likelihood of inundation of private property in major storm events. Other minor drainage upgrades are recommended at various locations around the Peninsula to reduce surface ponding.

Stormwater detention/infiltration basins are proposed to be integrated with several public reserves and vacant land parcels across the Peninsula. These locations include Nazar Reserve, Phillips Reserve, Warwick Avenue Reserve, Birkenhead Naval Reserve and Carnarvon Reserve. These basins will mitigate flows and improve the performance of downstream drainage systems, and also reduce the volume of urban stormwater runoff that is discharged to the Port River and Gulf St Vincent.

Flood damage estimates have been used to evaluate the effectiveness of the structural flood mitigation strategies, however floor level survey of properties that have been identified as vulnerable to stormwater inundation would be required to refine the flood damage estimates and confirm that the desired performance standard has been achieved for all properties.

Water quality improvement measures that are recommended in this Stormwater Management Plan include Gross Pollutant Traps, streetscape raingardens, infiltration basins at coastal outlets, vegetated swales and bioretention basins, as well as two constructed wetlands with Aquifer Storage and Recovery (ASR) schemes. The total budget cost for implementation of the proposed Water Sensitive Urban Design strategy is $7,770,000.

Water quality modelling has shown that the capital works identified in this Plan would contribute significantly towards the improvement in stormwater quality discharged to the Port River and Gulf St Vincent. However further measures would need to be implemented in order to ultimately achieve all pollutant reduction targets, particularly for catchments discharging directly to the Port River. The opportunity for further measures primarily exist at the street level, such as raingardens being incorporated into road reconstruction projects, and on private property. Actions have been identified in this Plan through which these additional opportunities can be identified and integrated into other capital works programs.

A Multi-Criteria Analysis was developed to enable relative priorities to be assigned to all identified future stormwater works taking into account financial, environmental and social variables. A consolidated list of the prioritised actions is presented in the table below, which also provides capital cost estimates and highlights the actions that are potentially eligible for Stormwater Management Authority funding support based on having a contributing catchment area greater than 40 hectares.

Priority	Project Location	Activities	Catchment	Capital Cost	SMA Eligible
High	Kolapore Avenue / Carnarvon Reserve	Drainage, Detention, Infiltration	Mersey Road	$1,310,000	✓
High	Anthony Street	Drainage, Infiltration	Largs Bay Shore	$1,175,000	
High	Hughes Street / Naval Reserve	Drainage, Detention, Pump Station, Bioretention	Semaphore Road East	$2,270,000	
High	Semaphore Road	Drainage, GPT	Carlisle Street / Semaphore Road East	$2,405,000	
High	Various	Raingarden	Various	$800,000	
High	Hargrave Street	Lateral Drainage	Hargrave Street	$1,675,000	
High	N/A	Rainwater Tanks	Various	N/A	
High	N/A	FloodSafe Program	Various	N/A	
High	N/A	Floor Level Survey	Various	N/A	
High	N/A	Business Plan Integration	Various	N/A	
High	N/A	Community	Various	N/A	

Priority	Project Location	Activities	Catchment	Capital Cost	SMA Eligible
		WSUD Education			
High	Largs North Reserve	Monitor Permeable Paving	Mersey Road	N/A	
Medium	Aldinga Street Reserve	Detention, Wetland and ASR	Mersey Road	$2,610,000	✓
Medium	Warwick Street / Jetty Road	Drainage, Detention, Pump Station, Infiltration, GPT	Jetty Road / Centre Street	$13,210,000	✓
Medium	Lulu	Drainage, Pump Station, GPT	Lulu	$14,235,000	✓
Medium	Railway Terrace	Detention, Pump Station, Infiltration	Taperoo Shore	$285,000	
Medium	Phillips Reserve	Detention, Infiltration	Carlisle Street	$305,000	
Medium	Goldsworthy Road	Drainage, GPT	Hart Street	$580,000	
Medium	Estella Street	Detention, Vegetated Swale	Hamilton Avenue	$840,000	
Medium	Various	Coastal Infiltration	Semaphore / Largs Bay / Largs North / Taperoo Shores	$875,000	
Medium	Carlisle Street / Nazar Reserve	Drainage, Detention, Vegetated Swale	Hart Street	$1,715,000	
Medium	North Haven	Wetland and ASR	North Haven	$1,895,000	
Low	Hamilton Avenue	GPT	Hamilton Avenue	$270,000	
Low	Carlisle Street	GPT	Carlisle Street	$270,000	
Low	Deslandes Street	Drainage	Hart Street	$340,000	
Low	Mersey Road North	GPT	Mersey Road	$425,000	
Low	Veitch Road	GPT	Mersey Road	$425,000	
Low	Midlunga Railway Station	Pump Station	Taperoo Shore	$1,185,000	
Low	Charon Reserve	Detention, Pump Station, Bioretention	Taperoo Shore	$1,360,000	
Low	Various	Drainage	Largs North Shore	$2,975,000	

A draft report was prepared in 2016 and utilised for consultation with the local community, interest groups, Council elected members and staff. Following the collation of feedback from this process, a revised draft report was submitted and approved by the City of Port Adelaide Enfield, Adelaide and Mount Lofty Natural Resources Management Board and the Stormwater Management Authority, subject to the inclusion of minor edits included in this final report.

1 Introduction

The Stormwater Management Plan for the Lefevre Peninsula has been prepared for the City of Port Adelaide Enfield in accordance with the requirements of the Stormwater Management Planning Guidelines (Stormwater Management Authority, 2007).

The Plan provides an overview of the existing catchments and issues relating to current stormwater management practices on the Lefevre Peninsula. 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 the 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 outlines in this Plan are proposed as a means of ensuring that the 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 has been prepared in consultation with the Natural Resources Adelaide and Mount Lofty Ranges (staff) and Department of Planning, Transport and Infrastructure (DPTI) (acting on behalf of the Stormwater Management Authority).

A draft report was prepared in 2016 and utilised for consultation with the local community, interest groups, Council elected members and staff. Following the collation of feedback from this process, this final draft report has been prepared for submission to the City of Port Adelaide Enfield, NRM Board and the Stormwater Management Authority for final approval.

2 Catchment Features

2.1 Boundary

The Study Area boundary for this Stormwater Management Plan consists of the entire Lefevre Peninsula, bounded by Bower Road to the south, Port River to the east and Gulf of St Vincent to the west. The total Study Area is 2,240 hectares in size and is not defined by a typical single contributory catchment area, but of numerous individual catchments that all discharge individually to either the Port River or Gulf of St Vincent.

Suburbs within the Study Area boundary include; Outer Harbour, Osborne, North Haven, Taperoo, Largs North, Largs Bay, Peterhead, Birkenhead, Exeter, Semaphore, Glanville, Semaphore South, New Port, and Ethelton.

The Study Area boundary is shown in Figure 2.1.

2.2 Topography

A surface elevation model was derived from the Digital Terrain Model (DTM) provided by Council. This elevation model is depicted in Figure 2.2 with areas shaded in red at relatively higher elevations than areas of green/blue.

Inspection of this surface elevation model indicates two distinct land features over the Peninsula:

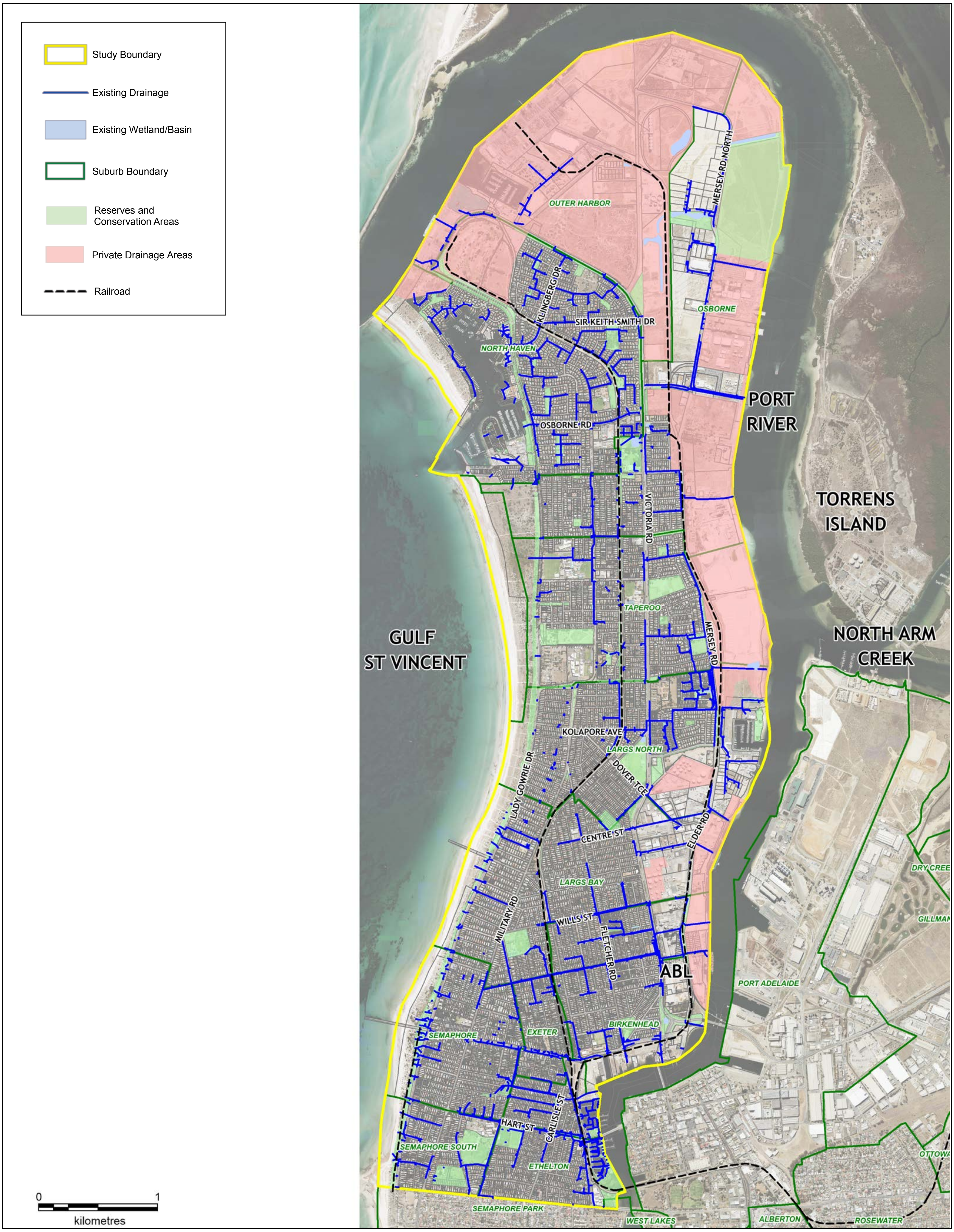
- The western length of the Peninsula is characterised by a series of sand dune ridges extending back from the coast. Many of these dunes, particularly at the southern end of the Peninsula, have historic development constructed directly over the dune undulations; and
- The eastern half of the Peninsula by comparison is characterised by flat, open, low-lying land.

The surface elevation model indicates that many trapped low points exist across the Peninsula, ranging from small single street catchments between dune ridges to large suburb-wide catchment low points. Some of the largest catchments with trapped low points are shown in the vicinity of Hart Road in Ethelton, Carlisle Street in Glanville, Hargrave Street in Peterhead and Hamilton Avenue in Osborne.

The Peninsula is generally low-lying. Elevations range from as low as 0.5 mAHD (Australian Height Datum) in areas of Semaphore South and Ethelton, to above 15 mAHD within the sand dune areas of the west.

2.3 Land Subsidence

Land subsidence has been identified as potentially occurring in Port Adelaide and the surrounding coastal regions in studies dating back to the 1970's. The key factors that are understood to have contributed to historical land subsidence in the Study Area are groundwater withdrawal, land reclamation by draining of wetlands (including the impact of Coastal Acid Sulfate Soils as described in Section 2.9.2), and land reclamation by filling. To a lesser extent, it is possible that long term subsidence of the St Vincent Basin may also be a contributing factor.



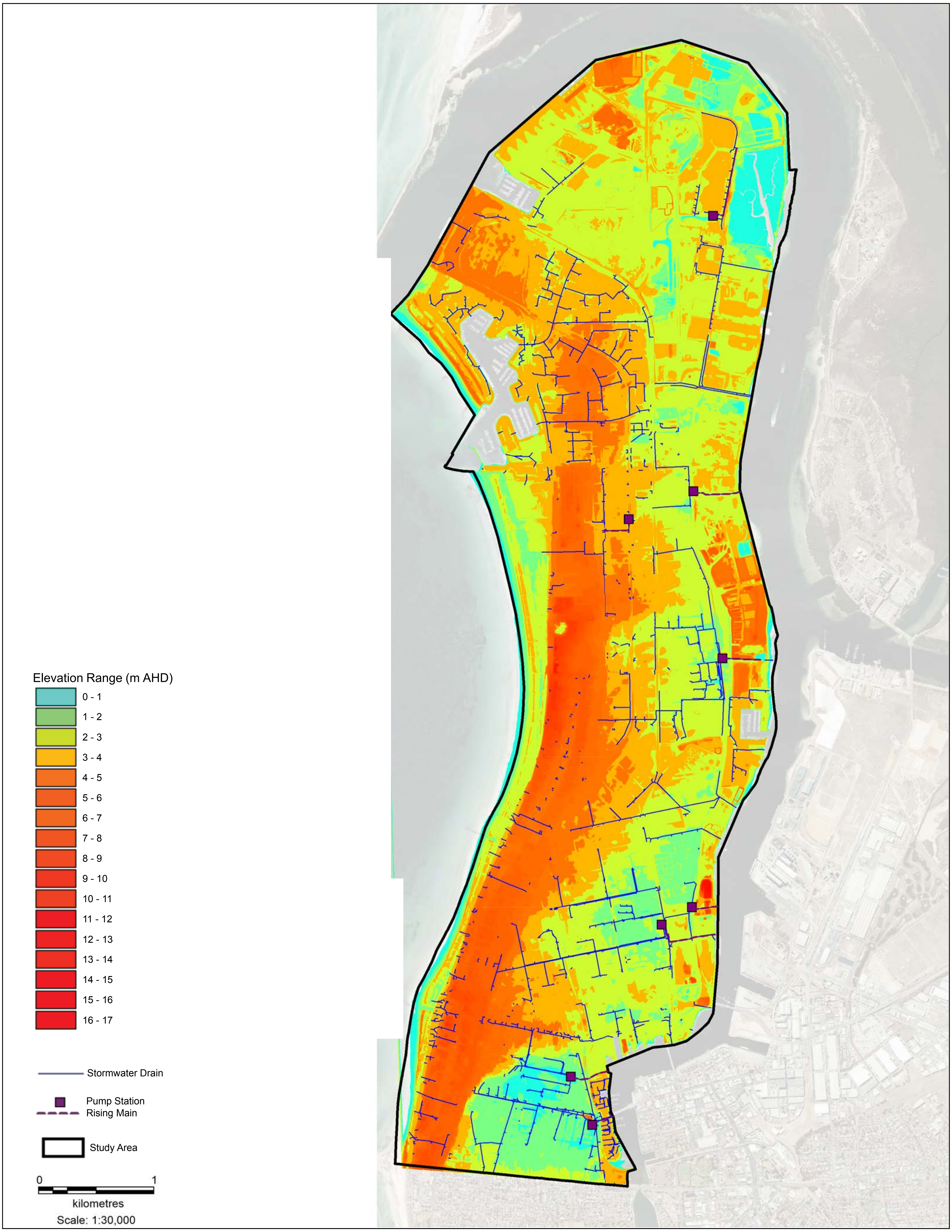
Data Sources:
City of Port Adelaide Enfield (Aerial Photograph, Stormwater Data)
Southfront (Pri. ate Drainage Areas)

southfront

Lefevre Peninsula
Stormwater Management Plan

Study Area

Figure 2.1



Data Sources:
City of Port Adelaide Enfield (Aerial Photograph, Stormwater Data)
Southfront (Elevation Ranges, Pump Stations)

Lefevre Peninsula
Stormwater Management Plan

southfront

Topography
Figure 2.2

Previous studies have assessed the available data relating to the average land subsidence of the Adelaide coastline. In particular the *Port Adelaide Seawater Stormwater Flooding Study* (Tonkin Consulting, 2005), which included an assessment of data from the *Beach Erosion Assessment Study* (Culver, 1970), adopted a single land subsidence rate of 2.1 mm/yr over the Study Area (which included the Lefevre Peninsula).

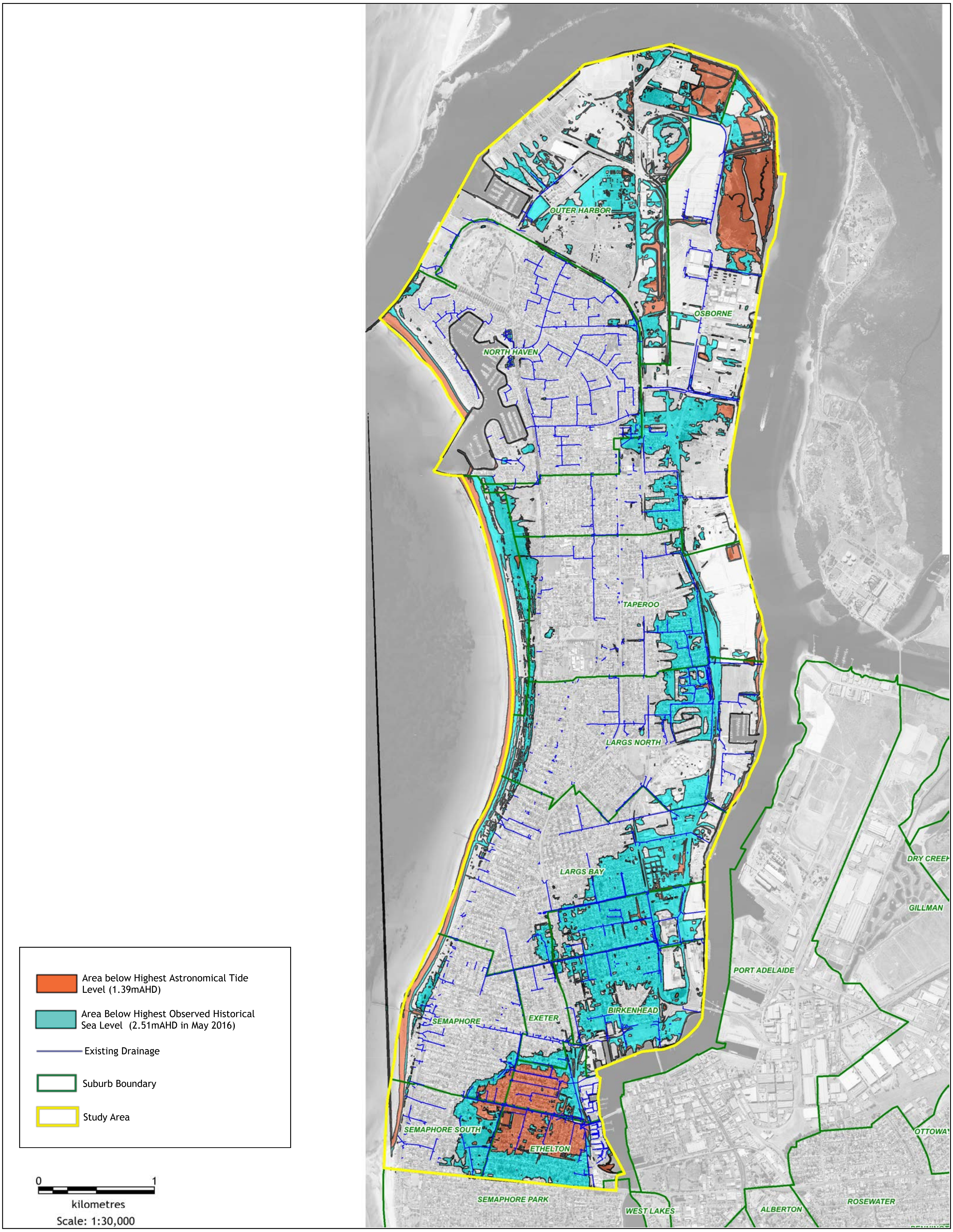
The *Western Adelaide Region Climate Change Adaptation Plan; Coastal and Inundation Modelling - Phase 1 Report* (Tonkin Consulting, 2015) has conducted a further assessment of recent Deep Benchmark Level Survey readings, indicating that a reduced land subsidence value of 1.5 mm/yr may be justified. This lower rate is consistent with the recommendation of 1-2 mm/yr for expected land subsidence along the Adelaide metropolitan coastline, as stated in the *Coast Protection Board Policy Document* (Coast Protection Board, 2012).

The above recommendations have been considered in the development of the stormwater management objectives and strategy of this Plan.

2.4 Tidal Interactions

The *Port Adelaide Seawater Stormwater Flooding Study* (Tonkin Consulting, 2005) showed that within the Study Area, portions of land are low-lying to the extent that some areas are below recorded high tide levels. Figure 2.3 shows the areas of the Peninsula that are below the Highest Astronomical Tide (HAT) level of 1.39 mAHD for Outer Harbor. At the time of the *Port Adelaide Seawater Stormwater Flooding Study* (Tonkin Consulting, 2005) the highest observed historical sea level (ie. tide plus storm surge) was 2.23 mAHD in July 1981, however an event in May 2016 resulted in a higher observed sea level (ie. tide plus storm surge) of 2.51 mAHD.

High tide inundating Jenkins Street, Birkenhead, April 2009 (ABC News online photograph)



Data Sources:
City of Port Adelaide Enfield (Aerial Photograph, Stormwater Data)
Southfront (Tide Elevations)

Lefevre Peninsula
Stormwater Management Plan

Area Below Highest Astronomical & Observed Tide Levels

Figure 2.3

southfront

The *Port Adelaide Seawater Stormwater Flooding Study* (Tonkin Consulting, 2005) reported that there is no reliable correlation between rainfall event probability and storm tide probability (ie. there is no strong tendency, say, for rainfall to be greater when storm surges occur). The performance of the stormwater drainage network within the low lying catchments is affected by the prevailing downstream tide level in St Vincent Gulf and the Port River. Catchments where the performance of the stormwater drainage network is independent of tide level include those with pumped outfalls and catchments with ground levels sufficiently high to allow unimpeded gravity drainage.

For the purposes of modelling the performance of the stormwater drainage network, the study adopted a 100 year ARI Tide Cycle with a peak of 2.38 mAHD (including tide plus storm surge and an allowance for an assumed long term subsidence rate of around 2 mm/yr). The Design 'Average' Tide Cycle was taken to be the Outer Harbour Mean High Water Springs (MHWS) level of 0.95 mAHD (assumed to be a constant level throughout the duration of the rain storm event).

The study adopted minimum desirable stormwater drainage performance requirements for a range of coincident rainfall and tide conditions, principally the 100 year ARI Tide Cycle as the receiving water level for gravity drainage systems in rainfall events less than the 5 year ARI, and the Design 'Average' Tide Cycle as the receiving water level for gravity drainage systems in rainfall events greater than or equal to the 5 year ARI.

The study showed that the performance of the gravity drainage systems with outlets to the Port River and North Haven Marina was similar for 1-2 year ARI rainfall events with the 100 year ARI Tide Cycle as the receiving water level, than it was for 5 year ARI rainfall events with the Design 'Average' Tide Cycle as the receiving water level. This observation has been considered when selecting the boundary conditions for the hydraulic models that assess the performance of the existing stormwater drainage system for this Plan.

The possible impacts of sea level rise on the performance of the stormwater drainage network of the Lefevre Peninsula are discussed in Section 4.

2.5 Rainfall

2.5.1 Statistics Analysis

Lefevre Peninsula has a rainfall pattern typical of Adelaide's Mediterranean climate, with annual average rainfall of 433 mm. Daily rainfall data from the nearby Bureau of Meteorology Torrens Island rainfall gauge (Station 23018) has been obtained for the years 1912 - 2013.

Statistics analysis of the annual rainfall variation is also provided by the Bureau of Meteorology, which reports variations from the annual mean as summarised in Table 2.1 below, and monthly trends as shown in Figure 2.4.

Table 2.1—Lefevre Peninsula Rainfall Statistics

Statistic	Annual (mm)	% Difference to Mean
Mean	433.1	-
Lowest	213.9	-50%
5th %ile	288.6	-33%
10th %ile	333.2	-23%
Median	425.6	-4%
90th %ile	566.8	31%
95th %ile	589.0	36%
Highest	620.9	43%

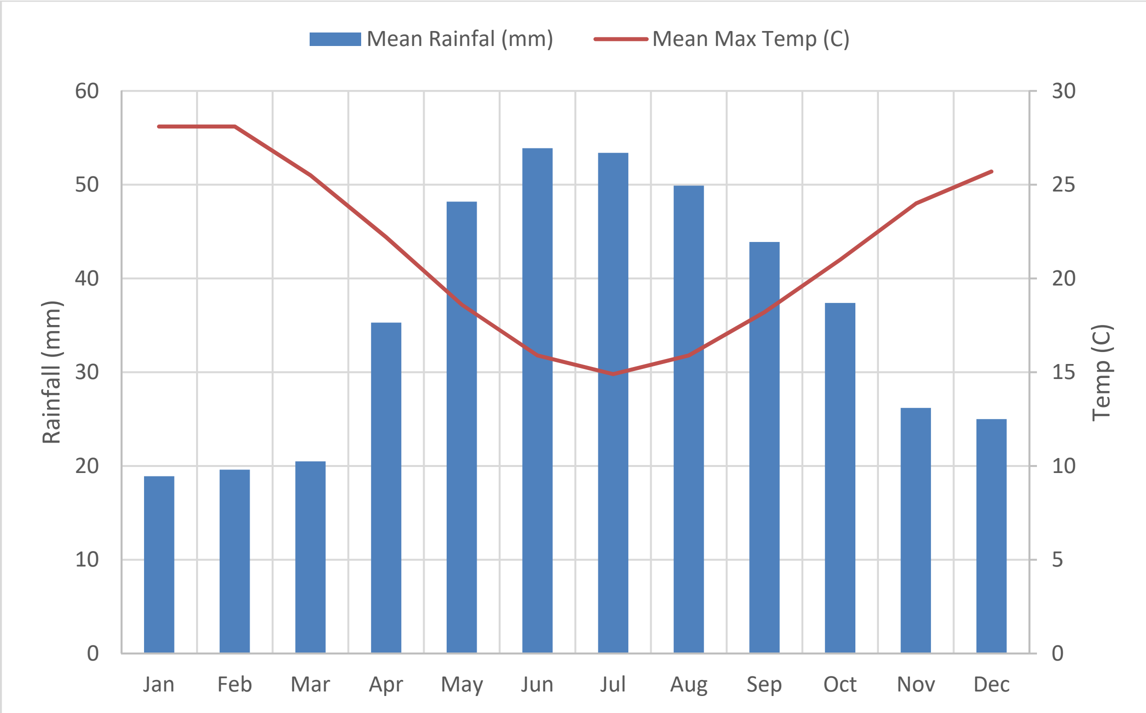


Figure 2.4—Lefevre Peninsula Monthly Rainfall Averages

2.5.2 Intensity-Frequency-Duration Data

Design Intensity–Frequency–Duration (IFD) data was prepared for the Study Area utilising the online procedure provided by the Bureau of Meteorology for the 1987 revision of *Australian Rainfall and Runoff* (ARR1987). This data is presented in Table 2.2 and has been used as the basis for the hydrological modelling for this Plan.

Table 2.2—Lefevre IFD Data (mm/hr)

Duration	Average Recurrence Interval (years)						
	1	2	5	10	20	50	100
5 min	39.5	53.9	77.5	95.2	119	156	189
6 min	36.8	50.1	71.9	88.3	110	145	175
10 min	29.6	40.3	57.4	70.3	87.8	115	138
20 min	21	28.5	40.3	49.1	61.1	79.3	95.3
30 min	16.7	22.6	31.9	38.7	48	62.2	74.5
1 hr	11	14.8	20.6	24.9	30.7	39.5	47.2
2 hr	7.07	9.48	13	15.6	19.1	24.4	29
3 hr	5.44	7.28	9.92	11.8	14.4	18.3	21.7
6 hr	3.47	4.61	6.2	7.33	8.88	11.2	13.1
12 hr	2.18	2.89	3.83	4.5	5.42	6.76	7.9
24 hr	1.34	1.76	2.31	2.7	3.23	4	4.66
48 hr	0.778	1.02	1.33	1.55	1.84	2.27	2.64
72 hr	0.551	0.721	0.941	1.08	1.29	1.58	1.83

Following the release of the draft of this Stormwater Management Plan, the Bureau of Meteorology released new Intensity–Frequency–Duration (IFD) design rainfalls as part of the 2016 revision of the national guideline document *Australian Rainfall and Runoff* (ARR2016). The new IFDs, while derived from a longer and more extensive rainfall dataset, were not available at the time of undertaking the hydrological modelling tasks and have not been adopted in this Plan.

However the design rainfall intensities of the two datasets have been compared and the changes to the rainfall intensity data, by duration and Average Recurrence Interval (ARI) are shown in Table 2.3.

Note that ARR 2016 uses the term Annual Exceedance Probability (AEP) to describe the probability of design rainfalls in lieu of the traditional term Average Recurrence Interval (ARI) which has been adopted in this Plan, as explained below:

- 1% Annual Exceedance Probability (AEP) - this rainfall event has a 1% probability of occurring or being exceeded within any given year, and is traditionally referred to as the 100 year Average Recurrence Interval (ARI) event; and
- 0.2 Events per Year (EY) - this rainfall event is likely to occur or be exceeded 0.2 times within any given year, and is traditionally referred to as the 5 year Average Recurrence Interval (ARI) event.

Table 2.3—Adjustment in IFD Values (Lefevre ARR1987 to ARR2016)

Duration	Average Recurrence Interval (years) / Annual Exceedance Probability						
	1 year ARI / 63.2% AEP	2 year ARI / 0.5EY	5 year ARI / 0.2 EY	10 year ARI / 10% AEP[1]	20 year ARI / 5% AEP	50 year ARI / 2% AEP	100 year ARI / 1% AEP
5 mins	-16%	-11%	-7%	-7%	-4%	-1%	2%
10 mins	-13%	-8%	-4%	-5%	-2%	2%	3%
30 mins	-8%	-4%	-1%	-2%	-1%	2%	3%
1 hour	-7%	-3%	-1%	-3%	-2%	-1%	1%
2 hours	-6%	-2%	-2%	-4%	-4%	-3%	-3%
3 hours	-5%	-1%	-2%	-5%	-5%	-5%	-4%
6 hours	-3%	0%	-1%	-5%	-5%	-4%	-5%
12 hours	-2%	2%	1%	-3%	-4%	-3%	-3%
24 hours	-1%	3%	3%	-1%	-2%	0%	1%
48 hours	-3%	1%	3%	1%	0%	3%	6%
72 hours	-6%	-1%	2%	-1%	0%	4%	8%

[1] 10% AEP corresponds to the 9.49 ARI

The comparison table shows a general trend of reduced rainfall intensities for shorter duration and higher frequency storms, and increased rainfall intensities for the longer duration and less frequent storms. The rainfall intensities for storms of 30 minute to 12 hour duration (the critical durations for catchments on the Lefevre Peninsula) tend to show more moderate differences in rainfall intensity.

In order to determine the changes in flow estimates that may result from the future adoption of ARR2016 data, the design rainfalls would need to be run with the updated temporal patterns that accompany the IFD data. It is recommended that the flood mitigation actions outlined in this Plan are assessed using both the ARR1987 and ARR2016 design rainfalls at the detailed design stage.

2.5.3 Impact of Climate Change on Rainfall Patterns

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 this would result in changes in levels of flood protection, stormwater drainage performance, and stormwater availability for harvesting and reuse.

A number of studies and assessments have attempted to improve the understanding of the likely changes to the Adelaide climate brought about by climate change. *The Western Adelaide Region Climate Change Adaptation Plan Coastal and Inundation Modelling – Phase 1 Report* (Tonkin Consulting, 2015) summarises research presented in *Climate Change in Australia – Technical Report 2007* (CSIRO and BoM, 2007) and published by the *Centre for Australian Weather and Climate Research* (CAWCR, 2009), which indicate either no change or a reduction in daily rainfall intensities for the Adelaide Region to later in this century.

However the Local Government Association recommends that an increase in rainfall intensity of 2% be adopted in the assessment of climate change impacts and development of adaptation plans in South Australia, based on the *Guidelines for Undertaking a Climate Change Adaptation Plan and Undertaking an Integrated Climate Change Vulnerability Assessment* (LGA, 2012), which references the above research and communications with the Bureau of Meteorology in relation to local changes in rainfall intensity.

For hydrological modelling of future scenarios for this Plan, it was therefore decided to apply a uniform 2% increase to all rainfall intensities currently predicted by the (ARR87) online IFD procedure provided by the Bureau of Meteorology, as summarised in Table 2.4.

Table 2.4—Lefevre IFD Data (mm/hr) for Climate Change Scenario

	Average Recurrence Interval (years)						
Duration	**1**	**2**	**5**	**10**	**20**	**50**	**100**
5 min	40.29	54.98	79.05	97.10	121.38	159.12	192.78
6 min	37.54	51.10	73.34	90.07	112.20	147.90	178.50
10 min	30.19	41.11	58.55	71.71	89.56	117.30	140.76
20 min	21.42	29.07	41.11	50.08	62.32	80.89	97.21
30 min	17.03	23.05	32.54	39.47	48.96	63.44	75.99
1 hr	11.22	15.10	21.01	25.40	31.31	40.29	48.14
2 hr	7.21	9.67	13.26	15.91	19.48	24.89	29.58
3 hr	5.55	7.43	10.12	12.04	14.69	18.67	22.13
6 hr	3.54	4.70	6.32	7.48	9.06	11.42	13.36
12 hr	2.22	2.95	3.91	4.59	5.53	6.90	8.06
24 hr	1.37	1.80	2.36	2.75	3.29	4.08	4.75
48 hr	0.79	1.04	1.36	1.58	1.88	2.32	2.69
72 hr	0.56	0.74	0.96	1.10	1.32	1.61	1.87

The AdaptWest research paper concludes that average annual rainfall is expected to decrease across the Western Adelaide region in the coming decades; median projections are for rainfall to decline by 2-5% by 2030 and between 5-20% by 2070 throughout South Australia (URPS, 2014). The research paper cites information from meteorological stations in Western Adelaide, indicating that the most likely outcome under a medium and high emissions scenario is for average annual rainfall to decline by about 60 to 75 millimetres per year by 2070. For the purposes of water quality and stormwater harvesting yield modelling for this Plan, it was therefore decided to utilise a subset of the existing rainfall record for the Lefevre Peninsula (or data from a suitable nearby rainfall gauge) that demonstrates a 10-15% reduction to the current mean annual rainfall.

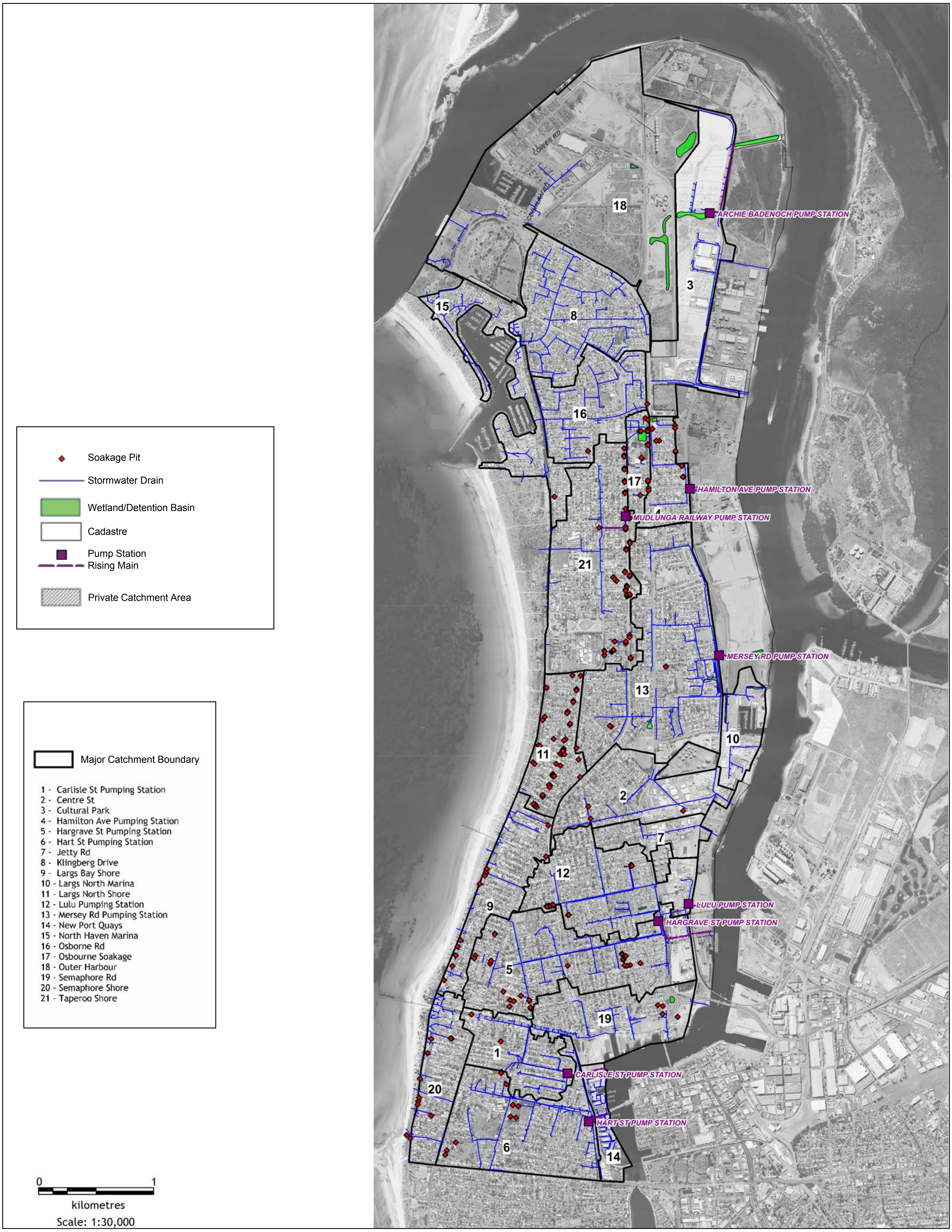
2.6 Infrastructure

2.6.1 Existing Infrastructure

The City of Port Adelaide Enfield maintains a GIS database of existing stormwater infrastructure, which has been utilised for a number of tasks undertaken for this Plan. Figure 2.5 provides and overview of the location and extent of existing stormwater infrastructure within the catchment, which includes gravity drainage, pumped systems, and soakage/infiltration systems. A summary profile of existing infrastructure is provided in Table 2.5.

Table 2.5—Stormwater Infrastructure Profile Summary

Asset Class	Description	Quantity
Pipes	100mm dia	113 m
	150mm dia	319 m
	225mm dia	1,858 m
	300mm dia	19,470 m
	375mm dia	18,359 m
	450mm dia	10,005 m
	525mm dia	5,545 m
	600mm dia	4,923 m
	675mm dia	3,585 m
	750mm dia	3,450 m
	825mm dia	871 m
	900mm dia	4,425 m
	1050mm dia	1,556 m
	1200mm dia	1,836 m
	1350mm dia	1,769 m
	1500mm dia	730 m
	1650mm dia	1,243 m
	1800mm dia	364 m
Box Culvert	<= 1200 wide	9,390 m
	> 1200 wide	1,810 m
Node	Side-entry pit	1,700
	Headwall	21
	Field Gully / Grated Inlet	233
	Inlet / Outlet / Outlet Control	108
	Junction Box / Sump / Inspection Point	1,144
Pump Stations	N/A	8
Gross Pollutant Traps	N/A	40
Soakage Systems	N/A	228
Detention Basins/ Wetlands	Detention Basin	11
	Wetland	2



Data Sources:
City of Port Adelaide Enfield (Aerial Photograph, Stormwater Data)
Southfront (Catchment Boundaries)

Lefevre Peninsula
Stormwater Management Plan

Existing Stormwater Infrastructure
& Catchment Plan
Figure 2.5

southfront

A review of background information identified that Council have been actively undertaking renewal and upgrade works to various stormwater management systems across the Lefevre Peninsula in recent years, as highlighted in Table 2.6. This table is intended to provide an overview of the location and type of stormwater infrastructure works completed since the late 1990's, and does not provide an exhaustive list of all works undertaken by Council over this period.

Table 2.6—Recently Completed Stormwater Projects

Project	**Catchment**	**Brief Description**	**Year of Completion**
Pump Station Upgrades			
Hargrave Street Pump Station Upgrades	Hargrave Street	New pump station and rising main	2015
Hart Street Pump Station Upgrades	Hart Street	New pump station and rising main	2015
Lulu Pump Station Upgrades	Lulu	Replacement of 1 of 5 pumps	2015
Moldavia Walk	Military Road	Rising main replacement	2008
Trunk Drainage			
Hargrave Street Trunk Drain	Hargrave Street	New trunk drain along Hargrave Street, between Fletcher Road and Victoria Road	2016
Semaphore Road Trunk Drain	Carlisle Street	New trunk drain along Semaphore Road, between Swan Terrace and Military Road	2012
Bucknall Road Trunk Drain	Carlisle Street	New trunk drain along Bucknall Road, between Swan Terrace and Carlisle Street	2007
Swan Terrace Trunk Drain	Carlisle Street	New trunk drain along Swan Terrace, between Bucknall Road and Semaphore Road	2007
Hargrave Street Trunk Drain	Hargrave Street	New trunk drain along Hargrave Street, between Fletcher Road and Woolnough Road	2002
Minor Drainage			
Carlisle Street	Hart Street	New lateral drain to service the intersections of Carlisle Street with Mary / Maud Streets, Glanville / Harvey Streets, and Pelham / Old Pelham Streets	2016
Peterhead Street	Hargrave Street	New lateral drain to service the intersections of Peterhead Street with McKay Street, Honorah Street,	2016

Project	Catchment	Brief Description	Year of Completion
		and Osborne Street	
Gilbert Street	Hargrave Street	New lateral drain to service the Hilton Street and Baker Street intersections	2016
Hart Street	Semaphore Shore	New 375mm diameter pipe coastal outfall	2001
Harrold Street	Largs Bay Shore	New 375mm diameter pipe coastal outfall	2001
Lady Gowrie Drive	North Haven	New lateral drain to service the intersections of Lady Gowrie Drive with Catriona Court and Marmora Terrace	2000
Esplanade	Semaphore South Shore	New lateral drains to soakage pits between Arthur Street and Paxton Street	1999
Large Soakage Systems			
Roslyn Street	Largs Bay Shore	New soakage system in Largs Bay Shore to service a trapped low point with no gravity outfall	2016
Adelaide Street	Lulu	New soakage system in Largs Bay to complement the existing underground drainage system	2014
Jervois Road	Semaphore South Shore	New soakage system in Semaphore South to complement the existing 300mm diameter pipe coastal outfall	2014
Coppin Street	Semaphore Shore	New soakage system in Semaphore to complement the existing 300mm diameter pipe coastal outfall	2011
Brenda Terrace	Mersey Road	New soakage system in Largs North to service a trapped low point with no gravity outfall	2005
Magarey Street	Largs North Shore	New soakage system in Largs North to service a trapped low point with no gravity outfall	2005
Persic Street	Largs North Shore	New soakage system in Largs North to service a trapped low point with no gravity outfall	2005
Farringdon Street	Largs North Shore	New soakage system in Largs North to service a trapped low point with no gravity outfall	2005

Project	Catchment	Brief Description	Year of Completion
Hall Street	Hargrave Street	New soakage system in Semaphore to service a trapped low point with no gravity outfall	2005
Estella Street	Hamilton Avenue	New soakage system in Osborne to service a trapped low point with no gravity outfall	2005
Detention Basins			
Railway Terrace	Taperoo Shore	New retention basin north of the Railway Terrace / Hutley Road intersection	2016
Charon Reserve	Taperoo Shore	New retention basin in Charon Reserve	2016
Olive Street/Mary Street	Lulu	New detention basin in Largs Bay	2014
Alfred Street/Mary Street	Lulu	Detention basin upgrades in Largs Bay	2014
Carnarvon Terrace	Mersey Road	New detention basin in Largs North	2013

2.6.2 Stormwater Asset Age

Council's GIS data includes an estimate of the age of existing stormwater infrastructure, as shown in Figure 2.6. Many of the trunk drainage systems across the southern portion of the Peninsula were originally constructed in the 1950's and 60's, with some systems being subject to upgrades and/or extensions since the late 1990's.

Throughout the suburbs of Largs North and Taperoo the majority of stormwater infrastructure was constructed in the 1960's and the drainage system that services the suburb of North Haven was constructed in the 1970's and 80's.

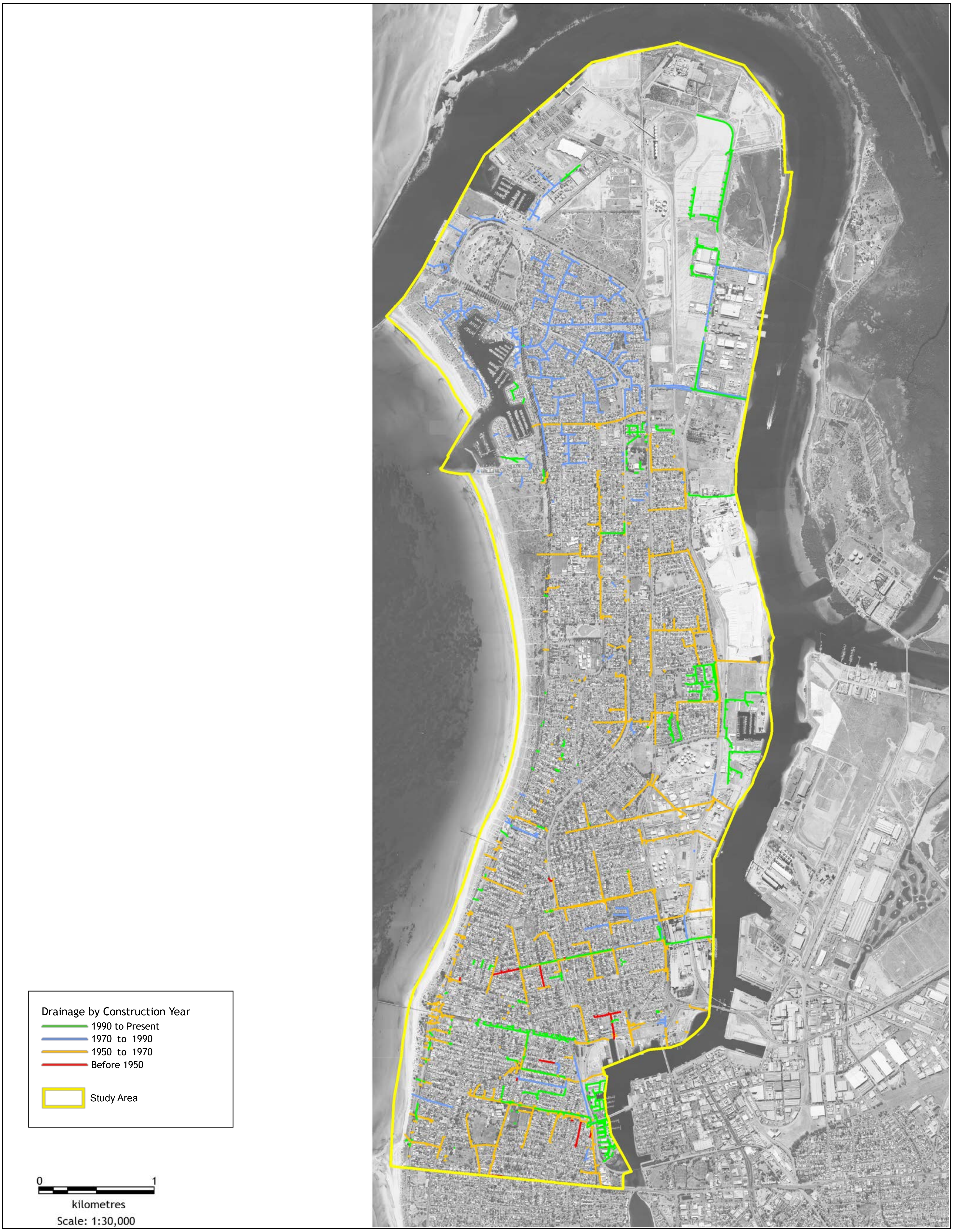
There have also been a number of more recent land developments which have seen new stormwater systems constructed in the 2000's, such as the Northern Lefevre Peninsula Osborne North Infrastructure Headworks Project (situated on land controlled by Defence SA and including the Techport precinct and Cultural Park) and New Port to the south.

Council's GIS data includes limited asset condition ratings for existing stormwater infrastructure where Closed Circuit Television inspections have been completed.

2.6.3 Previously Known Stormwater Management Issues

Stormwater flooding is known to occur throughout the Lefevre Peninsula, particularly across the southern extents. Recent rainfall events that have resulted in stormwater flooding include an event in February 2014 which affected the suburbs of Peterhead and Ethelton (the Lulu, Hargrave Street and Hart Street catchments), and two separate events in January 2012 which affected the suburb of Glanville (the Carlisle Street catchment).

Sandbagging of Mary Street, Peterhead, February 2014 (ABC News online photograph)



Data Sources:
City of Port Adelaide Enfield (Aerial Photograph, Stormwater Data)

Lefevre Peninsula
Stormwater Management Plan

southfront

Stormwater Asset Age

Figure 2.6

A sample of the streets affected by flooding, based on a review of previous studies and Council's GIS database, is shown in Table 2.7. It should be noted that this table does not represent an exhaustive list of all properties understood to be at risk of stormwater flooding, and that an objective of the floodplain mapping exercise undertaken for this Plan is to quantify flood risk across the Peninsula for a range of storm events.

Table 2.7—Sample of Known Stormwater Flooding Hotspots

Catchment	Known Flooding Hotspots
Semaphore Shore Catchment	Jervois Road, Semaphore South
Hamilton Avenue Catchment	Hamilton Avenue, Osborne Bridges Avenue, Osborne
Lulu Catchment	Adelaide Street, Largs Bay Wills Street, Peterhead Mary Street, Peterhead Alfred Street, Peterhead Walton Street, Peterhead
Hargrave Street Catchment	Hargrave Street, Peterhead Woolnaugh Road, Semaphore Hall Street, Semaphore
Carlisle Street Catchment	Swan Terrace, Glanville Bucknall Road, Glanville Exmouth Road, Glanville Mellor Road, Glanville Stewart Street, Glanville
Hart Street Catchment	Emu Street, Semaphore Freer Road, Semaphore Hanson Street, Semaphore Robin Road, Semaphore South Graham Street, Glanville Victoria Street, Glanville Rosetta Street, Glanville Mary Street, Ethelton Swan Terrace, Ethelton Carlisle Street, Ethelton Nazar Reserve, Semaphore South

2.6.4 Private Drainage Systems

There are a number of private stormwater drainage systems along the eastern and northern extents of the Lefevre Peninsula that cater for stormwater runoff from the industrial zone and are self-managed by the landowners and site operators. These include the BP Australia and Mobil Oil sites, and the land holdings of the Australian Submarine Corporation (ASC) and Defence SA.

The site-based Stormwater Management Plan for the Adelaide Brighton Cement site indicated that stormwater runoff from approximately 70% of the site discharges to the Port River via Council drainage infrastructure (ie. it forms part of the Lulu catchment). Stormwater runoff from the balance of the site is managed by a private stormwater drainage system.

The drainage and water quality performance of the private systems was not required to be assessed as part of this Plan, and therefore these systems have been truncated from the hydrological and hydraulic models (as shown in Figure 4.4). However the Plan has sought to identify possible interactions between these private systems and Council owned infrastructure and provide recommendations for further investigations (where required).

2.7 Existing Land Use and Zoning

The range of existing land uses across the Lefevre Peninsula, sourced from the *Valuer General's Generalized Land Use Dataset* (February 2015) which is based on actual land use rather than zoning, can be summarised as follows:

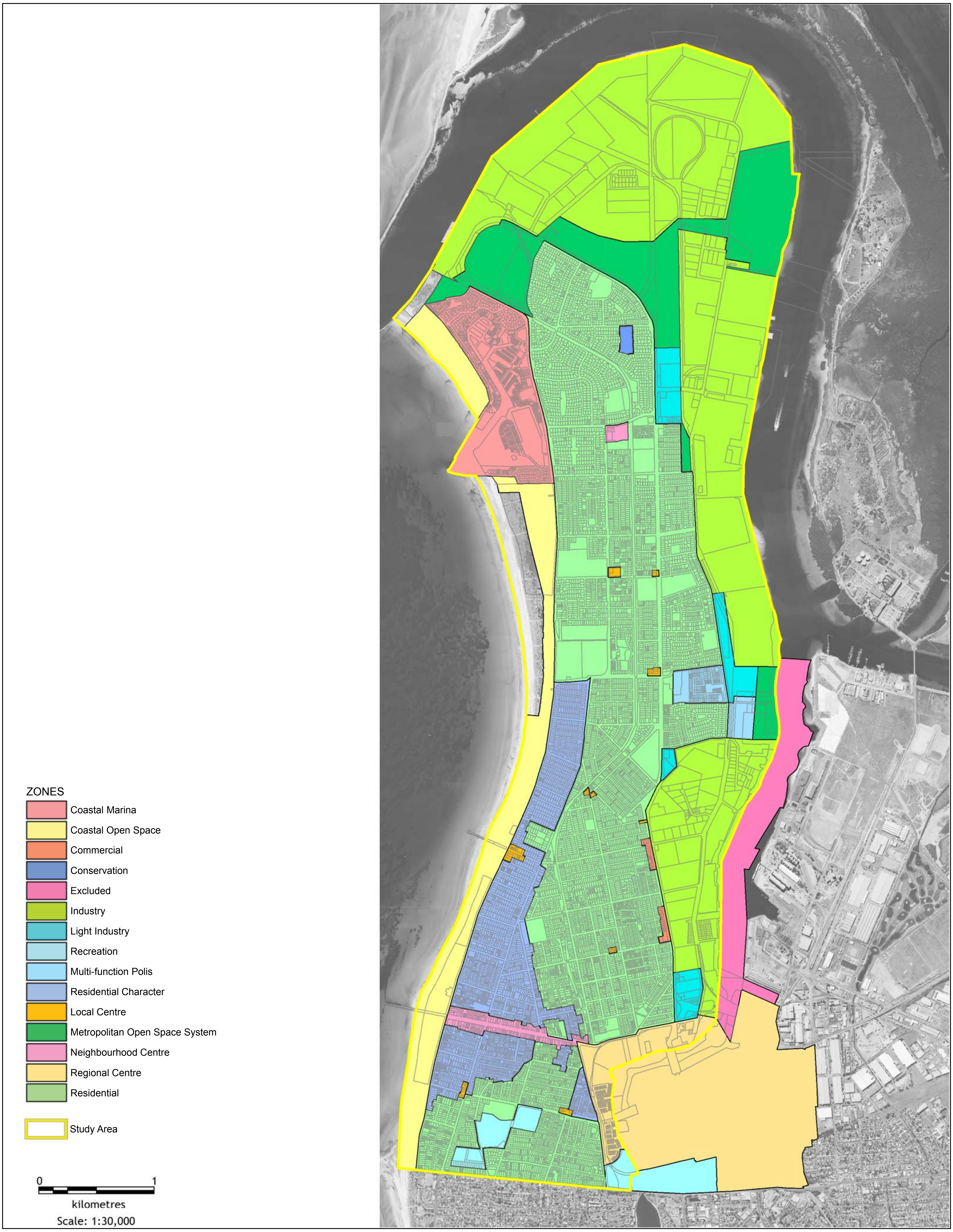
- Residential (644 ha) and Vacant Residential (335 ha). Note that 249ha of the land classified as Vacant Residential is actually situated within the Industry zone;
- Utility/Industry (318 ha) and Food Industry (30 ha);
- Commercial (77 ha);
- Education (33 ha)
- Recreation (66 ha) and Golf Courses (22 ha); and
- Reserve (54 ha).

The diversity in land use is reflected in the existing zoning framework, as summarised below:

- Residential and Residential Character Zones covering 998.5 ha (44% of the Study Area);
- Industry Zone covering 660.3 ha (29% of the Study Area) with an additional 41 ha of Light Industry Zone;
- Metropolitan Open Space System Zone covering 172.1 ha (8% of the Study Area); and
- Coastal Open Space Zone covering 142.2 ha (6% of the Study Area).

Figure 2.7 summarises the spatial extent of the land use zoning on the Peninsula. It is evident that the Residential Zones are located, in the main, across the southern and western extents of the Peninsula, including historical development in the vicinity of Semaphore, Exeter and Glanville.

The Industry Zones are located to the east and north, including large production plants for Adelaide Brighton Cement and Techport. The significant Metropolitan Open Space System (MOSS) Zone is predominately located across the north of the Peninsula, while the Coastal Open Space Zone flanks the entire western coastline.



Data Sources:
City of Port Adelaide Enfield (Aerial Photograph, Stormwater Data)

southfront

Lefevre Peninsula
Stormwater Management Plan

Land Use Zoning

Figure 2.7

2.8 Land Development Potential

Urban and Regional Planning Solutions (URPS) have undertaken an assessment of the development potential for the Study Area to identify recent and anticipated development trends in the Study Area. This assessment is based upon analysis of:

- Council's Development Plan (consolidated 16 April 2015);
- GIS analysis of existing land use, zoning and cadastral datasets;
- Targeted consultation with Council's Strategic and Open Space planners, personnel from DPTI and Renewal SA, key developers and real estate agents; and
- Review of a range of strategic planning documents that relate to the Peninsula including:
    - 30 Year Plan for Greater Adelaide;
    - 2012 Report of the Housing and Employment Land Supply Program;
    - DPTI Residential Land Supply Report 2013;
    - 2012 Strategic Directions Report for the City of Port Adelaide Enfield; and
    - City of Port Adelaide Enfield Open Space Plan 2013.

The assessment of development potential has been undertaken by URPS on a catchment basis. This is intended to enable the study to consider the impacts of planning policy and likely future urban development on individual catchments. This approach is considered to be particularly relevant to the Lefevre Peninsula due to the wide variety of stormwater management systems that are in place to service these catchments (eg. gravity drainage, pump and infiltration systems).

The key findings of this assessment and the related issues and opportunities for stormwater management on the Peninsula are summarised below.

2.8.1 Development Trends

A summary of the recent and projected development trends across the Study Area is provided below:

- Sustained infill development has occurred in the Study Area in recent times;
- The Study Area will accommodate sustained urban infill development in the short and long term, especially in the Lefevre Peninsula East Policy Area 57 where 850 additional allotments can be expected under current planning controls;
- There are residential areas, such as the North Haven Policy Area 59 which are unlikely to be redeveloped in the short term, but may experience infill development in the longer term;
- The Restricted Residential Policy Area 65 offers considerable long term development potential in the form of an additional 293 allotments if changes to industrial practices means the hazard risk no longer exists;
- The Fort Largs Policy Area 56 covers a 22.4 ha site which is zoned ready for comprehensive redevelopment in the event that it is no longer required for its current use;
- The Regional Centre Zone covers 40.1 ha which is earmarked for high density waterfront development;
- There are large areas of MOSS and Coastal Open Space Zones which are unlikely to be developed but may play a role in future stormwater management;

- There is 320 ha of vacant land within the Industry Zones which may be subject to future development; and
- Plans for higher density Transit Oriented Development along the Outer Harbor rail corridor are unlikely to materialise around key stations on the Peninsula in the short term, and priorities in the long term are likely to be influenced by the State Government's current revision of the 30-Year Plan for Greater Adelaide.

2.8.2 Identifying Sites for Stormwater Management Measures

An assessment has been undertaken to determine the availability of open space for the provision of future stormwater management upgrades. This assessment identified that there are large areas of State and Local Government owned land across the Lefevre Peninsula, as well as large amounts of vacant and undeveloped land, as summarised below:

- There is 561 ha of vacant land in the Study Area;
- There is 602 ha of State Government owned land in the Study Area; and
- The southern portion of the Study Area has limited open space. That is suitable for stormwater management purposes.

2.9 Groundwater Assessment

Australian Groundwater Technologies (AGT) have undertaken a review of available literature and public databases to assess the soil and groundwater conditions, the viability of Aquifer Storage and Recovery (ASR), and the potential risks associated with Coastal Acid Sulfate Soils on the Lefevre Peninsula. The key findings of the AGT report and the related issues and opportunities for stormwater management on the Peninsula are summarised below.

2.9.1 Soil and Groundwater Conditions

A review of the available drilling logs from existing groundwater wells across the Lefevre Peninsula has been undertaken. This review has identified that soils typically comprise of Quaternary sands to depths greater than 10 metres, with a number of wells on the eastern side of the Peninsula exhibiting clay bands at depths of 5 to 10 metres.

The depth to water table across the Peninsula varies from 6 to 10 metres on the western side, to <1 to 3m on the eastern side (where the presence of clay bands can lead to the creation of perched watertables and potential water logging of soils).

Over 100 stormwater infiltration systems are currently being used on the Peninsula as a means of stormwater disposal. These systems are more prevalent on the western side of the Peninsula (where soils are sandy and the depth to groundwater is greater), particularly in locations that are natural trapped low points. The systems are typically shallow drainage pit and/or box culvert installations that have a permeable floor (ie. ballast rock in lieu of concrete floor slabs). On the basis that these systems are less than 2.5m deep and do not intercept groundwater nor provide a direct means of stormwater discharge to an underground aquifer, they are not required to be licenced under the Environment Protection Act 2004.

This Plan has limited the recommendation of new infiltration systems to locations where the soil and groundwater conditions will allow them to perform most effectively.

2.9.2 Coastal Acid Sulfate Soils

Coastal Acid Sulfate Soils (CASS) are naturally occurring soils or sediments that contain iron sulfide, and are potentially present throughout most low lying coastal regions in South Australia. They are formed when seawater or brackish waters containing dissolved sulfate inundate organic rich environments such as swamps, mangroves and salt marshes. Under oxygen-depleted conditions, the iron present within the soils combines with sulfate to form iron sulphides. When these sulphides are disturbed and exposed to air, oxidation occurs and sulphuric acid is produced. Disturbance of CASS typically results from developments that involve drainage, dewatering, excavation or filling.

The western side of the Peninsula is classified as an area with a low probability of CASS occurrence. However there is a high probability of CASS material in the tidal zones on the eastern side of the Peninsula, and actual acid sulfate soils have been identified in the Port Adelaide /Gilman region.

This Plan has given consideration to the likelihood of CASS occurrence and appropriate management practices at proposed infrastructure sites.

2.9.3 Aquifer Storage and Recovery

The Lefevre Pensinsula is located within Hydrogeological Zone 3b, as defined in the *Overview of Hydrogeology of the Adelaide Metropolitan Area* (Gerges, 2006), which contains five to six Quaternary aquifers and three to four Tertiary Aquifers. The Quaternary aquifers of the Lefevre Peninsula are not considered appropriate for ASR due to their low yielding nature, shallow water table, and the potential for water logging.

The first and second Tertiary aquifers (referred to as the T1 and T2 aquifers) are the thickest and most productive aquifers, and exhibit low to brackish salinity. An assessment of the well yield, aquifer transmissivity and groundwater salinity of the T1 and T2 aquifers confirm that there is potential for implementation of an ASR scheme on the Lefevre Peninsula. Both the T1b (upper Port Willunga Formation) and T2 (lower Port Willunga Formation) aquifers show good potential for ASR, with the T1b aquifer exhibiting lower salinity levels and an expected lower establishment cost due to its shallower depth. An ASR scheme would require licensing through the Environment Protection Authority (EPA), and a groundwater license will be required via the Department of Environment, Water and Natural Resources (DEWNR) for groundwater recovery (extraction).

The overall injection capacity for an ASR scheme could be influenced by cumulative impacts from other ASR schemes located to the south of Bower Road (eg. the St Clair, West lakes and grange Golf Club ASR schemes). This Stormwater Management Plan considers the merits of implementing a future ASR scheme as part of the overall stormwater management strategy for the Lefevre Peninsula, and identifies further investigations required to confirm the feasibility of such a scheme (including drilling of wells, well testing, groundwater flow modelling and risk assessment).

2.10 Marine Benthic Habitats

South Australian Research and Development Institute (SARDI) Aquatic Sciences have undertaken a desktop review of existing data and literature relating to the marine benthic habitats surrounding the Lefevre Peninsula. The region of interest was taken to be that within a 5 kilometre radius of the Lefevre Peninsula Stormwater Management Plan Study Area boundary, from the shore to a maximum depth of 20 metres, or to the extent of benthic habitat data where different.

2.10.1 Habitat Classification

Data sources used include benthic habitat classifications and supporting video data used by DEWNR to create marine benthic habitat maps for the Adelaide and Mount Lofty Ranges NRM region (DEH 2008), data collected by SARDI Aquatic Sciences during reef health surveys (Turner *et al.* 2007; Collings *et al.* 2008) and surveys for the introduced alga *Caulerpa taxifolia* (Wiltshire 2010), seagrass mapping of the Adelaide coast (Bryars and Rowling 2008) and seagrass condition monitoring performed near Port Adelaide (Tanner *et al.* 2014). The locations of these data points are shown in Figure 2.8, overlain on a map of the major marine benthic habitats surrounding the Lefevre Peninsula.

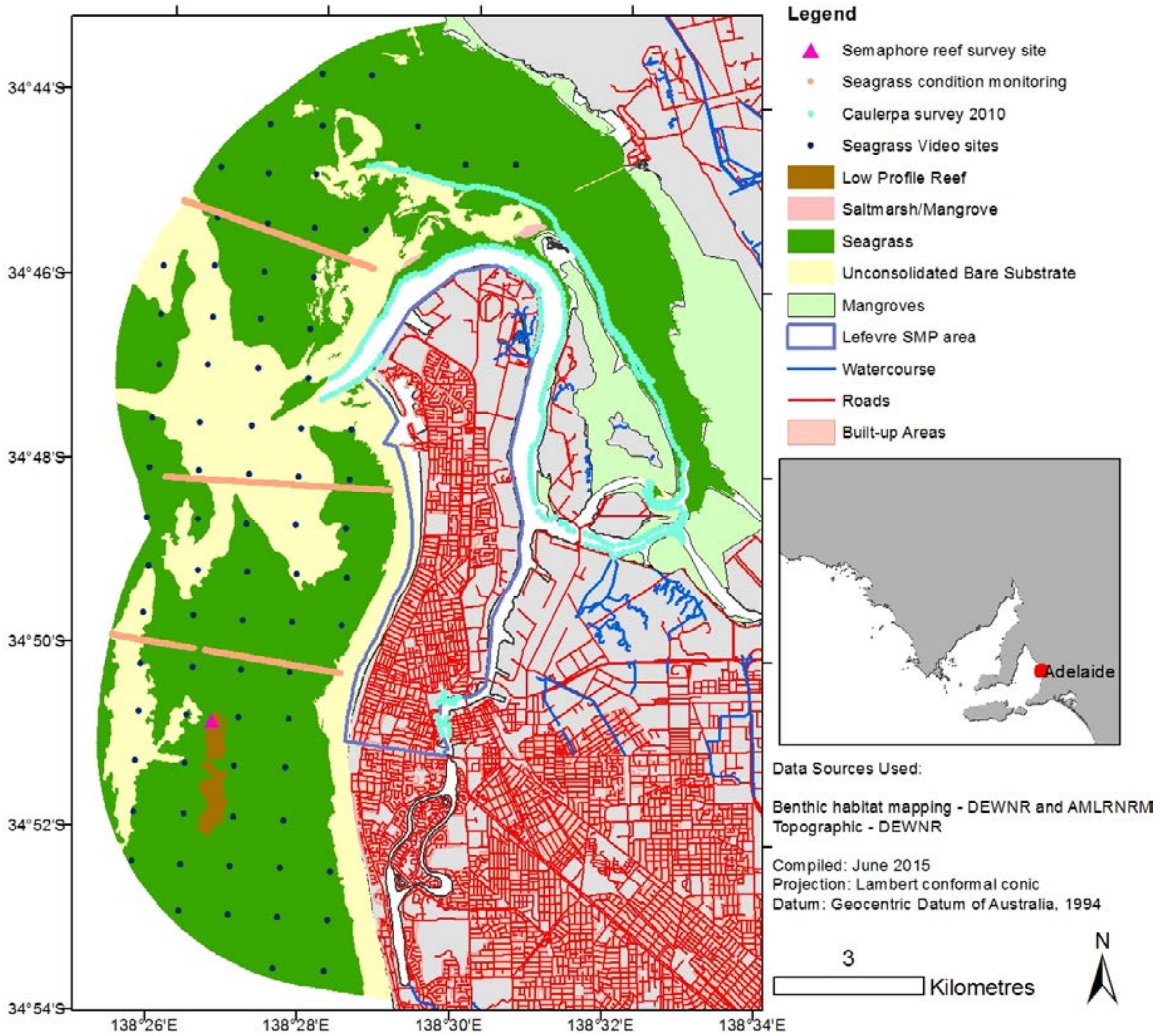


Figure 2.8—Marine Benthic Habitat Classification for the Lefevre Peninsula

2.10.2 Habitat Composition

Figure 2.9 shows the detailed habitat composition of the area of interest (from DEWNR benthic habitat data), as summarised below:

- Seagrass dominates the region, comprising 70.2% of the total habitat. In the Barker Inlet and the southern part of the region the seagrass beds are continuous and medium to dense, while other areas have patchy and/or sparse cover;
- Bare sand at the Port River inlet and along the coast, comprising 28.8% of the total habitat;
- Low profile reef with medium density macroalgal cover occurring offshore from Semaphore, comprising 0.8% of the total habitat; and
- Intertidal salt marsh at the north end of Torrens Island, comprising 0.2% of the total habitat.

DEWNR benthic habitat data is not available for the Port River or for the tidal flats along Barker Inlet and Torrens Island. These tidal areas are covered with grey mangrove, *Avicennia marina* var. *resinifera* (Johnston and Harbison 2005; Pfennig 2008), the cover of which is not included in the percentages above.

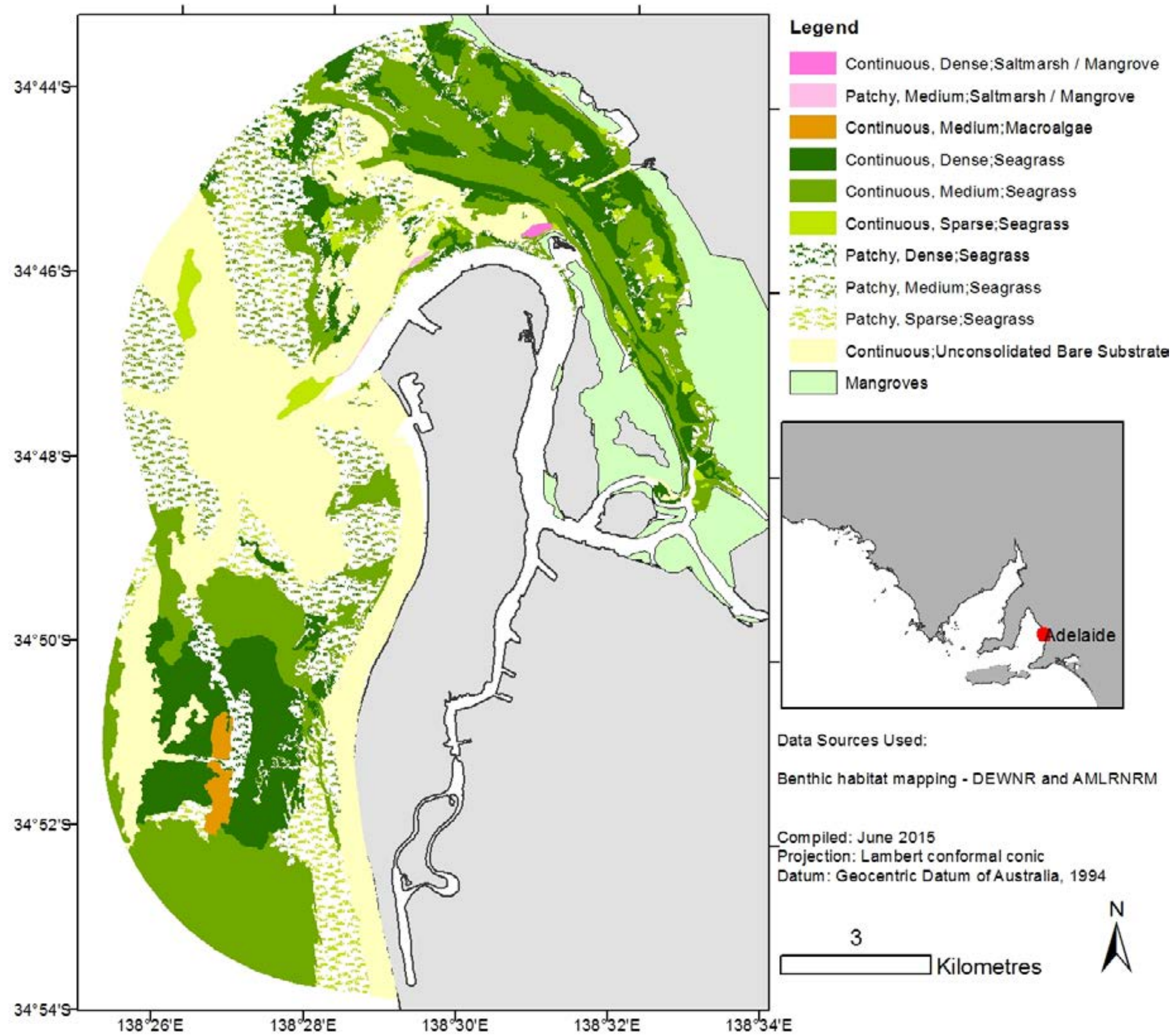


Figure 2.9—Marine Benthic Habitat Structure and Biota of the Lefevre Peninsula

2.10.3 Seagrass Type and Condition

The majority of seagrass recorded in the area by SARDI benthic and seagrass condition monitoring video data is *Posidonia*[1], but *Amphibolis antarctica* also occurs commonly offshore from Largs Bay to West Lakes. Some *Zostera*[1] spp. and a small amount of the annual species *Halophila australis* were also recorded (Bryars and Rowling 2008; Tanner *et al.* 2014; SARDI data). The condition of surveyed seagrasses was generally good, although epiphyte loads, particularly on the southernmost transect, were higher than those on seagrass surveyed outside the metropolitan area (Tanner *et al.* 2014).

Data on the habitats within the Port River and Barker Inlet is available from the information obtained by surveys for the introduced alga *Caulerpa taxifolia.* These surveys were conducted annually from 2004 to 2010 and also recorded an abundance of other major benthic cover including native seagrasses and other *Caulerpa* spp. (Wiltshire 2010). Seagrasses within the Port River and Barker Inlet are primarily *Zostera* spp. with some *Posidonia* in the outer Barker Inlet (Wiltshire 2010). The recorded range of *Zostera* and *Caulerpa* spp. in 2010 is shown in Figure 2.10.

Until 2010 *C. taxifolia* was largely restricted to the inner parts of the Port River and Barker Inlet; although several patches were found throughout Barker Inlet in 2008, these did not persist (Wiltshire 2010). In autumn 2015, however, *Caulerpa taxifolia* was found extensively in the vicinity of Outer Harbor (SARDI unpublished data), an area previously dominated by *Zostera*.

Caulerpa cylindracea (formerly *C. racemosa* var. *cylindracea*), another species likely to have been a human-mediated introduction to South Australia (Womersley 2003; Collings *et al.* 2004), is common through the Port River and particularly abundant on the Outer Harbor breakwaters and other hard substrate (Wiltshire 2010, SARDI data). This species was also found in shallow waters along the North Haven to Semaphore coast in 2004 (Westphalen and Rowling 2005), but was not observed in the video transects recorded in the same area in 2007-8 (Bryars and Rowling 2008). It is, however, also present within the marina at North Haven (Wiltshire 2010). Native *Caulerpa* spp., including *C. trifaria*, *C. brownii* and *C. scalpelliformis* also occur along the Outer Harbor breakwaters (SARDI data).

[1] The majority of *Posidonia* and *Zostera* spp are not distinguishable on video, but the main *Posidonia* known to form meadows in the Adelaide region are of the *Posidonia australis* group, comprising *P. australis, P. sinuosa* and *P.angustifolia*, with *P. australis* mainly restricted to shallow water (Bryars *et al.* 2008). The most common *Zostera* spp found subtidally in SA is *Zostera muelleri*; this species also occurs in the intertidal, along with *Z. nigricaulis* (formerly *Heterozostera tasmanica*) (State Herbarium of SA data).

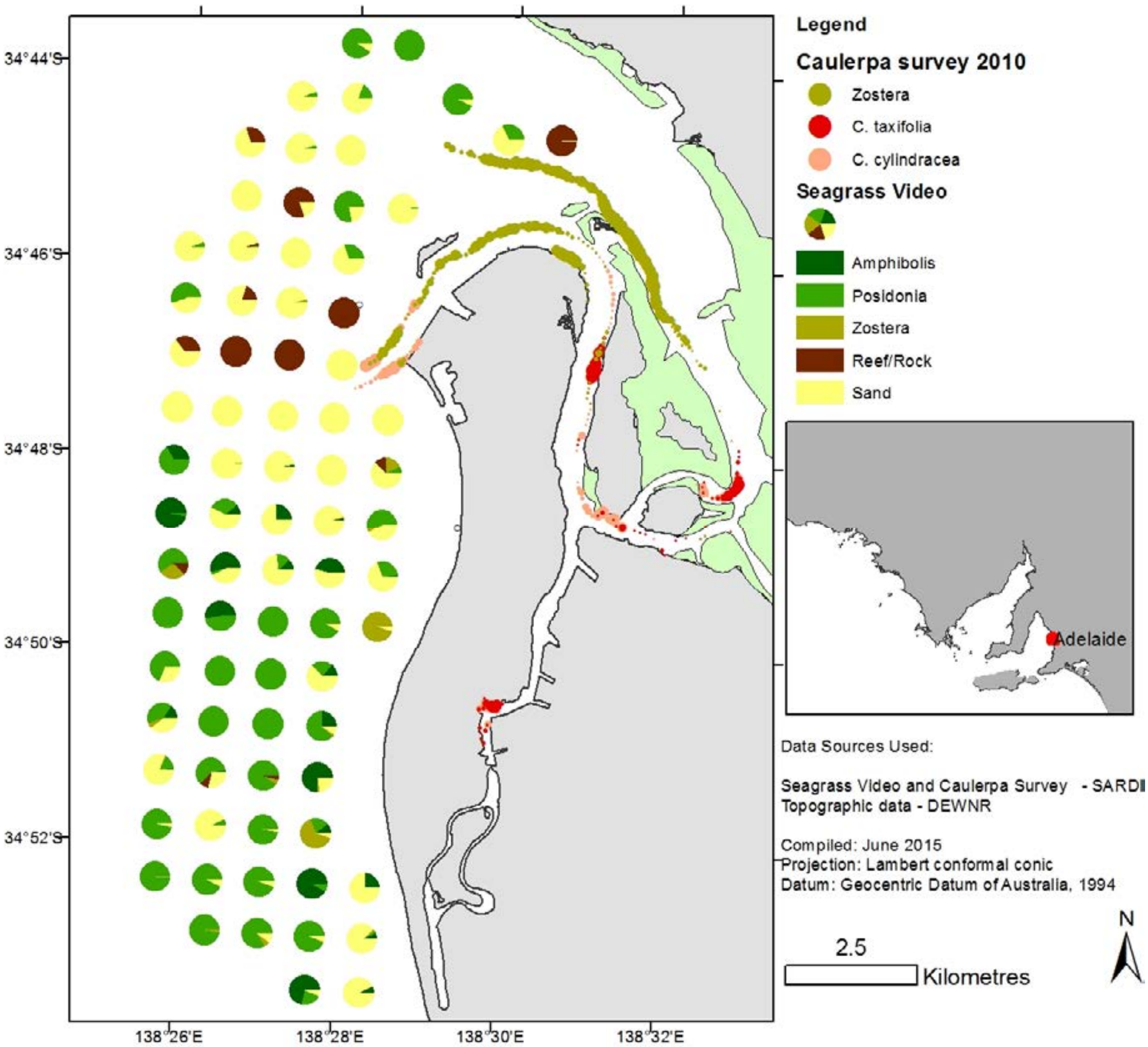


Figure 2.10—Seagrass and *Caulerpa* spp. Occurrence

2.10.4 Reef Type and Condition

Semaphore reef is also located within the area of interest (refer Figure 2.8). This reef was surveyed as part of the Reef Health program in 2005 and 2007 and was classified as being in poor condition by both surveys, with low (<10%) cover of brown canopy macroalgae and relatively low macroalgal diversity (Turner *et al.* 2007; Collings *et al.* 2008). The reef was dominated by bare rock, with red foliaceous species being the most common macroalgae; the canopy species present included species of *Sargassum* and *Caulocystis* (Fucales). Several native *Caulerpa* spp. were also recorded; some *C. cylindracea* was found in 2005 but none in 2007 (Turner *et al.* 2007; Collings *et. al.* 2008; SARDI reef health data).

3 Stormwater Management Plan Objectives

3.1 Policy Documents

The following policy documents have been used to guide the development of objectives for the Lefevre Peninsula Stormwater Management Plan:

- *Stormwater Management Planning Guidelines* (Stormwater Management Authority, 2007);
- *Port Adelaide Enfield Council Development Plan*;
- *City Plan 2010-2016* (City of Port Adelaide Enfield, 2010);
- *Strategic Plan for the Adelaide and Mount Lofty Ranges Region 2014-15 to 2023-24* (Adelaide and Mount Lofty Ranges Natural Resources Management Board, 2013);
- *WSUD – Creating more liveable & water sensitive cities in South Australia* (Department of Environment, Water and Natural Resources, 2013);
- *Port Waterways Water Quality Improvement Plan* (Environment Protection Authority, 2008);
- *Adelaide Dolphin Sanctuary Management Plan* (Department of Environment and Heritage, 2008), which is a statutory plan under the Adelaide Dolphin Sanctuary Management Act 2005; and
- *Coast Protection Board Policy Document* (Coast Protection Board, revised 2012).

The relevant excerpts of these policy documents are summarised in the section below.

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

- *Western Adelaide Region Climate Change Adaptation Plan – Phase 1 Report* (Tonkin Consulting, 2015);
- *AdaptWest Research Paper – Assets, Infrastructure and Economy* (URPS, 2014); and
- *Guidelines for Undertaking a Climate Change Adaptation Plan and Undertaking an Integrated Climate Change Vulnerability* (Local Government Association, 2012).

3.1.1 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."*

3.1.2 City of Port Adelaide Enfield's City Plan 2010-2016

The City Plan articulates City of Port Adelaide Enfield's vision for the year 2030 and provides clear directions to guide Council, the community and stakeholders towards achieving that vision. City Plan 2010-2016 (City of Port Adelaide Enfield, 2010) sets out the overall direction for Council until 2016, focussing on key areas as follows:

- A strong and diverse economy (SDE);
- A vibrant and resilient community (VRC);
- A Unique, Healthy and Sustainable Environment (UHSE);
- A Great Place to Live, Work and Play (LWP); and
- Committed and accountable governance (CAG).

Strategic goals, objectives and indicators/targets outlined in this document that are relevant to the Lefevre Peninsula Stormwater Management Plan are summarised in Table 3.1 below.

Table 3.1— City Plan 2010-2016 Extract

Goal	Objectives	Indicators / Targets
UHSE - natural and urban environments characterised by clean air, soil, water and biodiversity that are cared for and respected by businesses and the community	1. An effective and integrated approach to sustainable water management.	State water management objectives and targets are supported. Catchment-based water management objectives and targets are met.
	2. The impacts of climate change on the local community, the natural environment and Council's infrastructure are identified and addressed.	Key community concerns are identified and addressed in Council's Community Climate Change Plan.
LWP - a vibrant and attractive City that is well-planned and accessible, with safe and healthy places to live, work and play	4. Urban form shaped by appropriate policy and principle of development control expressed in the Port Adelaide Enfield (City) Development Plan.	Port Adelaide Enfield (City) Development Plan is regularly reviewed and updated.
	5. Port Adelaide Enfield urban development issues represented in strategic land use planning at a state level.	Effective communication and collaboration with State Government on key strategic land use projects.
	7. An urban environment characterised by attractive and sustainable landscaping and useable open space throughout residential and commercial areas.	The Open Space Plan is regularly reviewed and implemented.

Goal	Objectives	Indicators / Targets
	8. Equitably distributed and accessible community assets and infrastructure provided and maintained in a fit-for-purpose condition.	Objectives in Council's long term Asset Management Plans are achieved.
CAG - Elected Members and staff are committed to achieving the 2030 vision for the Port Adelaide Enfield community	6. Council understands and is responsive to the community's needs and aspirations.	Council conducts regular and meaningful community consultation.

3.1.3 City of Port Adelaide Enfield's Drainage Infrastructure Asset Management Plan

The goal of asset management 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 *Drainage Infrastructure Asset Management Plan* (City of Port Adelaide Enfield, 2013) 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 Lefevre Peninsula is situated within the West zone of the Council area, as defined in the Plan. The Plan articulates technical standards for the performance of the drainage systems, notably:

- New or upgraded "Minor" (underground) drainage systems:
  - Gutter flow width for 5 year ARI storms to be no greater than 2.5m;
  - Gutter flow width at pedestrian crossings for 5 year ARI storms to be no greater than 1m;
  - Hydraulic grade line (HGL) for 5 year ARI storms to be minimum 150mm below gutter level;
- "Major" (overland) drainage systems:
  - No above floor inundation of properties for all events up to and including the 100 year ARI storm;
  - New developments to achieve 200mm freeboard to the 100 year ARI flood level.

3.1.4 State Government WSUD Objectives

In recent years, 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).

Prior to the development of this Stormwater Management Plan, another document titled *WSUD – Creating more liveable & water sensitive cities in South Australia* (DEWNR, 2013) was released.

The water quality improvement targets outlined in this document are:

- 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.

3.1.5 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. It provides leadership, encourages community action and fosters valuable partnerships for better managing the region's natural resources.

The plan includes long-term goals and targets for the condition of natural resources in the region. The Board's investment priorities are defined over a three-year period and are delivered through a range of strategic actions.

The Plan sets out a 10-year strategic plan for the region that is consistent with the vision of the State NRM Plan. The Strategic Plan is supported by a *Business and Operational Plan 2014-15 to 2016-17* (Adelaide and Mount Lofty Ranges Natural Resources Management Board, 2013b) which outlines how the Board will invest the money that it raises through levies and other funding sources.

The plan refers 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 on the Lefevre Peninsula are shown in Table 3.2.

Table 3.2—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).

Target	Explanation	Indicator
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 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.	Condition of native vegetation (terrestrial, riparian, water dependent ecosystems).
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		

3.1.6 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 Lefevre Peninsula 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 2009-2014* outlines the following strategic priorities:

1 Adaptation of existing development to coastal hazards and the impacts of climate change.

2 Ensure new development is not at risk from current and future hazards.

3 Plan for resilience in coastal ecosystems to adapt to the impacts of climate change.

3.2 Stormwater Management Plan Objectives

The consolidated objectives that were adopted to guide the development of this Stormwater Management Plan are summarised in Table 3.3 below.

Table 3.3—Lefevre Peninsula Stormwater Management Plan Objectives

Goal	Strategic Link	Objective
Provide an acceptable level of flood protection to the community	Drainage Infrastructure Asset Management Plan	Aspire to achieve no above floor inundation of properties for all events up to and including the 100 year ARI storm. Where this is not practically achievable, a 20 year ARI standard shall be sought. New developments to achieve 200mm freeboard to the 100 year ARI flood level.

Goal	Strategic Link	Objective
Provide an acceptable level of performance in the minor (underground) drainage system and pits	Drainage Infrastructure Asset Management Plan	Aspire to achieve minimum service standards for new or upgraded drainage systems as follows: ➤ Gutter flow width for 5 year ARI storms to be no greater than 2.5m ➤ Gutter flow width at pedestrian crossings for 5 year ARI storms to be no greater than 1m ➤ Hydraulic grade line (HGL) for 5 year ARI storms to be minimum 150mm below gutter level
Improve the quality of runoff and reduce the impact of stormwater on receiving waters	City Plan 2010-2016 - UHSE AMLR NRM T2, T10 Port Waterways WQIP	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.
Make beneficial use of stormwater runoff	City Plan 2010-2016 - UHSE AMLR NRM T1 Port Waterways WQIP	Identify precinct-level opportunities for beneficial reuse of stormwater. Encourage landowners to implement allotment-level opportunities for the retention and reuse of stormwater.
Provide conditions which would allow desirable (improved) end-state values for receiving waterways to be achieved	City Plan 2010-2016 - UHSE AMLR NRM T3, T7, T8 Port Waterways WQIP	Support ongoing strategies seeking to restore and sustain the ecological processes, environmental values and productive capacity of the Port River and Barker Inlet by minimising the urban runoff volume and nutrient loads discharged to the Port Waterways. Maintain status quo of no urban stormwater ingress to Mutton Cove to protect the biodiversity of the samphire and mangrove woodland habitat.
Sustainable management of stormwater infrastructure, including maintenance	City Plan 2010-2016 – UHSE AdaptWest	Stormwater infrastructure will be resilient in consideration of the likely impacts of climate change. Durability criteria of new stormwater infrastructure to achieve minimum service life requirements with consideration of local environmental conditions (eg. 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.

Goal	Strategic Link	Objective
Desirable planning outcomes associated with new development and management of open space, recreation and amenity	City Plan 2010-2016 - LWP	Ensure new development complies with customised stormwater management development requirements, designed to achieve outcomes that are complementary to the Plan's objectives and goals. Including maximising the use of open space for stormwater/rainfall infiltration WSUD and/or stormwater reuse.
Effective communication and consultation with catchment stakeholders, businesses and community members	City Plan 2010-2016 - CAG	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 Plan and the activities of stakeholders and community volunteers.
Multi-objective outcomes for stormwater management projects involving open space	City Plan 2010-2016 - LWP	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 tree canopy cover and biodiversity. 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

4.1 Modelling Approach

The performance of the existing stormwater drainage infrastructure was assessed using the DRAINS modelling platform.

As described in the model documentation (Watercom, 2011), 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 km^2 using sub-catchments with ILSAX hydrology, and greater using storage routing model hydrology.

Working through a number of time steps that occur during the course of a storm event, it simulates the conversion of rainfall to stormwater runoff and routes the runoff through networks of pipes, channels and streams. In this process, it integrates:

- Design and analysis tasks;
- Hydrology (four 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 ILSAX, Rational Method and storage routing models, together with quasi-unsteady and unsteady hydraulic modelling of systems of pipes, open channels and surface overflow routes. It includes two automatic design procedures for piped drainage systems and also connections to CAD and GIS software.

DRAINS modelling of the Lefevre Peninsula was undertaken for the following scenarios:

- Assessment of the current drainage performance standard of the existing drainage network with the existing level of development for the 1, 2, 5 and 100 year ARI events; and
- Assessment of the future standard of the existing drainage network with evaluated future level of development for the 1, 2, 5 and 100 year ARI events.

The parameters developed to establish the model are described in detail below.

4.2 Drainage Data

The GIS based stormwater drainage data provided by Council formed the basis of the drainage data for this model. A number of modifications were made in order to prepare this data into a form that would be suitable for a DRAINS model. These changes included:

- Rationalisation of arc and polyline drain elements into single line segment elements;
- Snapping end points of connecting drain segments together, and connecting nodes to drain end points;

- Assignment of surface levels to all inlet/junction box nodes, using the Digital Terrain Model information; and
- Generation of drain invert data (few in number) through the generalised assumption of 600mm cover to all drains with a positive drain grade.

4.2.1 Pump Stations

Pump station parameters for the eight pump stations throughout the Peninsula were obtained from construction drawings, previous catchment based investigations and pump selection curves provided by Council (where available).

Consideration was given to pump duties for each of the pump stations given that many of the pump stations contain two or more pumps working in parallel. The system curve and pump performance curves were produced for each pump station. Hydraulic losses were approximated based on rising main alignments and static head was determined using the Digital Terrain Model and known pump station elevations.

An example of system and pump performance curves is shown below for the Carlisle Street pump station. This pump station contains four pumps, each with a maximum discharge of 400 L/s when operating individually. Due to the diminishing return of additional pumps in a parallel pumping system, the maximum discharge from the Carlisle Street pump station is 1,350 L/s when all four pumps are operating.

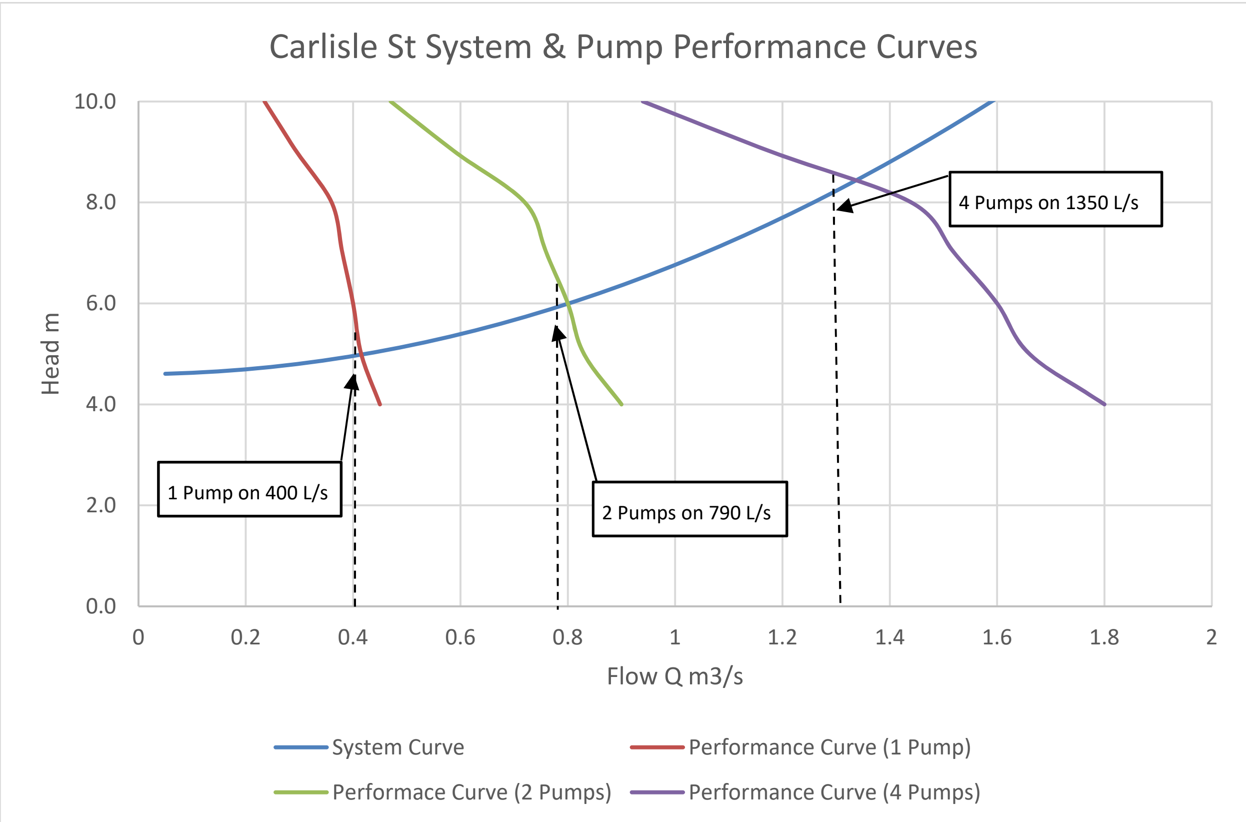


Figure 4.1—Carlisle Street Pump Station System and Performance Curves

Maximum discharge rates for the remaining pump stations (with all pumps operating) were calculated to be as follows:

- Hart Street: 3,160 L/s;
- Hargrave Street: 2,400 L/s;
- Lulu: 1,720 L/s;
- Mersey Road: 1,750 L/s;
- Hamilton Avenue: 50 L/s;
- Archie Badenoch Court (Osborne): 100 L/s; and
- Midlunga Railway Station: 30 L/s.

Council also provided start-stop times/elevations for each pump station.

4.3 Catchment Parameters

4.3.1 Existing Impervious Areas and Runoff Coefficients

Sample areas were selected for an assessment of impervious site coverage from nine distinct and varied residential sub-areas across the Study Area. These areas are summarised in Table 4.1 and a sample are shown in Figure 4.2. The sample sub-areas were selected from aerial photography as representative of impervious site coverage of their respective surrounding neighbourhoods.

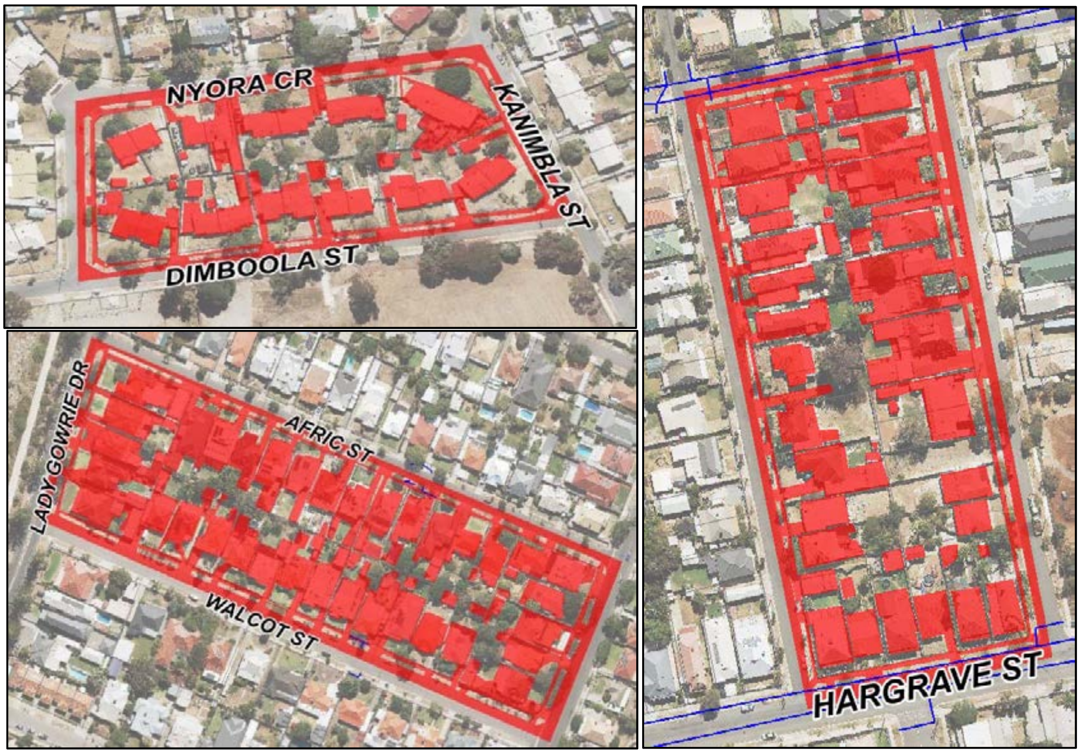


Figure 4.2—Sample Impervious Sub-areas

Table 4.1—Impervious Fraction Results

Sub-area	Percentage Impervious %	Percentage Pervious %
Sir Keith Smith Dr, North Haven	63%	37%
Koombana Tce, Osborne	63%	37%
Nyora Cres, Taperoo	50%	50%
Galway Tce, Largs North	64%	36%
Afric St, Largs North	69%	31%
Jean Street, Largs Bay	64%	36%
Hargrave St, Peterhead	61%	39%
Napier St, Exeter	65%	35%
Maud St, Ethelton	60%	40%

In determining the split of this fraction between directly connected and indirectly connected impervious areas, consideration was given to the Study Area characteristics, including:

- Development that has occurred within the last 30 years (ie. North Haven Marina, Klingberg Drive catchments) can be assumed to generally have 'conventional' drainage systems with a higher directly connected portion of impervious area to the street. Older areas (ie. Hargrave Street, Lulu catchments) were observed on-site to generally have fewer stormwater connections to the street with a higher proportion of indirectly connected pervious area; and
- Areas where there has been widespread redevelopment of existing older stock housing (ie. Largs Bay Shore, Semaphore Shore catchments) have a mixture of 'conventional' directly connected and indirectly connected allotments. Directly connected proportions varied for these areas depending on the level of redevelopment that has occurred in the individual sub-catchment.

The catchment characteristics for a 'typical' residential sub-catchment for each of the previously mentioned sub-areas are summarised in Table 4.2. These values have been varied on an individual sub-catchment basis, where varying land uses were identified using aerial photography.

Table 4.2—Typical Catchment Characteristics Applied to Sub-areas

Sub-area	Directly Connected Impervious (%)	Indirectly Connected Impervious (%)
Sir Keith Smith Dr, North Haven	44%	19%
Koombana Tce, Osborne	35%	29%
Nyora Cres, Taperoo	30%	20%
Galway Tce, Largs North	29%	35%
Afric St, Largs North	45%	24%
Jean Street, Largs Bay	27%	36%
Hargrave St, Peterhead	26%	35%
Napier St, Exeter	29%	36%
Maud St, Ethelton	27%	33%

For non-residential catchments, runoff coefficients were determined based on land use and visual inspection of aerial photography. Commercial areas (Semaphore Road, Semaphore Shore and Largs Bay Shore) were generally assigned an impervious fraction of 80 – 90%. Industrial catchments along the eastern side of the Peninsula were generally assigned impervious fractions of 85 – 95%.

4.3.2 Hydrological Model

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

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

A custom soil type was selected, with values entered to achieve a continuing loss of 3 mm/hour.

4.3.3 Ultimate Impervious Areas and 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 URPS to identify recent and anticipated development trends in the Study Area (see Section 2.9). This assessment primarily identified Policy Areas 57 and 58, comprising residential development in the central and western regions of the Study Area, where older housing stock is likely to be subject to infill development by subdivision.

A GIS analysis of Policy Areas 57 and 58 identified that there are 2834 and 320 allotments, respectively, that could theoretically be subdivided under current planning controls. In the absence of Capital Value/Site Value (CVSV) data for the Study Area, it has been assumed that 30% of these allotments will be redeveloped over the long term (this is consistent with the assumptions outlined in DPTI's Residential Development Capacity Handbook for properties with a CVSV ratio of over 1.3).

An assumed impervious fraction for new residential infill development of 85% (comprising 70% directly connected and 15% indirectly connected fractions) was applied to determine the ultimate development scenario runoff coefficients for sub-catchments located within Policy Areas 57 and 58. For many sub-catchments in these policy areas, this resulted in only a moderate increase in the overall impervious fraction. It did however have a relatively large impact on the proportions of directly and indirectly connected impervious areas, wherein catchments that previously had a greater proportion of indirectly connected impervious area changed to mostly directly connected.

Runoff coefficients for sub-catchments in the immediate vicinity of the Taperoo Railway Station have also been increased to reflect the potential for infill development at this location.

The Residential Character Zones west of Military Road (Policy Areas 70 and 72) are not expected to be subject to significant amounts of infill development by subdivision. These zones currently exhibit relatively high impervious fractions compared to those in other residential policy areas, which is typical of development in such close proximity to the coast. It has been assumed that redevelopment and/or improvements to existing dwellings will likely result in minor increases in the overall impervious fraction for these sub-catchments under the ultimate development scenario, with a greater proportion of this impervious area becoming directly connected to the street watertable.

The ultimate development scenario has not accounted for possible infill development throughout North Haven where housing stock is newer (1970's and 1980's) and already constructed at higher densities. The ultimate development scenario has also not considered the potential for precinct wide redevelopments such as that of Fort Largs Policy Area 56, as such redevelopments are expected to include independent site-based stormwater management systems.

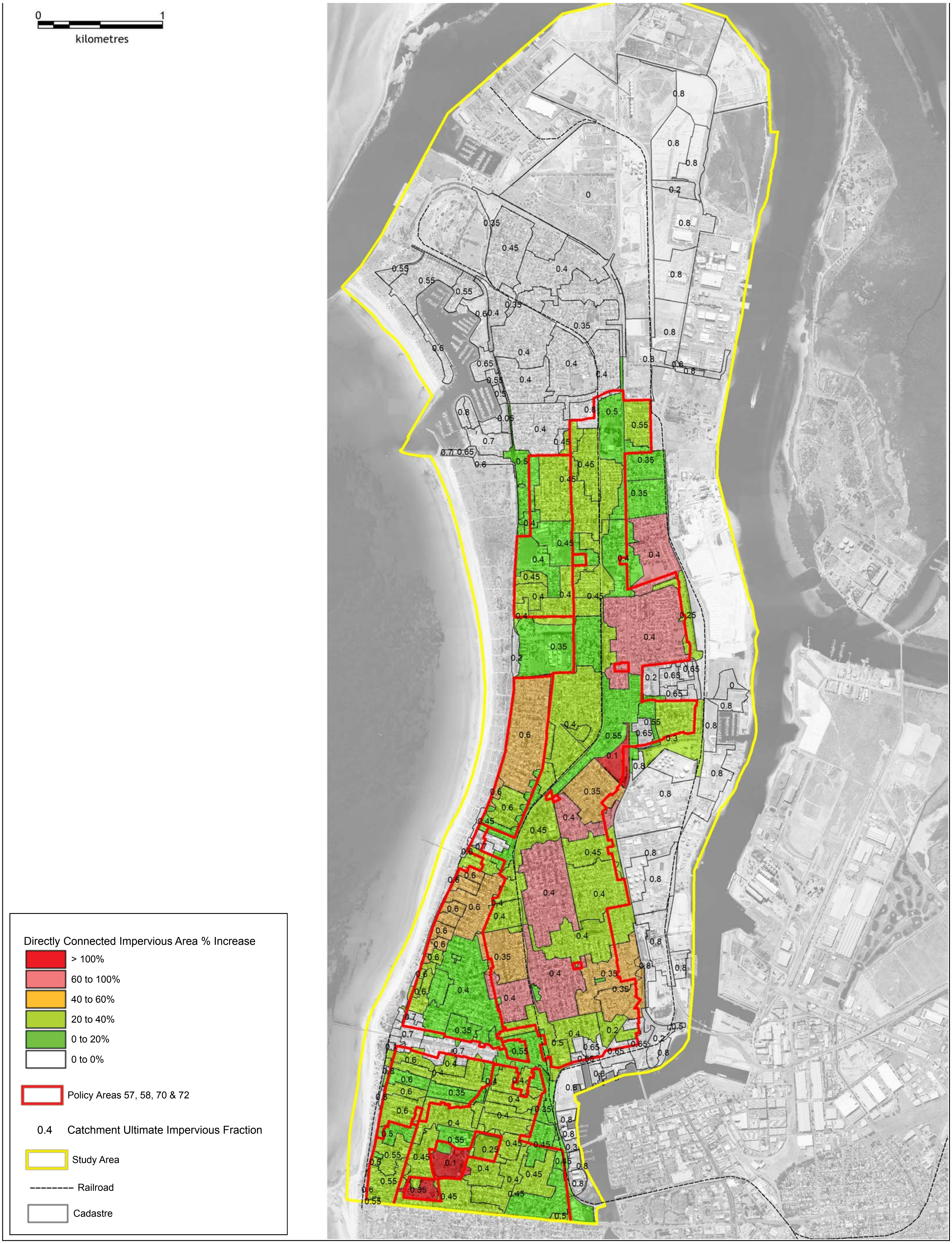
The predicted future increase in directly connected impervious area is shown in Figure 4.3.

4.3.4 Overflow Paths

Flow paths, defining the destination and travel time for overflows spilling from one inlet to the next, were assigned for all inlets based on Digital Terrain Model (DTM) information.

4.3.5 IFD Rainfall Data

Design Intensity Frequency Duration (IFD) data as presented in Table 2.2 has been utilised as the design rainfall data for the DRAINS model.



Data Sources:
City of Port Adelaide Enfield (Aerial Photograph, Stormwater Data)
Southfront (Catchments)

Lefevre Peninsula
Stormwater Management Plan

southfront

Estimated Increase in Directly Connected Impervious Area

Figure 4.3

4.4 Floodplain Mapping

Floodplain mapping of the Lefevre Peninsula has been undertaken as part of the development of this Stormwater Management Plan to define the flood levels and extent for the 5, 10, 20, 50 and 100 year ARI storm events, assuming the ultimate development scenario, 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 orientated 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 linked 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. Vertical 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.

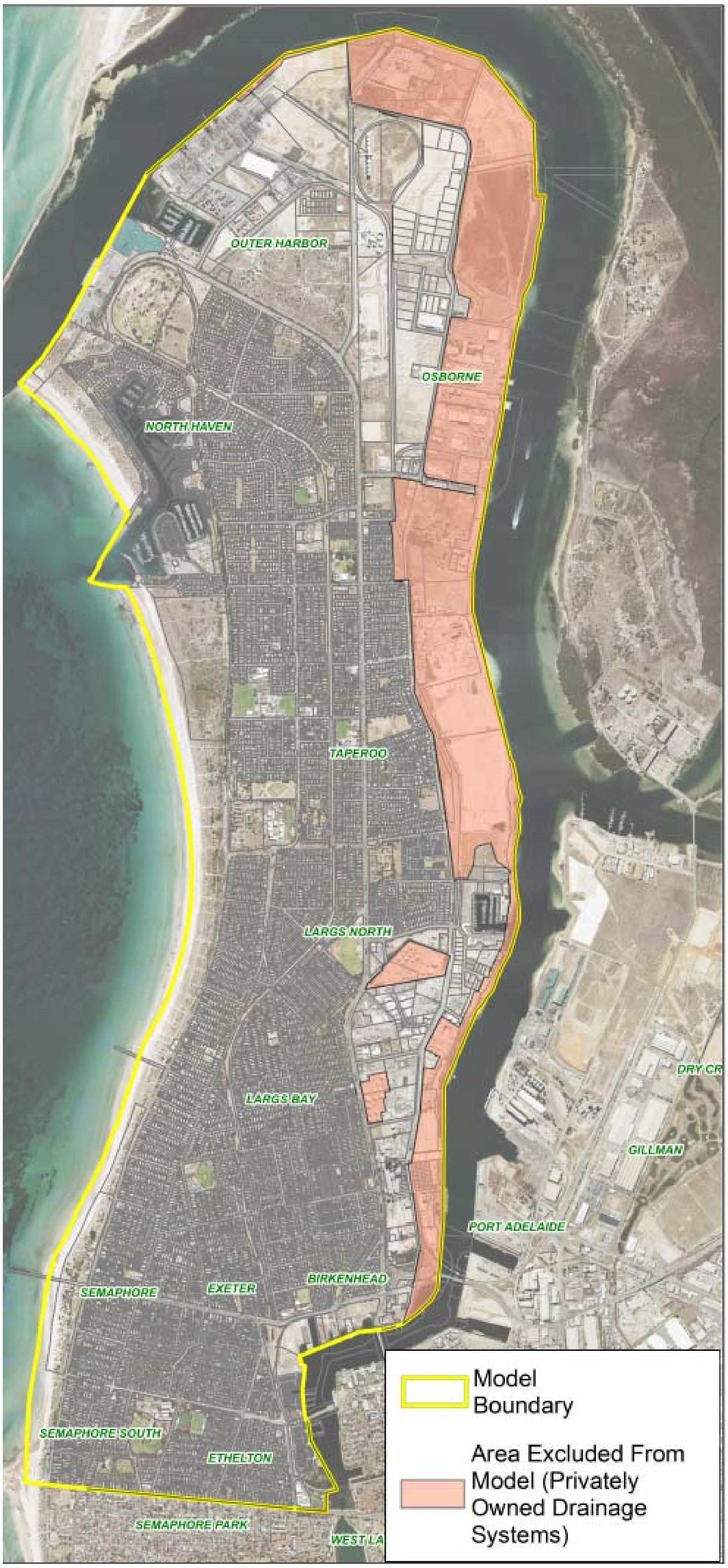


Figure 4.4—Lefevre Peninsula TUFLOW Model Boundary

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) using ESTRY, 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 3 metres was selected for modelling of the Lefevre Peninsula which corresponds to approximately 2.5 million cells within the model.

4.4.4 Time Step

Selection of an appropriate time step in the 2D domain is an important aspect of TUFLOW modelling as it is directly proportional to the running time of a model. A small time step will create more accurate results and is less likely to cause instabilities, however the simulation time can often stretch to days for long duration storm events. On the other hand, a large time step will shorten simulation times but increases the risk of inaccurate results.

A general rule for TUFLOW models (although this is not a necessity) is to use a time step (in seconds) equal to approximately half the cell size (in metres). A 2D timestep of 1.5 seconds and a 1D time step of 0.5 seconds was selected for the Lefevre Peninsula model.

The vast majority of the modelling computational effort is in solving the 2D surface flow equations and hence the impact of the time step on simulation times is negligible in the 1D domain.

4.4.5 Topography

A Digital Terrain Model (DTM) of each of the model domain areas was acquired to define the existing topography of the Peninsula. 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.

4.4.6 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 Materials values specified in GIS correspond to a user defined Manning's Roughness Coefficient described in the Materials File. This approach allows for a relatively quick and simple adjustment of Manning's Roughness Coefficient values.

The bed resistance values used in the modelling are specified in Table 4.3.

Table 4.3—Bed Resistance Parameters

Type of Land Use	Manning's Roughness Coefficient
Residential / Commercial Development	0.200
Roads	0.030
Sparsely Vegetated Open Space	0.040
Railway	0.040
Densely Vegetated Open Space	0.070

Relatively high values of Manning's Roughness Coefficient are used for residential and commercial development to compensate for the lack of building envelopes in the DTM. The Manning's Roughness Coefficient value used for modelling of underground drains was 0.012.

4.4.7 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.

At the downstream end of gravity drains that discharge directly into the Port River and North Haven Marina, the hydraulic performance is influenced by receiving waters due to tidal fluctuations. The receiving water levels used in the model for gravity drains was the Design 'Average' Tide Cycle level of 0.95 m AHD for all storm events. Limitations within the DRAINS model meant that modelling a downstream tide level that was higher than pit surface levels was not possible. Pit surface levels, particularly within the Semaphore Road East catchment, can be as low as 1.5 m AHD. Therefore modelling of higher tide levels in the minor 1 and 2 year ARI events with a 100 year ARI Tide Cycle level of 2.38 m AHD was not possible.

Within the 2D domain, the boundary condition is the edge of the model. The boundary condition adopted in the 2D domain varied depending on the scenario model. For the existing model a "HQ" (stage-discharge) type boundary was used with a water surface slope of 0.5%. 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. This is relevant to the southern edge of the model boundary, where flows overtopping Bower Road are removed from the model. It should be noted where overtopping of Bower Road will occur, as this will indicate the need to include these local catchments in any future flood study of the adjacent West Lakes catchment.

4.4.8 Inflows

The inflow hydrographs at each inlet were derived from DRAINS modelling. Flows were applied as point source inflows at the inverts 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 for 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 have no existing underground drainage infrastructure, inflow hydrographs were applied directly into the 2D domain. These locations were centred on the basins in the Outer Harbour catchment.

4.4.9 Soakage Systems

Soakage systems are used widely throughout the Peninsula as a method of stormwater disposal where conventional drainage systems are either not available, or have been observed to perform inadequately. Soakage systems are particularly prevalent at localised depressions or 'sag' points across the Peninsula. The soakage systems vary in size from individual side entry pits with no concrete floor, to larger underground storages constructed using box culvert arches.

The rate at which stormwater is able to infiltrate to the sub-surface is critical in understanding the effectiveness of the soakage systems. The infiltration performance of the soakage systems was investigated by field testing undertaken by Australian Groundwater Technologies (AGT).

A summary of the field results include:

- Infiltration rates depend on the underlying sub-surface materials, with the sandier soils of the western side of the Peninsula having greater permeability than the eastern side;
- Western soakage pit infiltration rate: 1.0 L/s/m^2 (high);
- Central soakage pit infiltration rate: 0.72 L/s/m^2 (medium);
- Eastern soakage pit infiltration rate: 0.22 L/s/m^2 (low); and
- Cleaning of the soakage systems was not observed to have a positive impact on the rate of infiltration.

To determine the effectiveness of the soakage systems in reducing peak overflows in event-based storms, sample DRAINS modelling was undertaken for a range of soakage system sizes and configurations. The DRAINS modelling indicated that small infiltration systems (less than 10 m^2 soakage area) had a negligible effect in reducing stormwater overflows in the system. Larger soakage systems (greater than 10m^2) resulted in a moderate reduction in peak overflows.

Modelling infiltration losses of the soakage systems in TUFLOW was therefore limited to systems larger than 10 m^2 in soakage area. No losses were modelled for smaller systems, although their underground storage was accounted for in the model.

Infiltration rates were calculated for each of the larger soakage systems based on their effective infiltration surface area and their location (with reference to the high/medium/low infiltration zones describe above). Water within these systems was 'removed' from the TUFLOW model at the infiltration rate determined to be appropriate for each system.

4.5 Drainage Performance

4.5.1 Minor System Performance

The DRAINS model of the existing drainage system under current development conditions has been executed for the 1, 2, 5 and 100 year ARI storm events. Drainage system 'failure' was defined as occurring whenever the hydraulic grade line level results in freeboard within the upstream pit of less than 150 mm. The performance standard at drainage nodes (ie. the corresponding ARI at which the DRAINS model reported this to occur) are illustrated in the plans presented in Appendix A. It is generally desirable for underground drainage networks to achieve performance standards of a 5 year ARI.

The capture capacity of the existing inlet pits was also assessed by analysing the magnitude of the 5 year ARI approach flows to individual pits. Figures in Appendix A depict stormwater inlets with peak 5 year ARI approach flows, categorised according to multiples of 75 L/s, which is equivalent to the maximum flow rate at which a standard City of Port Adelaide Enfield double side-entry pit (on a road with less than 1% longitudinal grade) will achieve 100% capture. These figures provide high-level guidance on locations where the provision of additional inlet pits may improve the performance of the existing underground drainage system.

It should be noted that gutter flows are likely to be conservatively overstated at locations where private properties are serviced by internal drainage systems that connect directly to the Council drainage system (ie. rear of allotment drains). This is expected to be particularly prevalent in commercial/industrial zones and newly developed residential areas.

Table 4.4 lists the existing drainage networks that were assessed to perform below the 5 year ARI target performance standard.

It should be noted that the process adopted for the assessment of drainage standards is suitable for the identification of deficiencies in areas containing existing drainage infrastructure. The assessment of areas lacking in drainage infrastructure was undertaken using floodplain mapping which is addressed below in Section 4.5.2.

The consequences of a 'minor' system with a flow capacity less than the desirable 5 year performance standard will not necessarily result in the inundation of private property or the unsatisfactory performance of the 'major' system. Of the drains shown that have failed to meet the desired performance standard, many will likely only result in excessive gutter flows and/or short-term localised ponding in roads and nature strips. However, there is particular concern for systems that when the drainage capacity is exceeded, have overland flow paths through adjacent private property.

Table 4.4 is provided as a summary of potential ponding hotspots or locations that are expected to be subject to large gutter flows. They do not necessarily identify areas that require immediate or any action if surface overflows from these systems can be appropriately managed, as determined from the floodplain mapping which is addressed in Section 4.5.2.

However when these existing drainage systems require renewal, Council may consider constructing larger underground drains and/or additional inlet pits to achieve the desired performance standard. Furthermore if an existing problem is due to inadequate pit inlet capacity and there is redundancy in the pipe system, the construction of additional inlet pits may be warranted in the short-term.

Table 4.4—Existing Underground Drains – Identified System Issues

Drains with Low Performance Standard	Performance Standard ARI
Hart Street Catchment	
Deslandes Street / Mary Street	< 1 year
Carlisle Street / Mary Street	2 – 5 year
Harvey Street and Maud Street	< 1 year
Swan Terrace (south of Hart St)	1 – 2 year
Robin Rd	< 1 year
Goldsworthy Rd	1 -2 year
Nile St / Causeway Rd	< 1 year
Semaphore Shore Catchment	
Jervois Road	< 1 year
Blackler Road	2 – 5 year
Carlisle Street Catchment	
Mellor Rd	2 – 5 year
Bucknall Road / Swan Terrace	2 – 5 year
Semaphore Road / Military Road	< 1 year
Semaphore Road Catchment	
Teakle Street / Semaphore Road	< 1 year
Mead Street	< 1 year
Hughes Street	< 1 year
Fletcher Road / Semaphore Road	< 1 year
Dickenson Street / Semaphore Road	< 1 year
Hargrave Street Catchment	
Wollnough Road (south of Hargrave Street)	1 - 2 year
Peterhead Street	< 1 year
Ruby Street	1 - 2 year
Workman Street / Rose Street	1 – 2 year
Hargrave Street (west of Fletcher Road)	< 1 year
Hargrave Street (east of Fletcher Road)	2 -5 year
Lulu Catchment	
Wills Street	1 - 2 year
Mary Street	< 1 year
Hamley Street	< 1 year
Fletcher Road (north of Wills Street)	< 1 year
Fletcher Road (south of Wills Street)	1 – 2 year
Walton Street	1 -2 year

Drains with Low Performance Standard	Performance Standard ARI
Jetty Road Catchment	
Jetty Road / Victoria Road	< 1 year
Largs Bay Shore Catchment	
Anthony Street / Military Road	< 1 year
Wigley Street	< 1 year
Percy Street	< 1 year
Centre Street Catchment	
Centre Street (Devon Street to Elder Road)	< 1 year
Fletcher Road (north of Centre Street)	<1 year
Kirby Terrace	< 1 year
Warwick Street	< 1 year
Largs North Shore Catchment	
N/A (soakage pits)	-
Mersey Street Catchment	
Railway Terrace (Strathfield Terrace to Dover Terrace)	< 1 year
Middleton Road	< 1 year
Victoria Road (north of Willochra Street)	< 1 year
Victoria Road (north of Strathfield Terrace)	< 1 year
Victoria Road (north of Gedville Road)	< 1 year
Collins Street	1 – 2 year
Taperoo Shore Catchment	
Military Road (south of Gedville Road)	2 – 5 year
Military Road (north of Inkster Avenue)	< 1 year
Wandana Terrace	< 1 year
Northolt Road	< 1 year
Military Road (north of Woodhall Road)	< 1 year
Hamilton Avenue Catchment	
Bridges Avenue / Mersey Road	< 1 year
Hamilton Avenue / Mersey Road	2 – 5 year
Osborne Road Catchment	
Osborne Road (east of Fraser Road)	< 1 year
Tapping Crescent / Sir Ewen Waterman Avenue	< 1 year
Read Court	< 1 year
Revere Drive	< 1 year
Klingberg Drive Catchment	
Oronsay Drive / Iberia Court / Chusan Court	1 – 2 year
Victoria Road / Sir Keith Smith Drive	< 1 year

Drains with Low Performance Standard	Performance Standard ARI
Schroder Court	1 – 2 year
Todd Street / Sir Ross Smith Avenue	1 - 2 year
North Haven Marina Catchment	
Australia 2 Avenue / Gulf Point Drive	1 - 2 year

Some drains are shown to have drainage standards which do not exceed or reach capacity in any of the modelled ARI events. This is generally due to restrictions in the upstream drainage system limiting the flows that can enter these drains (ie. undersized lateral drains), rather than these drains being oversized. An example of this is the Hart Street trunk drain between Swan Terrace to the Hart Street pump station within the Hart Street catchment. Modelling indicates the Hart Street trunk drain is of high capacity. The contributing lateral drains in Carlisle Street, Deslandes Street and Swan Terrace however are shown to have capacities of less than 2 year ARI standard. Should these lateral systems be upgraded, it is unlikely that the Hart Street trunk drain would perform at such a high ARI capacity standard.

Soakage systems were not modelled in DRAINS as they are typically a 'node' located at the downstream end of a drainage system, and as such their performance is not able to be represented in the same 'standards mapping' format that is used to display the performance of underground drains. Rather the soakage systems have been modelled in TUFLOW floodplain mapping, as that model is able to take into account underground storage, infiltration losses, and effectively reflect above ground storage within the road network. See Section 4.4.9 for soakage system modelling parameters.

4.5.2 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 5 year, 10 year, 20 year, 50 year and 100 year ARI events for the ultimate development scenario with existing drainage infrastructure. Various storm durations were modelled within each ARI event in order to determine which durations were critical for each catchment and event. Storm durations modelled for each ARI were the 20 minute, 30 minute, 1 hour, 2 hour, 3 hour, 6 hour, 9 hour and 12 hour storms.

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 ARI. The critical storm durations for each ARI are shown in Table 4.5.

Table 4.5—Critical Storm Durations for each ARI

Average Recurrence Interval	Critical Storm Durations
5 year	20 min, 1 hr, 3 hrs
10 year	20 min, 1 hr, 3 hrs, 6 hrs
20 year	20 min, 1 hr, 3 hrs, 6 hrs
50 year	20 min, 1 hr, 3 hrs, 12 hrs
100 year	20 min, 1hr, 6 hrs, 12 hrs

This report section provides an overview of the floodplain extents for the various ARI events. The purpose of this commentary is to identify areas on the Peninsula that are susceptible to inundation from stormwater runoff, and the possible causes. Whilst there was no historical flood records or gauge data provided to enable calibration of the hydrological and floodplain models, the floodplain maps were reviewed by Council staff and ground truthed and are understood to provide a realistic representation of flood behaviour on the Peninsula.

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 100 mm are unlikely to result in flooding of adjacent buildings or structures. It is recommended that building floor levels be surveyed in these areas in order to determine the likelihood of floodwater incursion and likely damages, and to inform the design development of flood mitigation strategies for the Peninsula.

5 year ARI Flood Mapping Commentary

The 5 year ARI floodplain map shows widespread ponding within the road network, indicating that the underground drainage network generally has less than a 5 year ARI capacity in many locations across the Peninsula.

Minor surface inundation of private property is shown to occur in some locations, particularly in the Hart Street, Carlisle Street, Hamilton Avenue and Taperoo Shore catchments. Inundation of private property is generally less than 100 mm deep in most areas, which is unlikely to cause above floor level flooding in the majority of residential dwellings (floor levels of residential dwellings are typically at least 150 mm above surrounding natural surface, though this can vary from house to house depending on factors such as age and location). Areas of interest are summarised by catchment below and in Table 4.6.

Hart Street catchment

Stormwater inundation of private property in the Hart Street catchment is shown to occur in sub-catchments south of the main trunk drain in Hart Street. These include Old Pelham Street, Mary Street, Harvey Street, Maud Street and Robin Road. This indicates the lateral drains south of the trunk drain do not have sufficient capacity to convey flow to the main drain in Hart Street.

Carlisle Street catchment

Stormwater ponding within the Carlisle Street catchment is generally centred on the Bucknall Road/Mellor Road/Swan Terrace precinct. Modelling indicates the Mellor Road and Bucknall Road drains have insufficient capacity to convey stormwater from this low point to the Carlisle Street pump station in both minor and major storm events.

Shallow inundation of private property is also shown to occur in Brown Street. This relatively large catchment (2.9 hectares) is drained only via soakage pits where Brown Street terminates to a cul-de-sac, with overflows from this system passing through private property. Shallow property inundation (< 100 mm deep) is also shown amongst the commercial properties near the intersection of Semaphore Road and Military Road at the upstream end of the catchment.

Semaphore Road East catchment

The Semaphore Road East catchment drains via a gravity system into the Port River. Areas of property inundation are shown to occur around Hughes Street which is particularly low-lying (between 1.8 and 2 mAHD). Flooding at Semaphore Road/Teakle Street (upstream of the railway line) is also shown in a number of private properties, up to 500 mm deep. Inspection of

Council's GIS data for the Semaphore Road drain indicates the Semaphore Road drain decreases in size from a 675 mm diameter pipe upstream of Teakle Street and 1200mm wide by 300 mm high box culvert under the railway line, to a 450 mm diameter pipe at the outlet. This reduction in drainage capacity is one likely cause of flooding at Teakle Street.

Hargrave Street catchment

Extensive roadway ponding and property inundation is shown to be occurring in the Peterhead Street sub-catchment. Likely above floor flooding of multiple residential properties can be observed with flood depths of up to 500 mm. Minor flooding is also occurring in the Woolnough Road and Hall Street sub-catchments. This inundation extent is indicative of the low capacity of the original (pre-2016) Hargrave Street trunk drain and lateral systems.

While the recently commissioned Hargrave Street pump station was included in the model for this scenario, the proposed Hargrave Street trunk drain (from Woolnough Road to Victoria Road) was excluded in order for the TUFLOW model to reflect the infrastructure that existed at the commencement of the Plan preparation. This trunk drain has been included in the Future Upgrades Scenario (outlined in Section 4.8) to demonstrate the overall improvement in the performance of the Hargrave Street drainage system on completion of the final section of trunk drain (from Fletcher Road to Victoria Road) in 2016.

Lulu catchment

Surface roadway ponding in the Lulu catchment is evident in Fletcher Road, Wills Street, Sanderson Street and Mary Street with depths of over 250 mm. Modelling indicates that both the Wills Street to Victoria Road drain and lateral drains in Mary Street and Fletcher Road are of low capacity (less than 1 year ARI capacity).

Taperoo Shore catchment

Roadway ponding in the Taperoo catchment is confined to the eastern boundary of the catchment adjacent to the Outer Harbour railway line. These sub-catchments are generally not drained via conventional gravity drainage systems but rely on soakage and underground storage for disposal of stormwater. Properties in the Lawhill Court/Charon Drive/Ormiston Court precinct are shown to be susceptible to shallow property inundation. The intersection of Railway Terrace and Hutley Road is also shown to experience shallow (< 250 mm) private property inundation.

Surface ponding is also shown to occur at Railway Terrace and Moldovia Walk with ponding of over 500 mm within the roadway and up to 250 mm within nearby private property. This catchment is serviced by the Midlunga Railway Station pumping station, which indicates this pump station does not have sufficient capacity to manage the 5 year ARI storm.

Floodplain maps show that catchments which entirely rely on soakage pits for removal of stormwater (Taperoo Shore, Largs North Shore and Largs Bay Shore) generally do not have sufficient underground storage to prevent surface ponding in the 5 year ARI event. Stormwater is shown to pond across the road surface and in some sub-catchments does spill into neighbouring private property.

Hamilton Avenue catchment

Properties in Bridges Avenue are shown to experience inundation of depths of up to 500 mm. Modelling indicates that the pump station capacity is insufficient to prevent surface ponding within this catchment.

Table 4.6—Flooding Hotspots 5 year ARI; Ultimate Development, Existing Infrastructure

Observed Surface Inundation Location	Approx. number of properties affected [1]	Maximum Observed Flood Depth (mm)
Hart Street Catchment		
Old Pelham Street and Bower Road	8	< 100 mm
Harvey Street and Maud Street	12	< 100 mm
Robin Road	5	< 250 mm
Semaphore Shore Catchment		
Jervois Road	6	< 250 mm
Carlisle Street Catchment		
Semaphore Road and Military Road	9	< 100 mm
Brown Street and Turton Street	6	< 100 mm
Exmouth Road and Nile Street	4	< 100 mm
Carlisle Street (near intersection with Bucknall Road)	3	< 100 mm
Semaphore Road Catchment		
Teakle Street / Semaphore Road	5	< 250 mm
Hargrave Street Catchment		
Hall Street	7	< 100 mm
Peterhead Street and Parr Street	24	<250 mm
Osborne Street	4	< 100 mm
Fletcher Street	11	< 250 mm
Lulu Catchment		
Mary Street	4	< 100 mm
Jetty Road Catchment		
Elder Road	2	250 mm
Largs Bay Shore Catchment		
Roslyn Street, Chester Street, Wigley Street	9	< 100 mm
Percy Street	2	< 100 mm
Centre Street Catchment		
Creswell Road	2	250 mm
Largs North Shore Catchment		
Farringdon Street and Cheapside Street	5	< 100 mm
Kybunga Terrace	4	< 100 mm
Chester Street / Roslyn St / Afric St	12	<100 mm
Mersey Street Catchment		
Middleton Road	4	< 250 mm
Railway Terrace	8	< 100 mm
Taperoo Shore Catchment		
Charon Drive, Lawhill Court and Ormiston Court	14	250 mm
Railway Terrace and Moldovia Walk	4	< 100 mm

Observed Surface Inundation Location	Approx. number of properties affected [1]	Maximum Observed Flood Depth (mm)
Dawlish Road	4	< 100 mm
Railway Terrace and Hutley Road	6	< 250 mm
Hamilton Street Catchment		
Bridges Avenue and Mersey Road	6	< 250 mm
Wheadon Street and Brookman Street	4	< 100 mm

[1] Refers to the ingress of stormwater runoff to privately owned land, and does not necessarily imply that above floor inundation will occur

10 year ARI Flood Mapping Commentary

The 10 year ARI floodplain map shows stormwater ponding slightly greater in depth and extent than that expected in the 5 year ARI described above. Areas where there is noticeable increase in flooding extent include the Hargrave Street, Lulu, Centre Street and Mersey Road catchments.

Hargrave Street catchment

Inundation of private properties (and likely above floor level flooding) in the Peterhead Street sub-catchment is shown to increase with depths across a number of properties rising to 500 mm. Roadway ponding and property inundation in the Woolnough Road and Hall Street sub-catchments are also shown to moderately worsen.

Lulu catchment

The limited capacity of the Wills Street drain results in increased inundation of private property in Fletcher and Sanderson Streets, when compared to the 5 year ARI. Roadway ponding in Alfred Street, Mary Street, Hamely Street, Adelaide Street and Woolbridge Street is shown to occur in the 10 year ARI event.

Centre Street catchment

Modelling indicates the Centre Street system is of low capacity (less than 1 year ARI) from Elder Road to the upstream drainage reaches in Centre Street and Warwick Street. Analysis of Council's GIS stormwater data indicates that the two drainage reaches converging at Creswell Road (1 x 600 mm diameter pipe and 1 x 675 mm diameter pipe) both discharge into a single 600 mm diameter pipe through drainage easement to Elder Road. This reduction in drainage capacity causes upwelling of stormwater and ponding in Creswell Road (including inundation of industrial land) and residential property inundation in the upstream reaches of Swansea Street, Warwick Street and Centre Street.

Taperoo Shore catchment

Inundation of private property is evident in the Military Road sub-catchment of the Taperoo Shore gravity drain system. Lateral drains to the main drain in Military Road are shown to be of low capacity with ponding occurring in Dawlish Road, Marmara Terrace and Moldovia Walk.

Extensive inundation of residential properties is shown to occur in the Lawhill Court/Charon Drive/Ormiston Court precinct due the limited capacity of the local soakage systems.

Mersey Road catchment

Property inundation is shown to occur in the Kolapore Avenue sub-catchment to the west of the railway line. There is potential for above floor flooding of several properties due to flood depths of over 500 mm in Railway Terrace, Middleton Road and Katoomba Terrace. This indicates that the Kolapore Avenue drainage system has inadequate capacity to cater for a 10 year ARI storm event.

Margueretta Street and Victoria Road (upstream end of the Kenmare Street drainage system) are shown to have poor drainage capacity with inundation depths of up to 250 mm in several properties on Victoria Road.

20 year ARI Flood Mapping Commentary

The 20 year ARI floodplain map shows inundation depths and extents slightly greater than those expected in the 5 and 10 year ARI's described above. Areas where there are noticeable increases in the floodplain extent include the Carlisle Street, Semaphore Road and Lulu catchments.

Carlisle Street catchment

The 20 year ARI flood map indicates an increase in the extent and depth of ponding in the Swan Terrace/Bucknall Street/Mellor Road sub-catchment. Roadway ponding depths of up to 500 mm are evident in nearby Graham Street, with shallow inundation extending through several properties up to Bucknall Street. Ponding in this low point of the catchment indicates that the Carlisle Street pump station is the likely restriction with a capacity of less than 10 year ARI.

Semaphore Road catchment

Inundation of private property within the Hughes Street sub-catchment is shown to worsen moderately in the 20 year ARI, with additional affected properties in adjacent May Street, Close Street and Emily Street. The capacity of the Dickenson Close/Semaphore Road drainage system is also shown to be exceeded, as evidenced by inundation of several properties.

Lulu catchment

The extent and depth of the ponding within the Lulu catchment is shown to increase significantly in the 20 year ARI. Based on the reported depth of inundation there is potential for properties on Mary Street, Alfred Street, Phillis Street and Trust Terrace to experience above floor flooding. Ponding in the roadway along almost the entire length of the Wills Street and Walton Street trunk drains is now evident west of Victoria Road.

50 year ARI Flood Mapping Commentary

The 50 year ARI floodplain map shows inundation depths and extents slightly greater than those expected in the 10 and 20 year ARI's described above. Areas where there are noticeable increases to the floodplain extent include the Hart Street, Lulu, Largs North Shore, Mersey Road, Taperoo Shore, Hamilton Avenue and Klingberg Drive catchments.

Hart Street catchment

The floodplain in the Hart Street catchment is shown to extend into private property in Deslandes Street, Mary Street, Glanville Street and Warrawee Road. Inundation of properties in the vicinity of Harvey Street and Maud Street is shown to moderately worsen (with depths of up to 250 mm). Modelling indicates that the pump station and Hart Street trunk drain likely has a 20 year ARI capacity.

Lulu catchment

Floodplain depths within the Lulu catchment are shown to increase significantly over a relatively large area, with multiple properties in low-lying sections of Alfred Street, Mary Street, Fletcher Road and Walton Street shown to be subject to inundation depths of over 500 mm.

Largs North Shore catchment
The capacity of the soakage systems in the Largs North Shore catchment are shown to be exceeded in the 50 year ARI event, with stormwater ingress to private property expected throughout the Largs North 'valley' bounded by Military Road to the east, Lady Gowrie Drive to the west, Wigley Street to the south and Strathfield Terrace to the north. Multiple properties are shown to be inundated by stormwater within these localised low points, with inundation depths of over 500 mm in the vicinity of Farringdon Street.

Mersey Road catchment
An increased number of residential properties at Middleton Road/Railway Terrace are shown to become inundated in the 50 year ARI event. Property inundation and above floor flooding is also likely at Kolapore Avenue.

It is estimated based on the floodplain mapping results that the Mersey Road pump station and major trunk drains east of Victoria Road likely have a 20 – 50 year ARI capacity. Flooding in the catchment in minor events is likely caused by the low capacity of lateral drains connecting into the major system.

Klingberg Drive catchment
Shallow ponding is shown to occur from Aurelia Drive to Oronsay Drive in the north-western extent of the Klingberg Drive catchment.

100 year ARI Flood Mapping Commentary
The 100 year ARI floodplain map shows relatively large areas of stormwater ingress to private property compared to the 20 and 50 year floodplain maps. The catchments that are worst affected by the 100 year ARI floodplain (and their type of drainage outfall), are summarised below:

- Hart Street catchment (pumped);
- Carlisle Street catchment (pumped);
- Semaphore Road catchment (gravity);
- Hargrave Street catchment (pumped);
- Lulu catchment (pumped);
- Centre Street (gravity);
- Mersey Road (pumped);
- Taperoo Shore (gravity and soakage);
- Hamilton Avenue (pumped); and
- Largs North Shore (soakage).

Modelling indicates that the worst affected catchments are those that are low-lying (often in areas where the ground surface is less than 2 mAHD) which mainly rely on pumped outfalls for flood protection. The estimated pump station performance standards, summarised in Table 4.7, take into account the storage within the underground drainage systems and are based on the ARI in which the pump station forms a restriction to stormwater flows being discharged from the catchment. If the capacity of the pump station is exceeded, upwelling from the underground stormwater drainage system would inevitably occur and stormwater would begin to pond within the low points of the catchment, potentially leading to flooding of properties.

It is possible that upstream stormwater drainage upgrades within the pump station catchments could have a detrimental effect on the performance of the existing pump stations, or cause flooding in other areas within these catchments. This is because more water will reach the pump station rather than being held up in other parts of the catchment. This will be analysed in the proposed upgrades scenario modelling in Section 4.8.

Table 4.7—Pump Station ARI Capacity Standards

Pump Station	Current Performance Standard (ARI)
Hart Street	20 year
Carlisle Street	5 - 10 year
Lulu catchment	5 year
Hargrave Street	20 year
Hamilton Avenue	< 5 year
Midlunga Railway Station (Taperoo Shore catchment)	< 5 year
Archie Badenoch Court (Cultural Park catchment)	100 year

Hart Street catchment
The Hart Street catchment shows inundation depths of over 100 mm to more than 150 properties in the 100 year ARI. The worst affected properties are those in the vicinity of Harvey Street, Maud Street and Mary Street. The low capacity of the lateral drainage systems and Hart Street trunk drain, combined with the limitation of the current pumped outflow from the Hart Street pump station, are the likely causes of flooding in this catchment.

Carlisle Street catchment
Based on the reported depth of inundation there is potential for properties in the low-lying areas of the Carlisle Street catchment to experience above floor level flooding during a 100 year ARI event. The limitation of the current pumped outflow from the Carlisle Street pump station is likely the primary cause of flooding in this catchment.

Semaphore Road catchment
Likely above floor flooding in the Teakle Street and Hughes Street sub-catchments indicates the low capacity of the gravity stormwater system to drain these low points in major storm events. The 100 year ARI event shows inundation depths of up to 500 mm in these low-lying sub-catchments. It should also be noted that a higher tide level at the outlet into the Port River (modelled at 0.95 m AHD) would further reduce the local drainage capacity and exacerbate flooding within this low-lying catchment.

Hargrave Street catchment
Property inundation and likely above floor flooding in the Hargrave Street catchment is indicative of the low capacity of the existing trunk drain and laterals in this catchment. The recently completed upgrades to the Hargrave Street trunk drain and lateral drains have been included in the Upgrades Scenario (refer Section 4.8) and are expected to result in an improved drainage performance and therefore decreased flood risk in this catchment.

Lulu catchment
Modelling shows widespread above floor flooding in the Lulu catchment in the 100 year ARI event. Overflows entering the Lulu catchment from the adjacent Hargrave Street, Largs Bay Shore and Jetty Road catchments is shown to exacerbate flooding in the low-lying areas of this

catchment. Inundation depths of 500 mm are affecting over 60 properties in the 100 year ARI event. Modelling shows the Walton Street and Wills Street drains are of low capacity.

Taperoo Shore catchment
The capacity limitations of the Lawhill Court/Charon Drive/Ormiston Court soakage systems could potentially lead to stormwater inundation of over 30 properties in this area in the 100 year ARI event.

Midlunga Railway Station pump station is also shown to have low capacity with a number of properties likely to be affected by above floor level flooding in the 100 year ARI event.

Hamilton Avenue
Inundation of private property in the vicinity of the Hamilton Avenue pump station suggests that it does not have sufficient capacity to protect properties from stormwater ingress in events greater than the 5 year ARI. Inundation of private property is shown to occur in Bridges Avenue, Martin Avenue, Hamilton Avenue, Camilla Avenue and Brookman Street in the 100 year ARI event.

A catchment summary of the number of properties subject to inundation of depths greater than 50 mm for each ARI is shown in Table 4.8.

Table 4.8—Property Inundation by ARI; Ultimate Development, Existing Infrastructure

Catchment	Number of properties inundated > 50 mm				
	5yr	10yr	20yr	50yr	100yr
Lulu	33	49	102	206	294
Hargrave Street	39	61	97	153	220
Mersey Road	19	31	46	90	139
Taperoo Shore	28	50	63	98	126
Hart Street	16	25	41	71	122
Carlisle Street	20	33	41	79	106
Semaphore Road	12	28	41	66	94
Hamilton Avenue	6	11	27	49	66
Largs North Shore	23	28	32	47	58
Centre Street	4	9	19	30	41
Klingberg Drive	1	1	2	6	22
Osborne Soakage	0	1	1	5	16
Largs Bay Shore	5	6	7	9	15
Semaphore Shore	3	5	8	10	14
Osborne Road	0	0	0	0	9
Jetty Road	5	5	5	5	6
North Haven Marina	0	0	0	1	1
Outer Harbour	0	0	0	1	1
Cultural Park	0	0	0	0	0
Largs North Marina	0	0	0	0	0
New Port Quays	0	0	0	0	0
TOTAL	214	343	532	926	1350

Flooding hotspots identified previously are summarised in Table 4.9. The referenced Critical ARI Threshold indicates the ARI in which the capacity of both the ‘minor’ (underground drainage) system and ‘major’ (above ground storage/overflow) system is exceeded and significant stormwater inundation occurs within nearby private property.

Table 4.9—Summary of Flooding Hotspots by Catchment

ID	Observed Surface Inundation Location	Critical ARI Threshold (years)	Approx. Maximum Flood Depth in 100 year ARI (mm)
	Hart Street Catchment		
F1	Old Pelham Street and Goldsworthy Road	<5	500
F2	Mary Street	5 - 10	600
F3	Harvey Street and Maud Street	5	400
F4	Robin Road	5	250
F5	Hanson Street, Freer Street, Emu Street	20	250
	Semaphore Shore Catchment		
F6	Jervois Road	5	600
	Carlisle Street Catchment		
F7	Semaphore Road and Military Road	<5	250
F8	Brown Street and Turton Street	<5	250
F9	Swan Terrace, Mellor Road and Bucknall Street	<5	500
F10	Graham Street	10 – 20	500
	Semaphore Road East Catchment		
F11	Teakle Street / Semaphore Road	<5	500
F12	Hughes Street / Emily Street / May Street	5 - 10	400
F13	Walker Street / Semaphore Road / Dickenson Close	5 - 10	350
	Hargrave Street Catchment		
F14	Hall Street	< 5	250
F15	Peterhead Street and Parr Street	< 5	700
F16	Osborne Street	< 5	500
F17	Fletcher Road	< 5	300
F18	Rose Street / Workman Street	10 - 20	500
	Lulu Catchment		
F19	Mary Street	< 5	500
F20	Fletcher Road / Sanderson Street	< 5	500
F21	Fletcher Road / Clouston Street	10 - 20	400
F22	Adelaide Street	5 – 10	400
F23	Alfred Street	10 – 20	500
F24	Trust Tce / Phyllis Tce	10 – 20	400
F25	Woolridge St	10 – 20	300
	Jetty Road Catchment		
F26	Elder Road / Jetty Road	5 - 10	500

ID	Observed Surface Inundation Location	Critical ARI Threshold (years)	Approx. Maximum Flood Depth in 100 year ARI (mm)
	Centre Street Catchment		
F27	Creswell Road / Elder Road	< 5	700
F28	Warwick Street / Swansea Street / Kenilworth Street	10	500
	Largs Bay Shore Catchment		
F29	Anthony Street	< 5	250
	Largs North Shore Catchment		
F30	Farringdon Street and Cheapside Street	< 5	600
F31	Kybunga Terrace	< 5	500
F32	Chester Street / Roslyn St / Afric St / Wigley Street / Persic Street	< 5	500
	Mersey Street Catchment		
F33	Middleton Road	5	500
F34	Railway Terrace / Kolapore Avenue	5	500
	Taperoo Shore Catchment		
F35	Charon Drive, Lawhill Court and Ormiston Court	5	500
F36	Railway Terrace and Moldovia Walk	<5	700
F37	Dawlish Road	5	250
F38	Railway Terrace and Hutley Road	<5	500
	Hamilton Street Catchment		
F39	Bridges Avenue and Mersey Road	5	600
F40	Wheadon Street and Brookman Street	5 - 10	300
F41	Victoria Road / Bridges Street	20	300

4.6 Impact of Sea Level Rise

The *Coast Protection Board Policy Document* (Coast Protection Board, 2012) suggests that the sea level is currently rising at a rate of approximately 1.5mm/yr at most parts of the South Australian coast, noting that the rate differs at a few locations because of local land subsidence or uplift. Current State Government Policy requires that coastal planning and design cater for sea level rise of:

- 0.3m between 1991 and 2050; and
- A further 0.7m between 2050 and 2100.

Sea level rise will have the effect of increasing the number of catchments (and overall area) of the Lefevre Peninsula that will require pumped outfalls to ensure that the stormwater drainage network performs adequately when tide levels are elevated in the receiving waters. Table 4.10 summarises the possible impact of sea level rise on the receiving water levels for gravity drainage systems.

Table 4.10—Impact of Sea Level Rise on Receiving Water Levels [1]

Tide Cycle	Sea Level Rise to 2050	Sea Level Rise to 2100
Design 'Average' Tide Cycle	1.25 mAHD	1.95 mAHD

[1] Receiving water levels exclude any allowances for wave run-up and freeboard

Catchments that may require replacement of existing gravity drainage outfalls with new pumped systems in the future to cater for predicted sea level rise to 2100 are summarised as follows; Semaphore Road East, Jetty Road and Centre Street. An added benefit of installing pumped outfalls in these catchments is the ability to complement the function of the sea walls and backflow prevention devices and mitigate the impacts of seawater ingress during high tides and storm surge events.

There are existing underground drains in the North Haven catchment that discharge to the marina via gravity outfalls that are situated below the Outer Harbour Mean High Water Springs (MHWS), which has been adopted as the Design 'Average' Tide Cycle for this study. In particular, the invert level of the Klingberg Drive trunk drain remains below the Design 'Average' Tide Cycle for much of its length, as shown in Figure 4.5. Whilst a pumped outfall is not expected to be required for these systems over the time horizon of this study (ie. to 2050) it is worth noting that projected sea level rise may have an adverse impact on their performance standard, in a similar manner to that reported in the *Port Adelaide Seawater Stormwater Flooding Study* (Tonkin Consulting, 2005) for gravity drainage systems discharging under high tide conditions (refer Section 2.4).

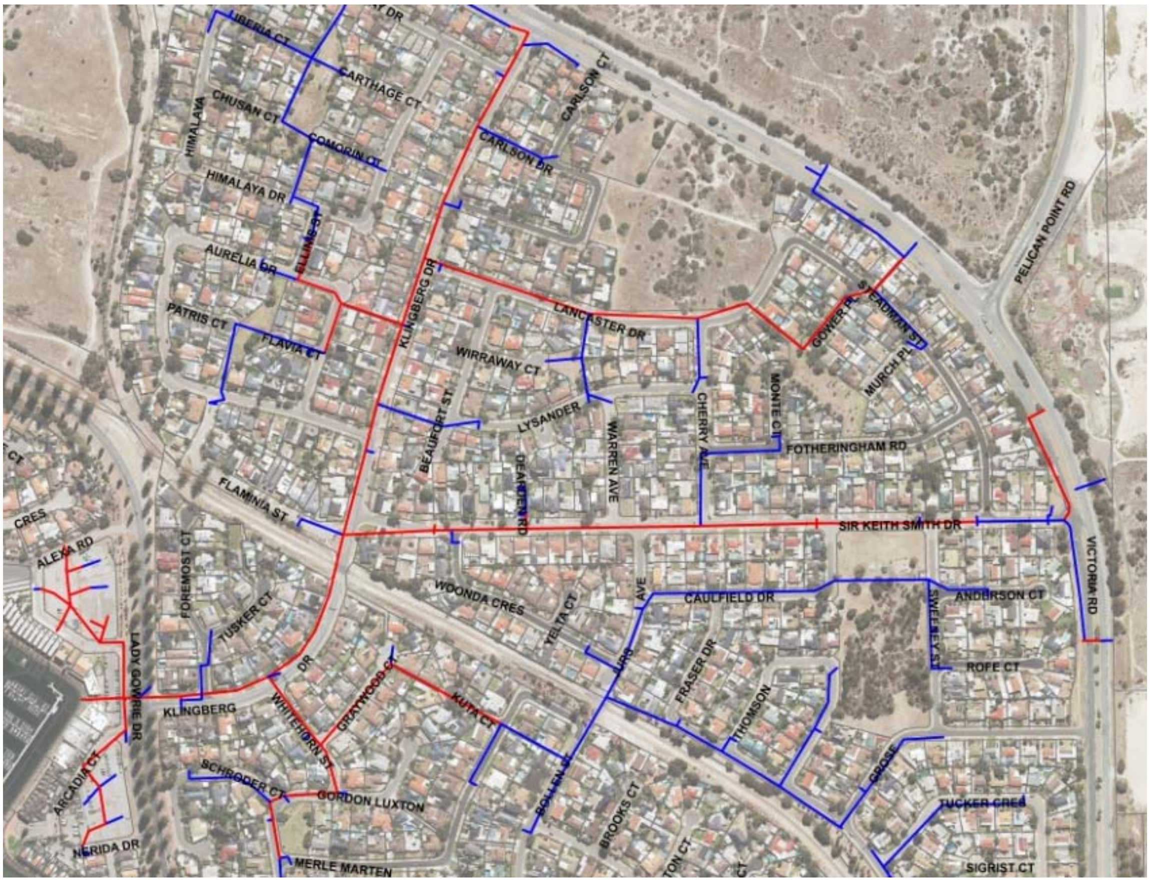


Figure 4.5—Drains Below Design 'Average' Tide Cycle (red), Klingberg Drive Catchment

The remaining gravity drainage outfalls on the Peninsula are not expected to be adversely impacted by sea level rise, as the invert levels of these drainage systems are predominantly situated above the predicted peak Design "Average' Tide receiving water levels.

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 Average Recurrence Interval (ARI).

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 are related to 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 Lefevre Peninsula, using the floodplain mapping results for the ultimate development scenario with existing 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 damage as a result of inundation.

Table 4.11—Assumed 'Improved Values' of Flood Affected Properties

Property Category	Improved Value
Residential	$185,000
Commercial – Office	$256,500
Commercial – Retail	$307,500
Industrial	$577,500

The flood depth at the centroid of each property was determined for the 5, 10, 20, 50 and 100 year ARI floodplain extents, falling into the following ranges:

- 0 - 0.1m;
- 0.1 – 0.15m;
- 0.15 – 0.25m;
- 0.25 – 0.5m;
- 0.5 – 1.0m;
- 1.0 – 1.5m; and
- 1.5 – 2.5m.

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

- Residential – Floor level 150 mm above the property centroid DTM level; and
- Commercial/Industrial – Floor level at the property centroid 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 4.12.

Table 4.12—Flood Damage Costs by 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	1.5 - 2.5
Residential	$3,885	$5,920	$51,060	$62,160	$76,590	$102,675	$170,940
Commercial – Office	$84,645	$106,191	$106,191	$129,276	$159,287	$212,382	$355,509
Commercial – Retail	$134,685	$169,740	$169,740	$575,640	$936,953	$1,628,520	$2,696,775
Industrial	$210,210	$282,398	$282,398	$604,065	$852,390	$1,261,838	$1,974,473

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 the aerial photography. The results of the analysis of the number of inundated properties for each ARI and depth range are shown in Table 4.13.

Table 4.13—Residential Damages, Ultimate Development / Existing Drainage Scenario

ARI (years)	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	
5	354	52	48	2	0	0	$4,258,330
10	408	94	63	22	0	0	$6,725,860
20	619	130	157	51	2	0	$14,514,175
50	960	178	234	164	6	1	$27,487,855
100	1180	262	326	269	24	1	$41,442,775

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 the aerial photography. The results of the analysis of the number of inundated commercial/industrial properties for each ARI and depth range are shown in Table 4.14, Table 4.15 and Table 4.16.

Table 4.14—Commercial - Office Damages, Ultimate Development / Existing Drainage Scenario

ARI (years)	No. of Commercial – 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	
5	10	0	4	1	0	0	$1,400,490
10	12	2	3	2	0	0	$1,805,247
20	15	5	4	4	0	0	$2,742,498
50	24	2	7	5	0	0	$3,633,579
100	28	4	5	9	0	0	$4,489,263

Table 4.15—Commercial - Retail Damages, Ultimate Development / Existing Drainage Scenario

ARI (years)	No. of Commercial – 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	
5	12	0	3	0	0	0	$2,125,440
10	16	1	1	2	0	0	$3,645,720
20	18	2	1	2	0	0	$4,084,830
50	18	5	1	2	0	0	$4,594,050
100	18	5	2	3	0	0	$5,339,430

Table 4.16—Industrial Damages, Ultimate Development / Existing Drainage Scenario

ARI (years)	No. of Commercial – 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	
5	1	0	0	0	0	0	$210,210
10	1	0	0	0	0	0	$210,210
20	6	2	0	0	0	0	$1,826,056
50	9	6	0	1	0	0	$4,190,343
100	11	1	9	1	0	0	$5,740,351

4.7.5 Summary of Total Damages

The total damages for the ultimate development scenario with existing drainage infrastructure are summarised in Table 4.17, and have been presented on a catchment basis in Table 4.18.

Table 4.17—Total Damages, Ultimate Development / Existing Drainage Scenario

ARI (years)	Residential	Commercial - Office	Commercial - Retail	Industrial	Total
5	$4,258,330	$1,400,490	$2,125,440	$210,210	$7,994,470
10	$6,725,860	$1,805,247	$3,645,720	$210,210	$12,387,037
20	$14,514,175	$2,742,498	$4,084,830	$1,826,056	$23,167,559
50	$27,487,855	$3,633,579	$4,594,050	$4,190,343	$39,905,827
100	$41,442,775	$4,489,263	$5,339,430	$5,740,351	$57,011,819

Table 4.18—Total Damages per Catchment, Ultimate Development / Existing Drainage Scenario

Catchment	Total Damages Estimate per Catchment				
	5yr	10yr	20yr	50yr	100yr
Lulu	$1,120,090	$2,378,865	$3,937,847	$6,525,972	$9,844,290
Hargrave Street	$1,186,235	$1,706,085	$3,654,092	$6,755,250	$9,706,893
Taperoo Shore	$370,185	$803,455	$2,424,580	$4,086,165	$5,332,781
Mersey Road	$535,310	$1,034,260	$2,078,585	$3,555,080	$5,207,907
Carlisle Street	$701,735	$1,401,525	$1,995,865	$3,806,873	$5,101,050
Semaphore Road	$1,503,691	$1,735,212	$2,602,363	$3,590,437	$4,697,284
Hart Street	$308,210	$405,705	$1,011,040	$2,314,615	$3,657,580
Centre Street	$943,472	$1,024,222	$1,719,954	$2,322,326	$3,253,310
Largs Bay Shore	$314,045	$421,061	$874,176	$1,450,304	$2,309,873
Largs North Shore	$390,265	$471,850	$960,300	$1,027,405	$1,508,861
Hamilton Avenue	$105,635	$211,640	$414,215	$962,000	$1,417,470
Semaphore Shore	$111,555	$213,775	$403,400	$1,048,515	$1,374,855
North Haven Mar.	$80,290	$133,385	$205,720	$872,968	$1,191,538
Jetty Road	$172,791	$185,926	$289,896	$314,686	$656,301
Klingberg Drive	$19,425	$38,850	$83,805	$297,110	$481,185
Outer Harbour	$0	$0	$210,210	$420,420	$424,305
Osborne Soakage	$11,655	$25,345	$80,290	$243,275	$409,590
Osborne Road	$13,690	$66,600	$91,945	$175,380	$299,700
New Port Quays	$106,191	$129,276	$129,276	$133,161	$133,161
Cultural Park	$0	$0	$0	$3,885	$3,885
Largs North Mar.	$0	$0	$0	$0	$0
TOTAL	**$7,994,470**	**$12,387,037**	**$23,167,559**	**$39,905,827**	**$57,011,819**

4.8 Flood Mitigation Strategies

Flood mitigation strategies for each of the major catchments 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, such as retaining existing major pump stations that are within their service life, and where possible utilising the existing rising mains to the Port River.

In accordance with the Plan's objectives outlined in Section 3.2, these strategies have aspired to achieve no above floor inundation of properties for all events up to and including the 100 year ARI storm. However where this is not practically achievable, a 20 year ARI standard has been sought. Floor level survey (not part of this study) would be required to confirm whether these performance standards have been achieved for all properties.

An overview of all upgrades is shown in Figure 4.6, and each of the proposed works packages have been assigned a Project ID which corresponds to the project location. A1 format floodplain maps have been prepared for each ARI to demonstrate the performance of the flood mitigation strategies, and are presented in Appendix C. None of the flood mitigation strategies propose to direct urban stormwater runoff to Mutton Cove, which is consistent with the Plan's objective to maintain the status quo of no urban stormwater ingress to Mutton Cove to protect the biodiversity of the samphire and mangrove woodland habitat.

Budget cost estimates have also 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; and
- 20% for contingencies on construction.

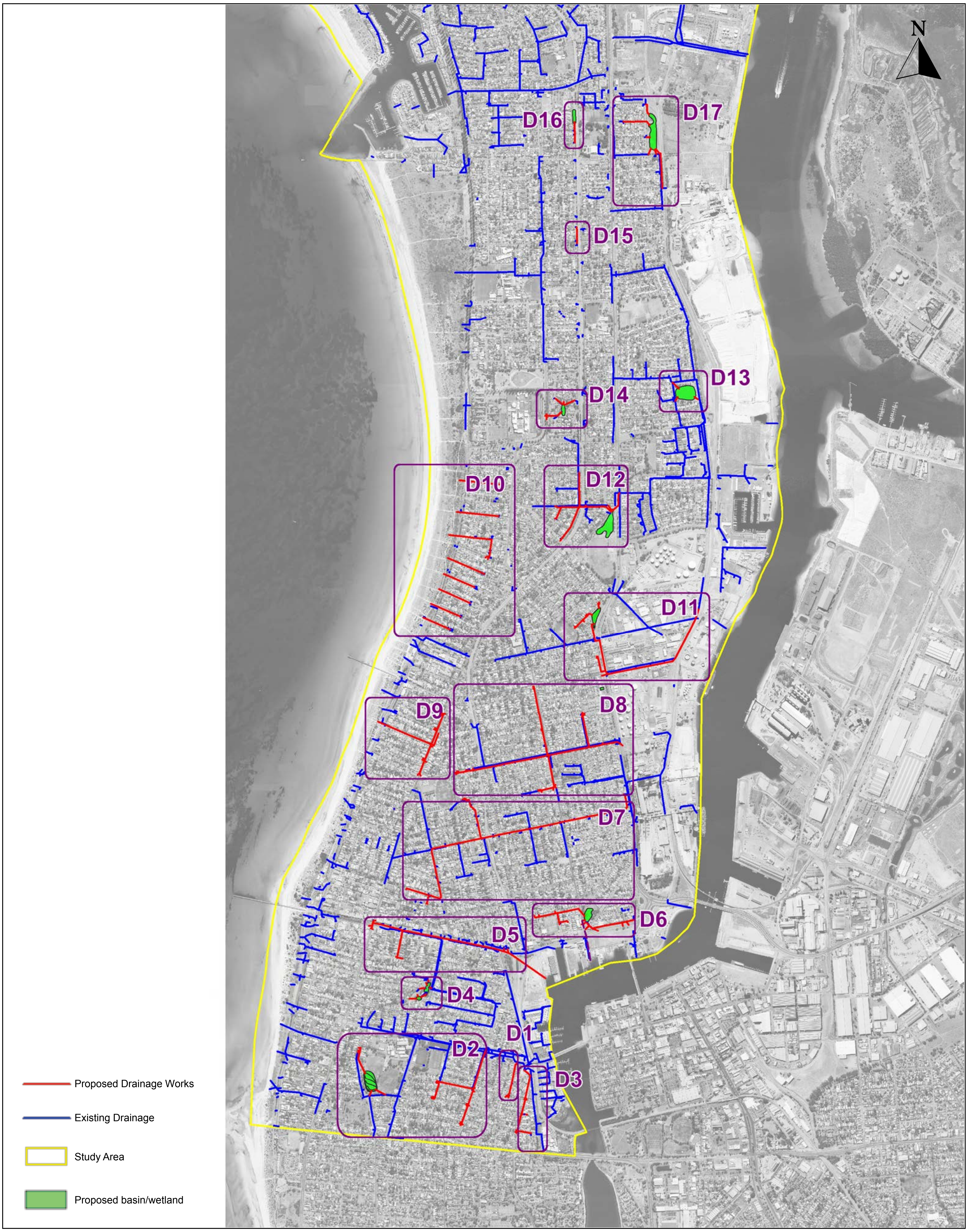
These cost estimates are based upon historical cost information and experience, and do not allow for latent or market conditions (ie. competition, escalation) or land acquisition.

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 suppliers for proprietary items such as packaged pump stations and Gross Pollutant Traps. Nominal allowances have been made for the augmentation of power supply to facilitate the new pump stations, based on similar applications at other locations, however we note that these costs are subject to change as they are dependent upon SA Power Networks pricing at the time of the works.

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 of turf areas and the establishment of riparian plantings associated with WSUD elements.



Data Sources:
City of Port Adelaide Enfield (Aerial Photograph)
Southfront (Drainage Data)

southfront

Lefevre Peninsula
Stormwater Management Plan

Proposed Flood Mitigation Works
Overview Plan
Figure 4.6

4.8.1 Hart Street Catchment

D1: Deslandes Street – Drainage

Replacement of the Deslandes Street drain is recommended to relieve roadway ponding and property inundation in the Deslandes/Mary Street intersection in events greater than the 5 year ARI. Replacement of the existing 300 mm diameter pipe with a larger drain (ranging up to 675 mm diameter) is recommended from the intersection with Mary Street to the Hart Street trunk drain via Deslandes Street.

Construction drawings for these works have been completed. The cost for these works is estimated to be $340,000.

D2: Carlisle Street – Drainage and Nazar Reserve – Detention

In order to reduce property inundation and the likelihood of above floor flooding in the Harvey Street and Maud Street 'sag' points, and improve the drainage capacity of the Carlisle Street drain, a new drain is recommended to extend from the Hart Street trunk drain to Pelham Street. Lateral drains are recommended to extend into the Maud Street and Harvey Street sag points. The new drain is to range up to a 750 mm diameter pipe at the downstream end.

In order to increase the capacity of the existing Swan Terrace drain, and reduce excessive surface flows from Swan Terrace spilling into Harvey Street and Maud Street, construction of a detention basin within Nazar Reserve is proposed (refer Figure 4.7). A detention basin will detain floodwaters, relieve the overcapacity Swan Terrace drain, and also allow construction of a new drain within Robin Road in order to reduce inundation and above floor level flooding of properties in that vicinity.

Figure 4.7—Proposed location of Nazar Reserve Detention Basin

The basin works are to be integrated into Nazar Reserve such that the impact (both visually and for usability) is minimised. Basin side slopes are to be gentle (maximum 1V:5H) with a maximum depth of 1.2 metres below natural surface at the southern end. The basin shall be sized to detain flows up to the 100 year ARI event. In minor rainfall events (less than 1 year ARI) stormwater flows are proposed to be contained within a low flow swale such that the entire floor of the basin is not inundated and the reserve remains available for recreation.

Modelling indicates that these works are effective at reducing property inundation in the majority of the flood prone areas of Maud Street, Harvey Street, Swan Terrace and Robin Road up to the 20 year ARI event.

Construction drawings for the Harvey, Maud and Carlisle Street drainage works have been completed. Concept drawings of the proposed Nazar Reserve basin are included in Appendix D. The cost for the Carlisle Street drainage works is estimated to be $970,000. The Nazar Reserve basin component is estimated to be a further $745,000.

D3: Goldsworthy Road – Drainage
In order to reduce roadway ponding and property inundation at the Old Pelham Road and Goldsworthy Street intersection, a new drain is proposed from this intersection to the Hart Street pump station via Goldsworthy Road and Warrawee Road. This will relieve the Causeway Road drain which modelling indicates would currently surcharge in Old Pelham Street in events greater than the 5 year ARI. The drain size is to range up to a 750 mm diameter pipe and connect directly into the Hart Street pump station.

Modelling indicates that the majority of properties shown to experience stormwater inundation within the Hart Street catchment in the existing scenario will experience a reduction of stormwater ingress up to the 20 year ARI event (the calculated capacity of the Hart Street pump station). The cost for these works is estimated to be $580,000.

4.8.2 Carlisle Street Catchment

Semaphore Road – Drainage
In order to reduce inflows to the Carlisle Street pump station and improve overall drainage performance in the catchment, a diversion of the Semaphore Road drain is recommended. A diversion of the drain at the corner of Semaphore Road and Swan Terrace will reduce the catchment contributing to the pump station by up to 25%.

An extension of the drain up to the intersection of Semaphore Road and Military Road is also recommended to reduce the extent of inundation of nearby commercial properties up to the 20 year ARI event, as well as extending the drain into Turton Street to complement an existing soakage system in Brown Street. A detailed description of the proposed Semaphore Road drain and associated cost estimate is presented in Section 4.8.3.

D4: Phillips Reserve – Detention
A detention basin is recommended within Phillips Reserve (refer Figure 4.8 and Figure 4.9) in order to reduce peak flows from the upstream catchment entering the vulnerable low-lying areas of Swan Terrace, Mellor Road and Graham Street. Surrounding minor lateral drains are to be diverted into the basin, with an outlet to the basin to be connected into the existing Swan Terrace drain. The basin is to be approximately 1 metre deep with a maximum detention volume of approximately 1,500 m^3. The modelling reports significant improvements in drainage capacity in the 20, 50 and 100 year ARI events as a result of these upgrades. Some removal of

trees, particularly in the centre of the reserve, will likely be required to facilitate these works. A playground will also require relocation.

Figure 4.8—Artist's impression of the proposed basin at Phillips Reserve

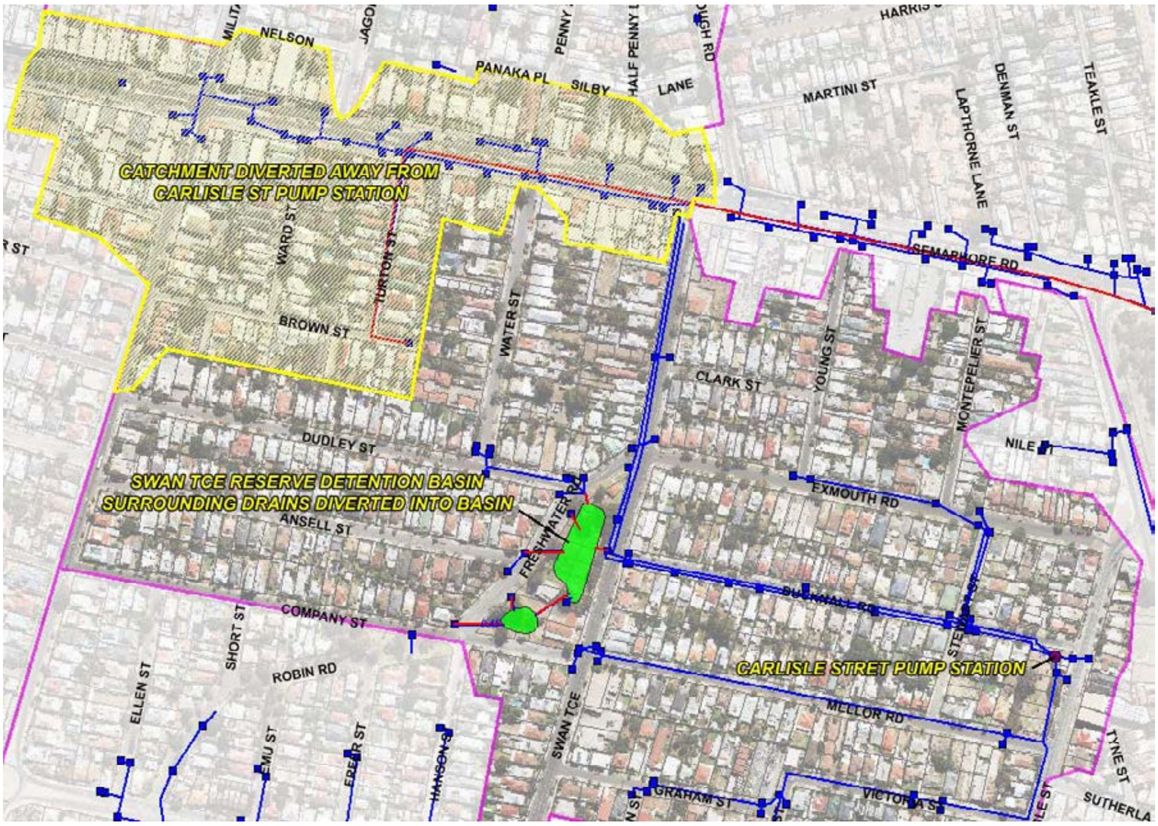


Figure 4.9—Proposed Carlisle Street Drainage Improvements

The total cost for these works (not including the Semaphore Road drain) is estimated to be $305,000.

4.8.3 Semaphore Road East Catchment

D5: Semaphore Road – Drainage
As described in Section 4.8.2, a diversion of the Semaphore Road drain is recommended to divert flows away from the Carlisle Street pump station. A new trunk drain is recommended along Semaphore Road to convey these flows to the Port River outlet and to improve the overall drainage capacity of the Semaphore Road catchment, where floodplain mapping indicates that stormwater ingress to private properties is prevalent in the vicinity of Teakle Street and the Outer Harbour train line, Semaphore Road/Military Road intersection and Turton Road/Brown Street.

A new Council drainage easement will be required from Semaphore Road to the Port River (indicative alignment shown). The existing drainage to the west of the railway is to be 'disconnected' from the existing drainage to the east, thus improving drainage capacity of the Mead Street gravity drainage system. Pipe sizes within Semaphore Road are to range up to 1050 mm diameter from the system outlet.

The cost for these works is estimated to be $1,980,000 which includes the drain extension to Military Road and Turton Street. A concept plan of the drain is shown in Appendix D.

Floodplain mapping results show a large reduction in property inundation in the low-lying portion of the Carlisle Street catchment as a result of these diversion works. These works have likely increased the capacity of the Carlisle Street pump station from a 5– 10 year ARI capacity to a 20 – 50 year ARI capacity system.

D6: Hughes Street – Drainage and Naval Reserve - Detention, Pump Station (Conversion from Gravity Outfall)
A large portion of the Semaphore East catchment is low-lying with significant areas of residential development that is below 2.23 mAHD; the highest recorded tide level in the Port River. It is recommended that these sub-catchments be provided with a pumped discharge in order to protect low-lying properties from sea water ingress via the existing gravity drainage system. This area is also at higher potential risk from climate change induced sea level rise.

To reduce the required size of the proposed packaged pump station, construction of a detention basin is proposed at the Birkenhead Naval Reserve at the corner of Fletcher Road and Heath Street is proposed (refer Figure 4.10). New underground drainage in Hughes Street, Close Street and Semaphore Road is to be directed into the basin. The assumed depth of the basin is 0.4 mAHD (1.2 – 1.4 metres deep from existing surface), with a detention volume of approximately 5,500 m^3. The modelled pump rate was 300 L/s. The basin footprint could potentially be reduced with a larger pump rate, or vice-versa for a reduced pump size. This would be determined in detailed design.

Floodplain mapping demonstrates a reduction of the extent of depth of ponding in this catchment in all modelled events as a result of these works. The total cost for these works is estimated to be $1,825,000.

Figure 4.10—Artist’s Impression of Proposed Basin at Birkenhead Naval Reserve

4.8.4 Hargrave Street Catchment

D7: Hargrave Street – Lateral Drainage

The new Hargrave Street trunk drain was modelled based on construction drawings provided by Council (with the final stages of the new drain constructed in 2016). The drain extends from the new Hargrave Street pump station on Victoria Road to Woolnough Road and ranges from a 1050 mm diameter pipe at Woolnough Road to a 1500 mm diameter pipe at the pump station on Victoria Road.

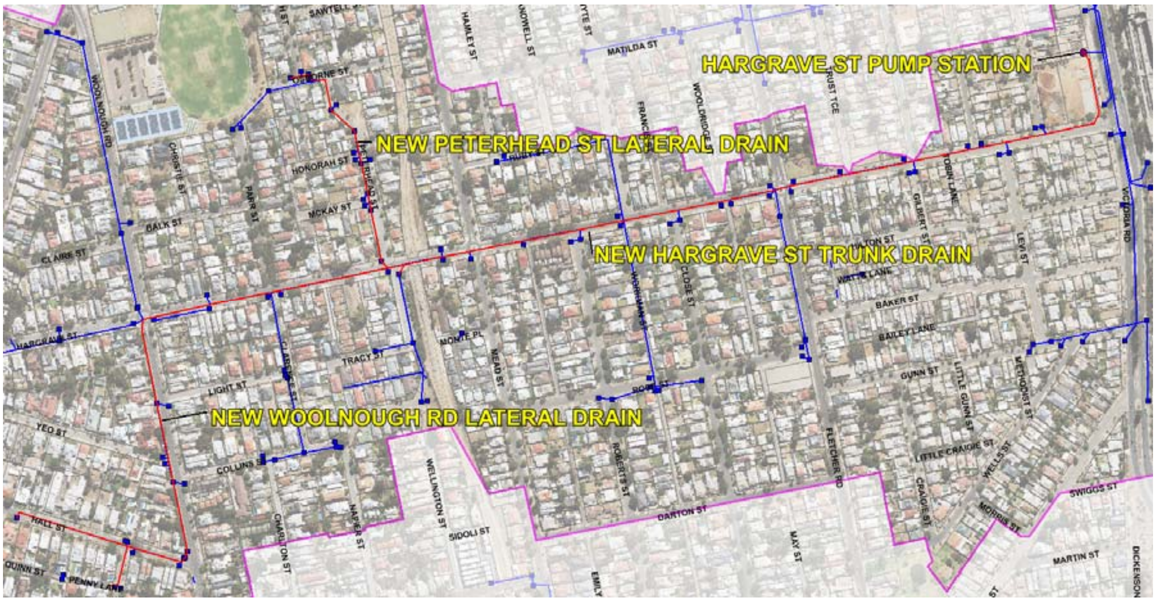


Figure 4.11—Proposed Hargrave Street Lateral Drain Improvements

Lateral drain upgrades were also modelled in Peterhead Street and Woolnough Road (to Penny Lane). These upgrades were based on preliminary design plans for the replacement of these drains. Drain sizes in Peterhead Street and Woolnough Road range up to a 750 mm diameter pipe. Floodplain modelling results indicate that a significant improvement in drainage performance will be realised as a result of these works for all storm events modelled. The total cost for these lateral drain works (not including the Hargrave Street trunk drain) is estimated to be $1,675,000.

4.8.5 Lulu Catchment

D8: Lulu – Drainage, Pump Station

A new pump station within the Lulu catchment and new trunk drain within Wills Street is recommended to reduce the number of flood affected properties in events greater than the 5 year ARI. The proposed new pump station would ideally be located on the vacant land at the intersection of Wills Street and Victoria Road. The new pump station is to have a maximum capacity of 2.5 m^3/s (equivalent of the 5 year ARI ultimate development flow from the catchment). A new 1200 mm diameter rising main will also be required from the new pump station to the Port River via Wills Street and Elder Road. The new pump station will include a Gross Pollutant Trap to treat stormwater flows prior to discharge to the Port River.

The trunk drain is to be upgraded from the proposed pump station on Victoria Road, along Wills Street as far west as the intersection with Joanna Street (to the west of the railway). Pipe sizes are to range up to a 1350 mm diameter pipe.

New lateral drains within Fletcher Road and Mary Street are also recommended as part of these works, together with a new drain linking the Matilda Street system to the new Wills Street trunk drain (via Fletcher Road). This will reduce private property inundation in the vicinity of Fletcher Road and Sanderson Street and relieve the capacity of the Walton Street stormwater system.

It should be noted that the existing Lulu pump station on Elder Road will also require refurbishment due to its current condition and age, as described in the *Lulu Pump Station Assessment* (Tonkin Consulting, 2014). As the contributing catchment will be significantly reduced due to the recently constructed Hargrave Street pump station and the proposed new pump station on Victoria Road, the Lulu pump station could potentially be refurbished to achieve a lower capacity than existing.

A benefit of constructing a new pump station on Victoria Road is that the existing Lulu pump station may remain operational during its construction period. Similarly, the new pump station on Victoria Road may remain operational during the refurbishment of the existing Lulu pump station, thereby maintaining a degree of flood protection for the catchment at all times.

The floodplain maps show a large reduction in property inundation and reduced likelihood of above floor flooding as a result of these proposed works, particularly in the vicinity of Alfred Street, Mary Street, Phyllis Terrace, Fletcher Road and Sanderson Street. The proposed works will complement the drainage works that have recently been undertaken in the adjacent Hargrave Street catchment.

The full extent of upgrades is shown in Appendix D. The cost estimate for these works is in the order of $14,235,000 which assumes an allowance of $500,000 for the provision of a new power supply to the proposed pump station on Victoria Road and an allowance of $1,000,000 for refurbishment of the existing Lulu pump station.

4.8.6 Largs Bay Shore Catchment

D9: Anthony Street – Drainage

An upgrade of the Anthony Street drain is recommended in order to increase its capacity and reduce overflows from Largs Bay Shore Catchment entering low-lying Peterhead Street within the Hargrave Street catchment. An extension of the drain along Military Road will also reduce the size of the contributing catchment at the intersection of Anthony Street and Military Road in order to reduce surface flows expected along Military Road in minor events. Lateral drains are to be extended to Kalgoorlie Road to the south and Musgrave Street to the north.

The existing drain is to be replaced with a drain ranging up to a 900 mm diameter pipe. The estimated cost for these works, including the drain extension in Military Road is $1,175,000.

4.8.7 Largs North Shore Catchment

D10: Largs North Shore – Conversion from Soakage System to Gravity Drainage

New gravity drains have been modelled for the many small catchments with trapped low points in the Largs North Shore catchment, currently drained via soakage systems. These new gravity drains systems are to generally be 200 to 300 metres long and will require deep excavation of up to 6 metres, partially through sand dunes in order to drain these sag points to the coast. It may be most appropriate to construct these drains using trenchless pipelaying techniques (eg. pipe jacking, micro-tunnelling). Each new gravity system will require a new coastal outlet.

Gravity drainage systems were inserted into the model at the following locations:

- Chester Street;
- Roslyn Street;
- Walcot Street;
- Afric Street;
- Persic Street;
- Magarey Street via Farringdon Street and Cheapside Street;
- Kybunga Terrace; and
- Koowarra Terrace.

Modelling indicates a significant reduction in flooding within the Largs North Shore sag valley in all modelled storm events. The total cost of these works for all streets is $2,975,000 and the pipelaying rates for these locations were increased to reflect the need for deep excavation in sandy soils and/or the use of trenchless pipelaying techniques. A concept plan for these drains is shown in Appendix D.

4.8.8 Jetty Road and Centre Street Catchments

D11: Warwick Street – Drainage, Detention

A new drain is proposed within Warwick Street, to assist in reducing the property inundation shown in floodplain mapping results for the 10 year ARI and greater. The drain is to be directed into a new detention basin in a small reserve between Victoria Road and Warwick Street, with all outflows redirected into a new outlet drain via Jetty Street. Redirecting the Warwick Street drain will relieve the existing Centre Street drain and increase its overall drainage performance for the remaining contributing catchment.

The proposed Warwick Street basin is to be approximately 1.5 metres deep (invert 1.6 mAHD) with a volume of approximately 4,000 m^3. The basin configuration shown will require the removal of a number of trees within the reserve.

A new drain is proposed from the Warwick Street reserve detention basin to a proposed pump station on Elder Road via Victoria Road and Jetty Street (described below). The Warwick Street reserve basin will reduce the required size of this new drain.

D11: Jetty Road – Drainage, Pump Station (Conversion from Gravity Outfall)
Jetty Road and Centre Street catchments are low-lying, with significant areas where the ground surface elevation is below 2.23 mAHD (the highest observed historical sea level at Outer Harbor). This low-lying area also extends south into the Lulu and Hargrave Street catchments. Due to its low-lying nature and susceptibility to high tides it is recommended these catchments be converted from gravity drain outlets to pump stations. This will ensure that the drainage system performs adequately during high tide conditions and will also serve to protect these low-lying areas from sea water ingress via the existing gravity drainage system.

The new pump station, to be located on Elder Road in the vicinity of London Court, is to combine both Jetty Road and Centre Street catchments to a single pump station outlet. The estimated maximum pump rate was calculated to be 3.0 m^3/s (the modelled ultimate development 5 year ARI flow entering the proposed pump station). At this pump rate, surface ponding is generally kept within the roadway reserve in events up to the 20 year ARI, with a moderate reduction in floodplain extent also evident in the 50 and 100 year ARI events. The new pump station will include a Gross Pollutant Trap to treat stormwater flows prior to discharge to the Port River.

Limited space in Elder Road/London Court will likely necessitate the acquisition of a portion of land from the adjacent large industrial properties. The concept plan of the works shown in Appendix D shows an indicative location for the new pump station. The final location will depend upon land suitability and availability, to be determined in detailed design. A new drain from the proposed Warwick Street reserve basin to the pump station is recommended, as described above. The drain is to range in size up to a 1350 mm diameter pipe.

The total cost for these works is estimated to be $13,210,000 including the pump station, and detention basin works within the Warwick Street reserve. This budget estimate assumes an allowance of $500,000 for the provision of a new power supply to the proposed pump station on Elder Road.

An alternative option was considered for this catchment, which would involve directing the Centre Street drain to a new detention basin within Almond Tree Flat Reserve. The proposed Warwick Street drain would also be directed into this basin. This would result in pipe diameters reducing by roughly two sizes between Centre Street and the proposed pump station on Elder Road, as well as a reduced pump rate from 3 m^3/s to 2.5 m^3/s. However Council staff have advised that this option is not favoured due to the arrangements in place to use Almond Tree Flat Reserve solely for recreation, and therefore it has not been considered further in this Plan.

4.8.9 Mersey Road Catchment

D12: Kolapore Avenue – Drainage and Carnarvon Reserve – Detention
Drainage improvements in Kolapore Avenue and the Carnarvon Terrace Reserve are proposed in order to reduce the inundation of private property and likelihood of above floor flooding in the

area west of the Outer Harbour train line in events greater than the 5 year ARI. Drainage improvements are proposed to include a new stormwater drain in Kolapore Avenue ranging up to a 750 mm diameter pipe. New lateral drains are also recommended in Railway Terrace (north and south of Kolapore Avenue) and Brenda Terrace.

The existing basin in Carnarvon Reserve (shown in Figure 4.12) is to be enlarged to the extent shown in the concept plan in Appendix D. Modelling assumed an invert level of 1.35 mAHD (approximately 1.2 – 1.5 metres deep from existing natural surface, or 0.2 metres deeper than the existing basin invert). This will provide a detention storage of approximately 10,000 m^3. A new 450 mm diameter outlet pipe from Carnarvon Reserve to the eastern side of Victoria Road is also required to drain the basin.

Floodplain mapping results show significant reduction in the floodplain extent for the surrounding area in the 5, 10, 20 and 50 year ARI events, with a minor reduction in the 100 year ARI event. Detention of stormwater in the Carnarvon Reserve would also improve the capacity of downstream drains and result in a reduction of surface flows downstream of Victoria Road (in Wollowra Crescent and Paluma Street) for all modelled events.

Figure 4.12—Existing Carnarvon Reserve Basin

The cost for these works is estimated to be $1,310,000. Concept plans of these upgrades is shown in Appendix D. These works could potentially be coupled with landscape and WSUD activities to improve the reserve's amenity and water quality benefits, as outlined in Section 5.7.

D13: Aldinga Street Reserve – Detention
Aldinga Street Reserve is a large, underutilised reserve adjacent to a number of large diameter drains which feed into the Mersey Road pump station (refer Figure 4.13). It is proposed that this reserve be used to relieve the pump station in large storm events by providing an area of detention storage once the pump station is operating at capacity.

This will eliminate any requirement for further capacity upgrades of the Mersey Road pump station. Flood modelling of the proposed basin in large events such as the 20, 50 and 100 year ARI shows that the number of properties affected by stormwater inundation would be significantly reduced.

The proposed invert of the basin of 0.5 mAHD is above the invert of adjacent drains. Stormwater flows will only spill into the basin via surcharge, once the level of the Hydraulic Grade Line (HGL) within the drain exceeds that of the basin inlet pipe. Floodplain mapping indicates that the depth of water in the basin during a 5 year ARI event would be less than 100 mm, while a depth of 1.5 metres is expected for the 100 year ARI. A one-way flap gate is proposed to be fitted to the basin outlet so that flows can be discharged back into the Mersey Road drainage system once the HGL levels in that system allow.

Figure 4.13—Existing Aldinga Street Reserve; Mersey Road catchment

These flood mitigation works are to be constructed in conjunction with a number of water quality improvement elements within the basin footprint. These elements are discussed in Section 5.7.

The cost for these works, excluding the WSUD or water reuse elements, is estimated to be $940,000. A concept plan of the proposed Aldinga Street reserve works is shown in Appendix D.

4.8.10 Taperoo Shore Catchment

D14: Charon Reserve – Detention, Pump Station

A detention basin and new packaged pump station is proposed to be constructed at Charon Reserve in order to improve the drainage performance for this catchment, a trapped low point, that is currently drained exclusively via soakage systems within the reserve (refer Figure 4.14). A number of nearby soakage systems on Charon Drive, Lawhill Court, Ormiston Court and Military Road are also to be connected to the new basin via new underground drainage.

Figure 4.14—Proposed location of Charon Reserve Detention Basin

The proposed basin is to have a depth of 1.5 metres with a total detention volume of approximately 3,000 m^3. A packaged pump station with maximum pump rate of 150 L/s is recommended within the reserve in order to drain the basin. Should Council wish to lessen the size (and thus impact) of the basin in the reserve, an increased pump rate could be chosen.

The packaged pump station will require construction of a new rising main to discharge into the sand dunes adjacent to Lady Gowrie Drive via Lawhill Court, Gorgon Street and Roy Marten Park. The rising main is to be 300 mm diameter and approximately 705 metres long. Modelling indicates that the proposed works will result in a significant reduction in the floodplain extent in 5, 10, 20 and 50 year ARI storms.

For modelling purposes, Council has indicated that drainage of the Police Barracks is self-contained up to the 100 year ARI event and thus these catchments were removed from the model. It was also assumed that runoff from future development at Fort Largs will not contribute to the Charon Reserve. Any development in this area will be required to discharge to the west of the Fort Largs site, which will likely take the form of a new coastal outlet.

The cost of these works were estimated to be $1,090,000. A concept plan is shown in Appendix D.

D15: Midlunga Railway Station – Pump Station
A new packaged pump station is proposed to be constructed in the vicinity of the Midlunga Railway Station in order to reduce property inundation and potential above floor flooding at the trapped low point at the corner of Railway Terrace and Moldavia Walk in events greater than the 5 year ARI. Modelling indicates that this trapped low point receives overflows from the under capacity Military Road drainage system and existing Midlunga Station Pump Station. It is therefore recommended to construct a new rising main to discharge flows from the new packaged pump station. The rising main is to be redirected and extended the full length of Moldavia Walk, connecting into an existing system at the intersection of Moldavia Walk and Lady Gowrie Drive, discharging into the adjacent sand dunes (approximately 720 metres).

The estimated pump rate of 400 L/s will provide the catchment with flood protection for up to the 20 year ARI event (currently less than 5 year ARI) and will require a new 500 mm diameter rising main. The cost of these works is estimated to be approximately $1,185,000.

D16: Railway Terrace – Detention, Pump Station
A retention basin is proposed for the vacant piece of land north of the Railway Terrace / Hutley Road intersection, adjacent to the railway. This retention basin shall discharge stormwater via infiltration. It is recommended that a number of nearby soakage systems on Railway Terrace be connected via overflow pipes into the new basin. Modelling indicates that the level of flood protection to adjacent properties will increase from less than the 5 year ARI to a 20 – 50 year ARI as a result of these works.

For modelling purposes the basin size has been maximised based on the amount of assumed available land. An assumed invert of 1.3 mAHD (1.5 – 2 metres deep), with 1V:3H side slopes and storage of approximately 2500 m^3 was assumed. A basin with such steep side slopes will likely require fencing off such that access is restricted to the public.

The cost of these works is estimated to be $285,000. A concept drawing of the proposed infiltration basin is shown in Appendix D.

To further increase the standard of flood protection for this catchment, a packaged pump station could be installed at the proposed basin site, with a rising main discharging into the Osborne Terrace drain to the north. The contributing catchment could also be extended to Marmora Terrace which would reduce ponding shown to occur in events up to and beyond the 5 year ARI.

4.8.11 Hamilton Avenue Catchment

D17: Estella Street - Detention
A detention basin is proposed to be constructed on the vacant land adjacent to Estella Street to provide a level of flood storage within the Hamilton Avenue catchment (refer Figure 4.15). A new 600 mm diameter balance pipe from the proposed new basin to Hamilton Avenue pump station (via Mersey Road) will allow for excessive flows at the pump station to spill into the new basin, rather than flooding into private property. Minor drainage works will also be required to re-direct flows from the surrounding streets of Marmora Terrace, Poole Street, Wheadon Street and Brookman Street to the proposed detention basin.

Figure 4.15—Proposed location of Detention Basin at Estella Street

These works are based on recommendations from the previous *Hamilton Road Drainage Study* (Southfront, 2015). The cost of these works is estimated to be $840,000. A concept plan is shown in Appendix D.

4.8.12 Non-structural Measures

To complement the proposed structural options, a number of non-structural flood mitigation options are also proposed. 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.

D18: Community Flood Response and Preparedness – SES Community FloodSafe Program
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 State Emergency Service 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 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;

- 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. Council may also elect to make the floodplain mapping of Lefevre Peninsula publicly available via Council's website, along with advice to residents on measures they can take to reduce their flood risk and steps to preparing a Personal Flood Action Plan.

Community Flood Response and Preparedness – Pump Station Telemetry
To further assist in preparedness for properties that are prone to inundation during large ARI rainfall events, it is recommended that Council consider utilising the pump station telemetry to generate catchment-specific flood warning messages. These messages could be displayed on Council's website and/or distributed to stakeholders via SMS or email. To achieve this functionality Council would be required to implement a more sophisticated and fully integrated Supervisory Control and Data Acquisition (SCADA) system for the pump stations than exists at present. The design phase for the proposed Lulu and Jetty Road pump stations will provide an opportunity to establish the requirements for such a system.

Development Controls – Floor Levels
It is recommended that Council continue to ensure that all new development on the Lefevre Peninsula has a floor level that provides at least 200mm freeboard above the 100 year ARI floodplain, as depicted on the floodplain maps of the area, consistent with Council's Drainage Infrastructure Asset Management Plan.

The finished floor levels 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.

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 4.19—Residential Damages, Ultimate Development / Upgrades Scenario

ARI (years)	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	
5	168	16	7	0	0	0	$1,104,820
10	254	26	21	1	0	0	$2,275,130
20	400	39	49	12	0	0	$5,032,740
50	703	118	120	45	4	0	$12,660,475
100	1076	194	206	116	4	1	$23,466,695

Table 4.20—Commercial - Office Damages, Ultimate Development / Upgrades Scenario

ARI (years)	No. of Commercial – 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	
5	4	0	0	0	0	0	$338,580
10	7	1	0	0	0	0	$698,706
20	14	3	1	0	0	0	$1,609,794
50	25	4	3	1	0	0	$2,988,738
100	27	6	8	2	0	0	$4,030,641

Table 4.21—Commercial - Retail Damages, Ultimate Development / Upgrades Scenario

ARI (years)	No. of Commercial – 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	
5	2	0	0	0	0	0	$269,370
10	2	1	0	0	0	0	$439,110
20	11	1	0	0	0	0	$1,651,275
50	16	2	2	0	0	0	$2,833,920
100	18	3	5	0	0	0	$3,782,250

Table 4.22—Industrial Damages, Ultimate Development / Upgrades Scenario

ARI (years)	No. of Commercial – 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	
5	0	0	0	0	0	0	$0
10	0	0	0	0	0	0	$0
20	4	0	0	0	0	0	$840,840
50	6	1	1	0	0	0	$1,826,056
100	4	6	1	1	0	0	$3,421,691

Table 4.23— Total Damages, Ultimate Development / Upgrades Scenario

ARI (years)	Residential	Commercial - Office	Commercial - Retail	Industrial	Total
5	$1,104,820	$338,580	$269,370	$0	$1,712,770
10	$2,275,130	$698,706	$439,110	$0	$3,412,946
20	$5,032,740	$1,609,794	$1,651,275	$840,840	$9,134,649
50	$12,660,475	$2,988,738	$2,833,920	$1,826,056	$20,309,189
100	$23,466,695	$4,030,641	$3,782,250	$3,421,691	$34,701,277

The total reduction in direct tangible damages when comparing the future scenario to the existing scenario is shown in Table 4.24.

Table 4.24—Potential Reduction to Damages

ARI (years)	Existing Damages	Future Damages	Reduction in Damages	% Reduction in Damages
5	$7,994,470	$1,712,770	$6,281,700	79%
10	$12,387,037	$3,412,946	$8,974,091	72%
20	$23,167,559	$9,134,649	$14,032,910	61%
50	$39,905,827	$20,309,189	$19,596,638	49%
100	$57,011,819	$34,701,277	$22,310,542	39%

A breakdown of the reduction of damages by catchment is shown in Table 4.25. It should be noted that in four catchments there is a minor increase in damages shown for the ultimate development scenario with the proposed upgrades in place. This is the effect of both increased rainfall intensity based on the climate change rainfall predictions and increased sea level at drain outlets for this scenario. Damages show the increase is relatively minor compared to overall damages over the entire Study Area.

Table 4.25—Reduction in Damages by Catchment

Catchment	Total Damages Estimate and Reduction per Catchment ($000)									
	5yr		10yr		20yr		50yr		100	
	Est.	Red.	Est.	Red.	Est.	Red.	Est.	Red.	Est.	Red.
Lulu	$80	$1,040	$245	$2,134	$580	$3,358	$1,696	$4,830	$3,307	$6,538
Hargrave Street	$317	$869	$817	$889	$1,589	$2,065	$3,850	$2,905	$6,223	$3,484
Taperoo Shore	$72	$298	$292	$512	$846	$1,578	$2,248	$1,838	$3,473	$1,859
Mersey Road	$323	$213	$538	$497	$779	$1,300	$2,016	$1,539	$3,707	$1,501
Carlisle Street	$51	$651	$170	$1,231	$813	$1,183	$2,318	$1,489	$4,468	$633
Semaphore Road	$196	$1,308	$322	$1,413	$1,464	$1,138	$2,343	$1,248	$3,144	$1,553
Hart Street	$109	$199	$166	$240	$410	$601	$1,054	$1,260	$2,276	$1,382
Centre Street	$232	$711	$267	$757	$532	$1,188	$737	$1,585	$1,256	$1,998
Largs Bay Shore	$31	$283	$43	$378	$204	$670	$405	$1,045	$775	$1,535
Largs North Shore	$175	$216	$188	$284	$247	$713	$331	$696	$514	$995
Hamilton Avenue	$4	$102	$37	$175	$291	$123	$627	$335	$1,121	$296
Semaphore Shore	$19	$92	$129	$84	$200	$204	$697	$351	$1,105	$270
North Haven Mar.	$76	$4	$133	$0	$408	-$202	$691	$182	$995	$196
Jetty Road	$4	$169	$8	$178	$112	$178	$283	$32	$422	$234
Klingberg Drive	$12	$8	$31	$8	$68	$16	$203	$94	$484	-$3
Outer Harbour	$0	$0	$0	$0	$420	-$210	$420	$0	$496	-$72
Osborne Soakage	$8	$4	$16	$10	$25	$55	$183	$61	$368	$42
Osborne Road	$4	$10	$12	$55	$39	$53	$119	$56	$454	-$154
New Port Quays	$0	$106	$0	$129	$106	$23	$89	$45	$110	$23
Cultural Park	$0	$0	$0	$0	$0	$0	$4	$0	$4	$0
Largs North Mar.	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0

The number of properties shown to experience inundation of more than 50 mm in the future scenario is presented in Table 4.26. A direct comparison by catchment can be made in Table 4.8 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 future scenario would be required to confirm that the minimum performance standard has been achieved for no above floor flooding up to and including the 20 year ARI storm event.

Table 4.26—Property Inundation by ARI; Ultimate Development, Proposed Infrastructure

Catchment	Number of properties inundated > 50 mm				
	5yr	10yr	20yr	50yr	100yr
Hargrave Street	17	27	55	107	151
Lulu	3	4	13	49	115
Mersey Road	6	11	22	58	102
Taperoo Shore	12	17	25	57	96
Carlisle Street	2	5	14	44	79
Hart Street	4	6	10	37	78
Semaphore Road	5	8	16	34	63
Hamilton Avenue	0	10	20	39	57
Klingberg Drive	1	1	3	9	28
Centre Street	1	3	6	11	27
Largs North Shore	5	5	8	11	15
Semaphore Shore	3	5	9	12	14
Largs Bay Shore	2	4	5	7	13
Osborne Soakage	0	1	2	4	10
Osborne Road	0	0	0	1	9
Jetty Road	0	0	2	5	5
North Haven Marina	0	0	0	1	1
Outer Harbour	0	0	0	1	1
Cultural Park	0	0	0	0	0
Largs North Marina	0	0	0	0	0
New Port Quays	0	0	0	0	0
TOTAL (% Reduction)	**61 (71%)**	**107 (69%)**	**210 (61%)**	**487 (48%)**	**864 (36%)**

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 4.5.2. The Flood ID (outlined in Table 4.9) identifies the location in which the proposed works is addressing.

Table 4.27—Flood Mitigation Strategy Action Summary

Project ID	Project Location / Activity	Flood ID Addressed	Catchment	App D Sheet	Related WSUD Action	Budget Estimate	Design ARI, Description
D1	Deslandes Street – Drainage	F2	Hart Street	N/A	Nil	$340,000	20 year; replacement and upgrade of underground drainage
D2	Carlisle Street – Drainage / Nazar Reserve – Detention	F3, F4	Hart Street	15 / 16	Multi-objective WSUD	$1,715,000	20 year; replacement and extension of existing drainage, new detention basin
D3	Goldsworthy Road – Drainage	F1	Hart Street	03	Water quality improvement	$580,000	20 year; new lateral drain from Hart Street pump station to Old Pelham Road
D4	Phillips Reserve – Detention	F9, F10	Carlisle Street	09	Multi-objective WSUD	$305,000	20 year; new basin within Phillips Reserve to address ponding within Swan Terrace
D5	Semaphore Road – Drainage	F7, F8, F10, F11	Carlisle Street / Semaphore Road East	08 / 08a	Water quality improvement	$1,980,000	20 year; diversion of flows away from the Carlisle Street pump station and extension of drain to Military Road
D6	Hughes Street – Drainage / Naval Reserve - Detention, Pump Station	F12, F13	Semaphore Road East	04	Multi-objective WSUD	$1,825,000	20 year; new pumped outfall to Port River and upgrade of Hughes Street drainage
D7	Hargrave Street – Lateral Drainage	F14, F15, F16, F17, F18	Hargrave Street	N/A	Nil	$1,675,000	-
D8	Lulu – Drainage, Pump Station	F19, F20, F21, F22, F23, F24, F25	Lulu	10	Water quality improvement	$14,235,000	20 year; new pump station and trunk drain in Wills Street

Project ID	Project Location / Activity	Flood ID Addressed	Catchment	App D Sheet	Related WSUD Action	Budget Estimate	Design ARI, Description
D9	Anthony Street – Drainage	F29	Largs Bay Shore	05	Multi-objective WSUD	$1,175,000	5 year; upgrade and replacement of drain within Anthony Street and extension of lateral drains along Military Road
D10	Largs North – Conversion from Soakage System to Gravity Drainage	F30, F31, F32	Largs North Shore	11 / 12	Water quality improvement	$2,975,000	100 year; Replacement of soakage systems with gravity drains to coastal dunes for eight streets
D11	Warwick Street – Drainage, Detention / Jetty Road – Drainage, Pump Station	F26, F27, F28	Jetty Road / Centre Street	02	Water quality improvement	$13,210,000	20 year; replacement of gravity system with pumped outfall, upgrade of Warwick Street drain including new detention basin
D12	Kolapore Avenue – Drainage / Carnarvon Reserve – Detention	F33, F34	Mersey Road	06	Multi-objective WSUD	$1,310,000	20 year; new parallel system in Kolapore Avenue, with lateral drains on Railway Terrace and Middleton Road, including detention basin in Carnarvon Avenue
D13	Aldinga Street Reserve – Detention	-	Mersey Road	01	Multi-objective WSUD	$940,000	100 year; new basin to receive surcharge flows from the Mersey Road pump station
D14	Charon Reserve – Detention, Pump Station	F35	Taperoo Shore	07	Multi-objective WSUD	$1,090,000	20 year; new basin and pumped outfall from Charon Reserve, replacement of existing soakage only system

Project ID	Project Location / Activity	Flood ID Addressed	Catchment	App D Sheet	Related WSUD Action	Budget Estimate	Design ARI, Description
D15	Midlunga Railway Station – Pump Station	F36	Taperoo Shore	13	Water quality improvement	$1,185,000	20 year; upgraded pump station with new rising main to Lady Gowrie Drive
D16	Railway Terrace – Detention, Pump Station	F38, (F37)	Taperoo Shore	14	Multi-objective WSUD	$285,000	20 year; new infiltration basin (optional pump to Osborne Road system with extension of drain to Dawlish Road)
D17	Estella Street - Detention	F39, F40, F41	Hamilton Avenue	17	Multi-objective WSUD	$840,000	100 year; new detention basin and balance pipe from Hamilton Avenue pump station
D18	FloodSafe Program	N/A	Various	N/A	N/A	-	Engage with local SES group to deliver program
D19	Floor Level Survey	N/A	Various	N/A	N/A	-	Included in design allowance
					TOTAL	**$45,665,000**	

5 Water Sensitive Urban Design

5.1 Receiving Waters

Stormwater runoff generated by the sub-catchments on the eastern side of the Lefevre Peninsula is typically discharged directly to the Port River via pumped or gravity drainage outfalls. The sub-catchments on the western side of the Peninsula typically discharge to Gulf St Vincent via gravity drainage outfalls. With the exception of the drainage outfalls located at the North Haven Marina, many of these outfalls are located to the rear of the coastal dune system, where stormwater discharges are unlikely to directly reach Gulf St Vincent (except possibly in major storm events).

The habitats most likely to be impacted by stormwater discharges, therefore, will be those along the Port River, particularly to the south-west of Torrens Island, and those in the immediate vicinity of North Haven Marina. 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.

There are also numerous soakage systems located in trapped low points across the Peninsula that currently discharge via infiltration to the subsurface profile. It is possible that these sub-catchments may be serviced by pumped or gravity drainage systems discharging to Gulf St Vincent or Port River in the future.

Based on DEWNR habitat mapping data the habitat within 100 m of the existing outfalls is bare sand, while within 1 km, the composition is 61.8% sand, 37.7% seagrass and 0.5% mangrove/saltmarsh. However these proportions do not include the *Zostera* or *Caulerpa* spp. dominated seagrass habitats in the Port River area which were not covered by the DEWNR mapping, or the intertidal mangrove and saltmarsh on Torrens Island (refer Figure 5.1).

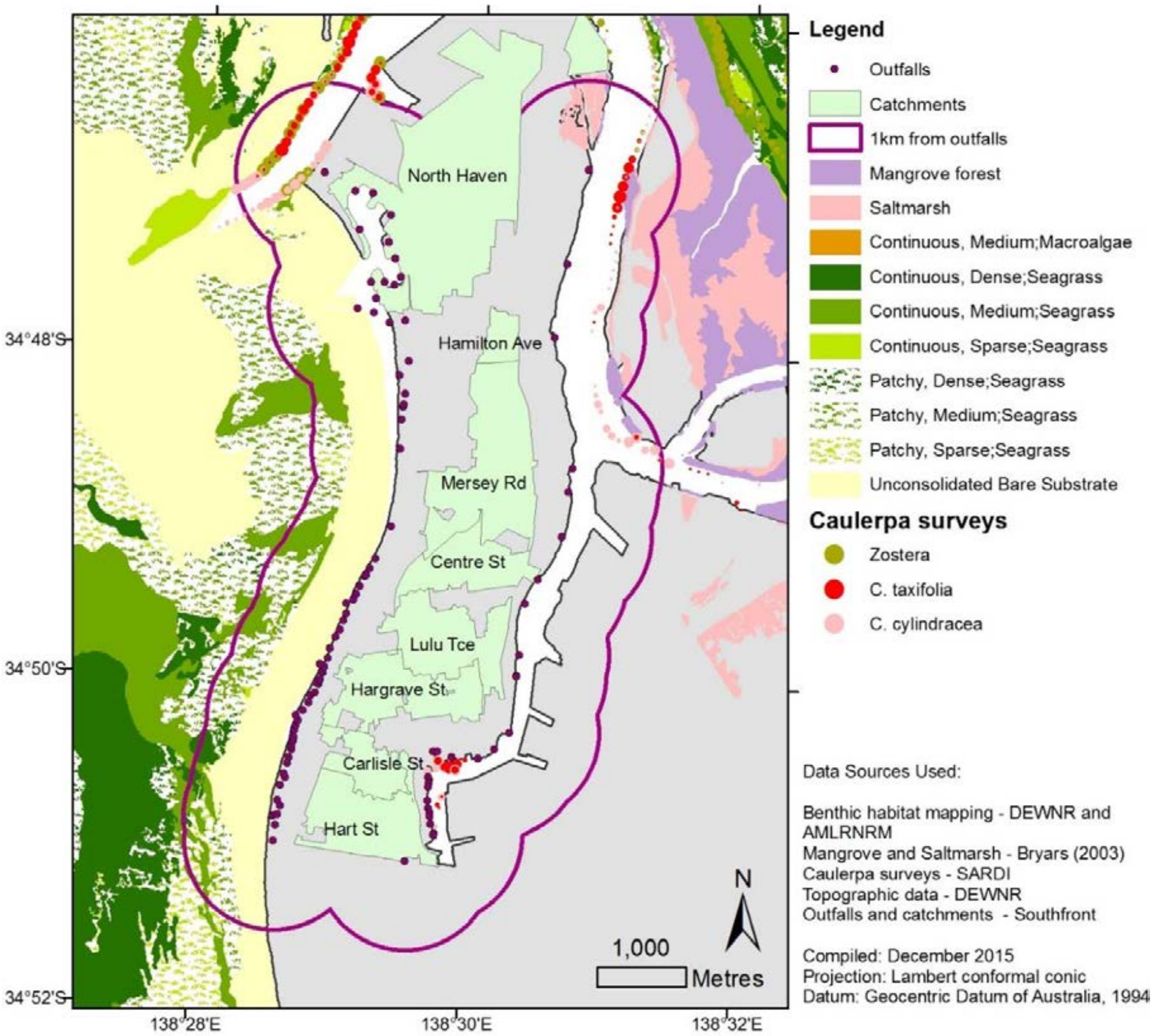


Figure 5.1—Map of Habitats Within 1 km of Existing Stormwater Drainage Outfalls

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).

The general risks to the environments of the Lefevre Peninsula region are discussed below, with focus on impacts on the benthic habitat forming species that support these environments. Motile species can often move to escape contaminants, but may be impacted through loss or degradation of habitat. Where direct impacts on fauna are possible, however, these are also discussed.

5.2.2 Suspended Sediments

Sediments carried by stormwater are the main cause of turbidity in shallow waters (<5 metres deep) along the Adelaide coast and because discharged stormwater in this area tends to move along-shore with minimal mixing with deeper water, discoloration may persist for several days, increasing impacts on near-shore habitats (Fox et al. 2007; Gaylard 2009b). Turbidity increases light attenuation, leading to a lesser proportion of light penetrating to a given depth (Collings et al. 2006b). Light limitation has negative impacts on seagrass including reducing maximum depth range for growth (Abal and Dennison 1996), and causing decreased biomass, shoot density and productivity, and depletion of starch resources (Ruiz and Romero 2001; Ruiz and Romero 2003; Mackey et al. 2007). Macroalgae are similarly impacted by light reduction due to turbidity (Turner and Collings 2008; Gaylard 2009b).

In Adelaide's shallow coastal waters (3-6 metres deep) average light intensity is in the range sufficient for seagrass growth, but variability in available light due to periodic sediment influxes may reduce productivity and contribute to loss of seagrass in this zone (Collings et al. 2006b). Interactive effects between turbidity and nutrients may also contribute to seagrass loss and shifts in benthic community composition (De Casabianca et al. 1997; Wear et al. 2006).

Sediments also have impacts through siltation. Sedimentation may restrict light by accumulation on the surface of seagrass leaves, and smother plants by preventing gas exchange (Ralph *et al.* 2006). Burial of shoots and seeds, and erosion by sediment movement can also cause damage to or loss of seagrass (Marba and Duarte 1995; Preen *et al.* 1995; Duarte *et al.* 1997; Bryars *et al.* 2008). Smothering and erosion by scour negatively impact reef macroalgae and other biota, and sedimentation can also reduce the availability of hard substrate for macroalgae and sessile organisms, thereby reducing or preventing recruitment (Airoldi 2003).

Deposition from a dredge plume decreased recruitment of canopy algae species to southern Adelaide reefs (Turner 2004) and increased sedimentation from terrestrial sources promotes a shift toward macroalgal communities dominated by turfing rather than canopy species (Airoldi and Cinelli 1997; Gorgula and Connell 2004). Sedimentation can also cause changes in unvegetated soft bottom habitats by altering sediment structure, smothering or burial of organisms, and clogging of gills and filter feeding structures (Mills and Williamson 2008; Gaylard 2009b).

A study of sedimentation on Adelaide's metropolitan reefs found that Semaphore Reef experienced relatively low sedimentation compared to reefs further south. Sediments at Semaphore, however, had the highest nitrogen content and showed the greatest anthropogenic influence, likely due to inputs from wastewater and the Penrice soda plant (Fernandes 2008; Fernandes *et al.* 2008).

5.2.3 Nutrients

Wastewater effluent is currently the major source of nutrients entering Gulf St Vincent, but the contribution from stormwater is also substantial (Gaylard 2009b; McDowell and Pfennig 2011). Elevated nutrients promote the growth of epiphytic algae on seagrass, eventually causing loss of above-ground seagrass biomass; *Amphibolis* appears more sensitive to this process than *Posidonia,* which may explain why a greater proportion of *Amphibolis* has been lost from Adelaide's coast than *Posidonia* (Collings *et al.* 2006a; Bryars and Rowling 2008).

Eutrophication also promotes a shift in macroalgal community structure, with increased cover of turfing species (Gorgula and Connell 2004). High concentrations of water column nutrients can have acute toxic effects on seagrass (Collings *et al.* 2006a; Ralph *et al.* 2006) or promote microalgal blooms that reduce available light (De Casabianca *et al.* 1997; Ralph *et al.* 2006) and may lead to low oxygen availability (Gillanders *et al.* 2008a).

The opportunistic green macroalgae that are common in the Lefevre Peninsula area, particularly *Ulva* spp. can also bloom in high nutrient conditions (Baker and Gurgel 2011), causing 'green-tides', in which large masses of seaweed wash up on the shore and, if not removed, decompose, becoming anoxic and producing toxic hydrogen sulphide gas (Smetacek and Zingone 2013). Excessive *Ulva* growth can be detrimental to mangroves by preventing propagule settlement and smothering pneumatophores, causing stress in adult trees (Edyvane 1999; Harbison 2008).

Nutrients also promote blooms of toxic microalgae such as the *Alexandrium* spp. that occur in the Port River (Edyvane 1999) and growth of the invasive algae in the area; *Caulerpa taxifolia, C. cylindracea* and *Codium fragile*. High nutrient levels favour the growth of these species over that of seagrasses and native macroalgae, potentially facilitating intensification of invasive populations and further spread or invasion of new areas (Ceccherelli and Cinelli 1997; Pedersen and Borum 1997; Ceccherelli and Sechi 2002; Street 2007; Burfeind and Udy 2009; Gennaro and Piazzi 2014; Gennaro *et al.* 2015). If present, these invasive algal species are likely to occur in the vicinity of outfalls, based on previous records (Wiltshire *et al.* 2010).

Sediment-bound nutrients have fewer toxic effects than water column nutrients, but in high concentrations these can lead to sediment anoxia and production of sulphides, both of which negatively impact seagrasses (Ralph *et al.* 2006). Nutrients and sediments have interactive impacts that are greater than either factor acting alone (Abal and Dennison 1996; De Casabianca *et al.* 1997; Gorgula and Connell 2004). The impact of nutrients is greatest in waters that are usually oligotrophic, such as those of Gulf St Vincent (Gorman *et al.* 2009).

5.2.4 Other Contaminants

Other contaminants often found in stormwater include trace metals, hydrocarbons, including Polycyclic Aromatic Hydrocarbons (PAHs), pesticides (including insecticides, herbicides and fungicides), emerging organic contaminants such as pharmaceutical, personal care products and endocrine disrupting chemicals, and litter (Burton *et al.* 2000; Mills and Williamson 2008; Gaylard 2009b; Tremblay *et al.* 2011). Stormwater also causes localised reduction of salinity (Mills and Williamson 2008; Gaylard 2009b). Specific information on several of these contaminants is provided below; detailed aquatic toxicity data and guideline values for many toxicants are provided by ANZECC and ARMCANZ (2000a,b).

Metals, hydrocarbons, and pesticides may have acute or chronic toxic effects, and many can accumulate in sediments or in tissues, leading to bioaccumulation and magnification through the food chain (Mills and Williamson 2008; Gaylard 2009b). Many toxicants bind to sediment or organic matter and are found at highest concentrations in stormwater that also carries high sediment and nutrient loads, and accumulate in depositional environments (Mills and Williamson 2008). Sediment-bound toxicants are generally less toxic to flora than soluble forms (Ralph *et al.* 2006), but can accumulate until they become acutely toxic to benthic fauna, for example flounder in a contaminated Auckland estuary showed evidence of poor health, including higher incidences of liver lesions than those from unpolluted sites (Mills and Williamson 2008). Sporadic pulses of contaminants, such as occur in stormwater discharges, can lead to greater toxic effects than exposure to constant concentrations, therefore, some toxicity data may underestimate risks associated with stormwater (Burton *et al.* 2000). Synergistic effects between co-occurring contaminants in stormwater can also lead to greater toxicity than exposure to a single toxicant alone (Burton *et al.* 2000).

Metals

Copper, lead and zinc are the metals most commonly found at elevated levels in stormwater, and are derived from road dust and roof runoff (Burton *et al.* 2000; Mills and Williamson 2008; Gaylard 2009b). The concentrations of these metals in stormwater increase with the number of dry days preceding a given rainfall event, and all have been regularly recorded at above ANZECC trigger levels in Adelaide stormwater, although concentrations have decreased since the mid-1990s (Gaylard 2009b). These metals have many acute and chronic toxic effects, including on seagrass species and the kelp *Ecklonia radiata* (see Gaylard 2009b). Due to chemical similarity, non-essential metals can mimic required elements and bind to receptors, facilitating uptake, but then alter several biological processes (Gauthier *et al.* 2014).

Metals inhibit metabolic pathways, disrupt enzymes, and promote formation of reactive oxygenated compounds (Prange and Dennison 2000; Gauthier *et al.* 2014). In plants, including seagrasses, photosynthetic processes are impacted, leading to reduced growth and potentially plant death (Prange and Dennison 2000). Although required for biological processes, essential metals can exhibit toxicity when present in sufficiently high concentrations (Gauthier *et al.* 2014).

Toxicity of metals depends largely on bioavailability, which is dependent on water chemistry and sediment organic content (Mills and Williamson 2008; Gaylard 2009b). Copper and lead are most likely to be toxic in soft, acidic freshwater with low organic content. Increasing water hardness, alkalinity and pH, and natural dissolved organic matter (eg. humic acids) generally reduce toxicity, but interactions are complex. Toxicity of lead is also reduced by chloride complexing in saline waters; lead may bioaccumulate but is rarely present in sufficient quantities for this to occur.

Zinc toxicity similarly decreases with increasing hardness, alkalinity and salinity, but pH effects are not linear. Below pH 8, zinc toxicity increases with decreasing pH, with conflicting results found at higher pH. Zinc binds to clay and organic matter, but the effects of sediment-binding on zinc toxicity are variable. Copper and zinc are essential trace elements and most organisms have mechanisms for regulating sub-lethal concentrations of these metals. They are therefore unlikely to bioaccumulate (ANZECC and ARMCANZ 2000b; Gaylard 2009b).

Other metals that may be found in elevated concentrations above background levels in stormwater are cadmium, iron, chromium, nickel, antimony, platinum and molybdenum (Mills and Williamson 2008). Cadmium is of concern in Adelaide metropolitan waters because it has been implicated in toxic effects observed in bottlenose dolphins (Lavery *et al.* 2009). Toxicity of these, and other, metals and metalloids, with the exception of platinum, is discussed, and guideline values provided, in ANZECC and ARMCANZ (2000b).

Metals often bind to sediments and accumulate in depositional environments (Mills and Williamson 2008; Gaylard 2009b). Mangroves in the Port River system trap fine sediments, and mangrove muds in this region have high trace metal concentrations, with release of sediment-bound metals to the water column occurring during extended slack water periods due to the conducive pH and redox conditions that develop at these times (Harbison 1986).

Hydrocarbons
PAHs may be present in stormwater and are of concern due to their potential for acute toxicity and ability to bioaccumulate (Mills and Williamson 2008; Gaylard 2009b). PAHs in stormwater are derived primarily from vehicle emissions, with some contribution from tyre wear (Mills and Williamson 2008). Toxicity of PAHs is caused by their metabolism to genotoxic, carcinogenic and reactive oxygenated derivatives, but some PAHs are also directly toxic to aquatic organisms, primarily through causing damage to membranes and so affecting ion transport (Gauthier *et al.* 2014).

PAHs, especially longer-chained compounds, bind strongly to sediment, particularly fine sand (125-250 µm size fraction), and to organic matter (ANZECC and ARMCANZ 2000b; Mills and Williamson 2008) and accumulate in depositional environments such as estuaries (Mills and Williamson 2008). Lower molecular weight PAHs are more soluble but are removed by volatilisation and biological degradation, so are shorter-lived in aquatic environments (ANZECC and ARMCANZ 2000b; Mills and Williamson 2008). Exposure to UV light greatly increases the toxicity of PAHs due to creation of reactive oxygenated compounds (ANZECC and ARMCANZ 2000b; Mills and Williamson 2008).

The association of both metals and PAHs with fine sediment fractions means that these contaminants often co-occur, and emerging research shows that their combined impacts are often additive and sometimes synergistic (Gauthier *et al.* 2014). Cadmium, copper, nickel and zinc all show increased toxicity to aquatic organisms in the presences of at least some PAHs, possibly because PAH-induced membrane damage may increase uptake of metals (Gauthier *et al.* 2014).

Pesticides
Pesticides are often highly toxic and able to bioaccumulate and biomagnify through the food chain (Gaylard 2009b). Organochlorine Pesticides (OCPs) have largely been phased out because of these properties (ANZECC and ARMCANZ 2000b), but residues remain in the environment and can be found in stormwater, particularly in runoff from historically horticultural land (Mills and Williamson 2008; Gaylard 2009b). The toxicity of OCPs is generally not affected by water chemistry, but some compounds are more toxic to certain species at higher temperature, e.g. >20ºC, compared with <10ºC (ANZECC and ARMCANZ 2000b). Organophosphorus Pesticides (OPPs) include some currently widely used insecticides (eg. chlorpyrifos and malathion). The toxicity of these and other OPPs increases with temperature; chlorpyrifos is also more toxic at higher pH (9 c.f. 7.5).

In general, OPPs are much more toxic to crustacea and insects than to algae, molluscs or fish, but within taxonomic groups species show widely varying sensitivities. Some OPPs have the potential to bioaccumulate (ANZECC and ARMCANZ 2000b). Pyrethroid pesticides bind to suspended matter and biological films and so are rapidly removed from the water column, but may pose a threat to surface-feeding species such as cladocerans (ANZECC and ARMCANZ 2000b). Herbicides are much more widely used than insecticides and are generally more toxic to seagrasses and algae than to fish or invertebrates since they inhibit photosynthesis (ANZECC and ARMCANZ 2000b; Gaylard 2009b).

The toxicity of some herbicides is increased at higher pH, while toxicity of others increases with temperature. Water chemistry and temperature have little impact on the toxicity of several compounds, but there is a lack of data for many herbicides (ANZECC and ARMCANZ 2000b).

Emerging Organic Contaminants

Emerging organic contaminants are rarely monitored anthropogenic contaminants that have the potential to cause adverse environmental effects; these include Endocrine Disrupting Chemicals (EDCs), Pharmaceuticals and Personal Care Products (PPCPs), and their metabolites (Tremblay *et al.* 2011). Many of these contaminants are not new, but were previously not detectable; advances in analytical techniques now allow their measurement (Tremblay *et al.* 2011). Wastewater is the major source of EDCs and PPCPs entering the environment as these compounds are not fully removed by current treatment processes (Fernandes *et al.* 2010; Tremblay *et al.* 2011), but they may also occur in stormwater and industrial discharges (Tremblay *et al.* 2011). In urbanised areas, potential sources of these contaminants in stormwater are from surfactants, and leachates from solvents, plasticisers, pharmaceuticals and petroleum products (Tremblay *et al.* 2011).

EDCs affect the operation of endocrine systems and have the potential to disrupt hormone controlled processes, including growth, immunity and reproduction (Porte *et al.* 2006). Impacts of EDCs have been demonstrated on a range of aquatic organisms, including bacteria, algae, invertebrates (echinoderms, molluscs and crustaceans), and fish (Porte *et al.* 2006; Fernandes *et al.* 2010; Tremblay *et al.* 2011), but the mechanisms of their actions are poorly understood (Porte *et al.* 2006). Some EDCs also show carcinogenic effects (Tremblay *et al.* 2011). Most EDCs are resistant to degradation in the environment and are able to bioaccumulate and magnify up the food chain, posing a threat to higher trophic levels (Porte *et al.* 2006).

Several EDCs have been detected in sediments in the Barker Inlet, with triclosan and its derivative methyl-triclosan being most widespread (Fernandes *et al.* 2010). PPCPs include veterinary and human medicines, with antibiotic residues being of particular concern due to the potential for development of antibiotic resistance and impacts on important bacterial ecosystem processes such as decomposition (Tremblay *et al.* 2011)

Freshwater

Marine organisms have variable tolerances to salinities above and below their optimal range, and these can vary within a species depending on genotype, acclimation and condition (Nell and Holliday 1988; Westphalen *et al.* 2005; O'Loughlin *et al.* 2006; Gaylard 2009b). Seagrasses are relatively tolerant of periods of lowered salinity, but long-term exposure leads to reduced photosynthetic efficiency and eventually death (Westphalen *et al.* 2005; Touchette 2007).

Many macroalgae are also tolerant of short-term low salinity exposure, but this varies greatly between species; estuarine and intertidal species typically tolerate broader salinity ranges than subtidal species (Kirst 1990). Fish and invertebrates that live in estuaries and intertidal zones similarly show greater salinity tolerance than subtidal species (Nell and Holliday 1988; O'Loughlin *et al.* 2006). Australian water quality guidelines recommend that changes to salinity in marine environments should be less than 5% of background levels (ANZECC and ARMCANZ 2000a).

Litter

Litter includes rubbish (plastic bags, bottles etc) and also organic waste. Around 60% of the litter intercepted by Gross Pollutant Traps in the Patawalonga catchment is organic material (Gaylard 2009b). A survey of beach litter over several Gulf St Vincent sites found that the majority by quantity (79.7%) and mass (51.3%) was plastics, with glass and ceramic comprising 10.2 % by abundance or 8.5% by mass (Peters and Flaherty 2011). Although this survey was not specifically of material carried in stormwater, it is likely that anthropogenic litter in stormwater will have a similar composition. Plastic waste and ropes have been widely implicated in causing environmental harm including deaths of marine birds, turtles and mammals (Gaylard 2009b;

Peters and Flaherty 2011); while organic waste may cause oxygen depletion through microbial breakdown (Gaylard 2009b).

Risks to habitats in the vicinity of stormwater outfalls
Habitats in the immediate vicinity of stormwater outfalls are most at risk, since these will receive largely undiluted stormwater. The load and concentration of pollutants reaching marine environments away from outfalls will be determined by local hydrodynamics, but it is likely that contaminants will be rapidly diluted away from outfalls.

The preferred method for determining water quality trigger values for nutrients, suspended solids and salinity is to use reference data applicable to the specific ecosystem and area, but in the absence of such data, ANZECC and ARMCANZ (2000a) provide default trigger values for Total Nitrogen (TN), Total Phosphorus (TP), and turbidity. The default trigger values for marine ecosystems in south central Australia - low rainfall areas - slightly disturbed habitats are 1 mg/L TN and 0.1 mg/L TP (ANZECC and ARMCANZ 2000a). The guideline values for TN and TP in South Australia were based on limited data; EPA studies have since demonstrated that likely nutrient impacts, including seagrass loss, have occurred in regions where nutrient concentrations were within the guidelines, indicating that the trigger values may be too high to afford protection in South Australia's normally oligotrophic waters (Gaylard 2009a).

Ambient water nutrient concentrations may also not be appropriate measures in productive environments, where nutrient loads may be high but rapidly incorporated by algal growth (ANZECC and ARMCANZ 2000a; McDowell and Pfennig 2011). A 90th percentile water quality objective for TN of 0.2 mg/L has therefore been set by the ACWQIP for the Port Waterways and Adelaide coastal waters, based on local data obtained by the EPA and through the ACWS (McDowell and Pfennig 2011). No specific objective is set for TP by the ACWQIP because phosphorus concentrations are generally low in Adelaide waters, and inputs from wastewater have already been reduced (McDowell and Pfennig 2011), but the previous Port Waterways WQIP included a target of <0.025 mg/L TP (Pfennig 2008).

Turbidity is correlated with Total Suspended Solids (TSS), but the exact relationship varies depending on the nature of the solids involved, making assessment of turbidity based on TSS measurements difficult (ANZECC and ARMCANZ 2000b), and no specific guideline value for TSS concentration is provided by ANZECC and ARMCANZ (2000a). Some overseas jurisdictions specify maximum TSS concentrations of 25 mg/L or a maximum change from background levels of 10 mg/L (ANZECC and ARMCANZ 2000b). The objective for the ACWQIP is for TSS to be <3 mg/L 90% of the time, thereby allowing for higher levels following storm events (McDowell and Pfennig 2011).

Turbidity trigger values in marine environments should generally be lower than those for estuaries, although inshore waters are generally more turbid than offshore (ANZECC and ARMCANZ 2000b); the Port River-Barker Inlet system is considered an embayment rather than an estuary as it receives minimal freshwater inflows (Pfennig 2008). TSS is also a useful proxy for other contaminants in water quality modelling, since concentrations of these, particularly metals and PAHs, are highly correlated with TSS (ANZECC and ARMCANZ 2000b; Mills and Williamson 2008). Stormwater is recognised as the major source of TSS and other pollutants, especially metals, to Adelaide waters, and the ACWQIP calls for a reduction in stormwater inputs of 75% from 2003 levels to assist in achieving the water quality objectives for TSS and metals (McDowell and Pfennig 2011).

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 2002-2005. The average annual rainfall for this period was 420mm (compared to the annual average rainfall of 433mm for the Lefevre Peninsula for the years 1912 – 2013).

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 Lefevre Peninsula 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 sub-catchments based on the relative proportions of urban development and open space within the sub-catchment area under the ultimate development scenario; hence the 'effective impervious' fractions for the MUSIC sub-catchments 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 40mm and 'field capacity' of 30mm 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 sub-catchments 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 (ie. 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 Lefevre Peninsula have been structured to enable results to be reported for all drainage outfalls to receiving waterbodies (96 in total, excluding soakage systems).

5.4 Baseline Scenario MUSIC Model

A MUSIC model was compiled for the Lefevre Peninsula 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 with no pre-treatment. The purpose of the baseline MUSIC model is to estimate the pollutant loads generated by the catchment under ultimate development conditions, to inform a habitat based risk assessment by SARDI Aquatic Sciences, and to facilitate an assessment of the water quality improvement performance of existing and proposed treatment measures.

Therefore the baseline model included sub-catchments that currently discharge stormwater via soakage systems (infiltration), as it is possible that these sub-catchments may be serviced by pumped or gravity outfalls to the Gulf St Vincent or Port River in the future.

A summary of the average annual pollutant loadings and quantity of stormwater runoff generated by the Study Area are provided in the table below, categorised by receiving environment.

Table 5.1—MUSIC Model Results; Baseline Scenario

Parameter	Gulf St Vincent	Port River	Total
Flow (ML/yr)	848	1,680	2,520
Total Suspended Solids (kg/yr)	162,000	321,000	483,000
Total Phosphorous (kg/yr)	336	664	1,000
Total Nitrogen (kg/yr)	2,400	4,760	7,170
Gross Pollutants (kg/yr)	36,200	70,400	107,000

5.5 Marine Habitat Impact Assessment

SARDI Aquatic Sciences have assessed the baseline MUSIC model results with respect to the ACWQIP objectives and ANZECC guidelines, to assess the potential risks posed to the local marine habitats by stormwater discharges. This assessment has focussed primarily on catchments with drainage outfalls that discharge directly to receiving waters, such as the Port River and North Haven Marina.

The MUSIC model shows median concentrations of TN of 2.17 mg/L and TP of 0.167 mg/L at outfalls, which exceed the ACWQIP objectives and ANZECC guidelines by factors of between ~2 and 10. The median TSS concentration at outfalls is predicted to be 13.6 mg/L; the 90th percentile concentrations, expected after heavy rain, between 112 to 194 mg/L. It should be noted that these are the concentrations in stormwater, which will be diluted away from outfalls. The sand habitats in the immediate vicinity of outfalls may, however, be exposed regularly to concentrations at or above the target values for TN, TP and TSS, and algal habitats within North Haven may also experience these concentrations.

Annual nutrient loads may be a more important factor than median concentrations in determining impacts on seagrass and algal growth, but appropriate annual loads depend on the specific location, and no default values can be given (ANZECC and ARMCANZ 2000a). The majority of average annual stormwater runoff volume from the Lefevre Peninsula enters the Port River, so modelled total nutrient outputs to the Port River are therefore higher than for Gulf St Vincent, although median concentrations at outfalls are similar (refer Table 5.2).

The Port River receives nutrient inputs from multiple sources in addition to stormwater; industry, the Bolivar Wastewater Treatment Plant (WTP), and sediment fluxes from the upper Port where treated wastewater effluent was discharged until 2004 (Pfennig 2008; McDowell and Pfennig 2011). The greatest nutrient inputs to the Port River in 2004 were Penrice soda products (820 tonnes N) and the Bolivar WTP (477 t N, 232 t P).

Stormwater contributed approximately 12 t N and 1.5 t P in total (Pfennig 2008), with local stormwater input from the Lefevre Peninsula being only a minor source (these reported values represent the total nutrient inputs from all catchments contributing to the Port River, including the Lefevre Peninsula, Torrens, Hindmarsh, Enfield and Prospect catchments). The baseline MUSIC model reports that the average annual nutrient inputs from the Lefevre Peninsula catchments would be 5 t/yr N and 0.7 t/yr P under ultimate development conditions, with no treatment measures in place.

Under the ACWQIP, the Penrice N output had decreased to 575 t/yr in 2010, with a target of 300 t/yr (McDowell and Pfennig 2011), but this plant ceased operation in 2013 (Tanner et al. 2014). The Bolivar WTP has been upgraded, and further improvements are planned to reduce nutrient inputs (McDowell and Pfennig 2011). The relative contribution of stormwater to nutrient inputs in the Lefevre Peninsula area is, therefore, likely to increase, although overall nutrient levels, particularly nitrogen, are likely to decrease due to the reduction in outputs from these major sources.

Stormwater is the overall largest source of TSS in Adelaide waters, and TSS loads from the Lefevre Peninsula are likely to be a major contributor to local turbidity. The baseline MUSIC model reports that the average annual sediment input from the Lefevre Peninsula catchments would be 334 t under ultimate development conditions, with no treatment measures in place. Stormwater flows to the Barker Inlet are higher than to the Port River due to creek inputs, contributing 1,460 t TSS in 2008; the Bolivar wastewater plant also contributes significantly, with 840 t TSS in 2008, and a target of 635 t/yr under the ACWQIP (McDowell and Pfennig 2011).

Table 5.2—MUSIC Model Results; Baseline Concentrations and Loads by Catchment

Guideline[1]:	**TN**		**TP**		**TSS**	
	0.2 (1)		**0.025 (0.1)**		**3**	
Region	Median (mg/L)	Total load (kg/yr)	Median (mg/L)	Total load (kg/yr)	Median (mg/L)	Total load (kg/yr)
GSV	2.17	2,470	0.167	349	13.6	167,000
Port River	2.17	5,030	0.167	696	13.6	334,000
Catchment	90th percentile (mg/L)	Mean daily load (kg/day)	90th percentile (mg/L)	Mean daily load (kg/day)	90th percentile (mg/L)	Mean daily load (kg/day)
North Haven	2.82	2.94	0.402	0.412	197	196
Hamilton Ave	2.78	0.25	0.393	0.035	183	16.1
Mersey Rd	2.79	2.15	0.401	0.300	133	143
Centre St	2.80	1.13	0.389	0.159	193	78.3
Lulu	2.85	1.49	0.402	0.209	194	99.8
Hargrave St	2.29	1.23	0.395	0.171	188	80.6
Carlisle St	2.84	0.646	0.403	0.091	189	42.8
Hart St	2.81	1.33	0.399	0.185	193	88.3

1 90th percentile TN and TSS water quality objectives from the ACWQIP (McDowell and Pfennig 2011), TP from Pfennig (2008). Default TN and TP trigger values for south central Australia – low rainfall area – slightly disturbed habitats (ANZECC and ARMCANZ 2000a) are shown in brackets.

5.6 Recommendations for Water Quality Improvement Strategy

There are important marine habitats in the receiving waters for stormwater outflows from the Lefevre Peninsula, particularly seagrasses in Gulf St Vincent and mangrove and saltmarsh areas along the Port River. Under ultimate development conditions in the catchment, if there are no stormwater treatment measures in place the predicted median values of TN, TP and TSS are expected to be >10 times the ACWQIP target values for these contaminants, so it is likely that areas adjacent to outfalls in the Lefevre Peninsula region will be regularly exposed to nutrient and TSS concentrations above the ACWQIP targets.

Given the reduction in other nutrient inputs to the area, notably due to the closure of the Penrice soda plant, total nutrient inputs to habitats in the area are likely to decrease, but the relative contribution of stormwater will be greater. Historical nutrient loads were probably a major factor in wide-scale seagrass loss in the region, leading to the recommendations for reduction that are implemented in the ACWQIP (Fox et al. 2007; McDowell and Pfennig 2011).

In addition to contributing to chronic nutrient effects on a wider scale, local impacts from stormwater nutrients, such as the growth of opportunistic (Ulva spp.) or invasive (Caulerpa and Codium spp) green algae could occur in the vicinity of outfalls, with concomitant detrimental effects on seagrass and mangrove habitats. Habitats in the vicinity of North Haven Marina and along the Port River (eg. Zostera seagrass beds and mangroves and saltmarsh along the western side of Torrens Island) would be at greatest risk from nutrient inputs. Although phosphorus is not noted as being of concern currently in Adelaide waters, phosphorus inputs can promote algal blooms where nitrogen is not limiting (Pfennig 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.

Implementation of stormwater treatment measures on the Lefevre Peninsula would assist in reducing loads of nutrients, suspended sediments and associated contaminants that pose risks to the habitats of the area.

5.7 WSUD Strategy

A Water Sensitive Urban Design (WSUD) strategy has been developed for the Lefevre Peninsula in order to reduce the volume and improve the quality of stormwater discharges to the Port River and Gulf St Vincent. In accordance with the objectives outlined in Section 3, the implementation of the WSUD strategy shall target a reduction in average annual loads of:

- Total Suspended Solids (TSS) by 80 per cent;
- Total Phosphorus (TP) by 60 per cent;
- Total Nitrogen (TN) by 45 per cent; and
- Gross Pollutants (GP) by 90 per cent.

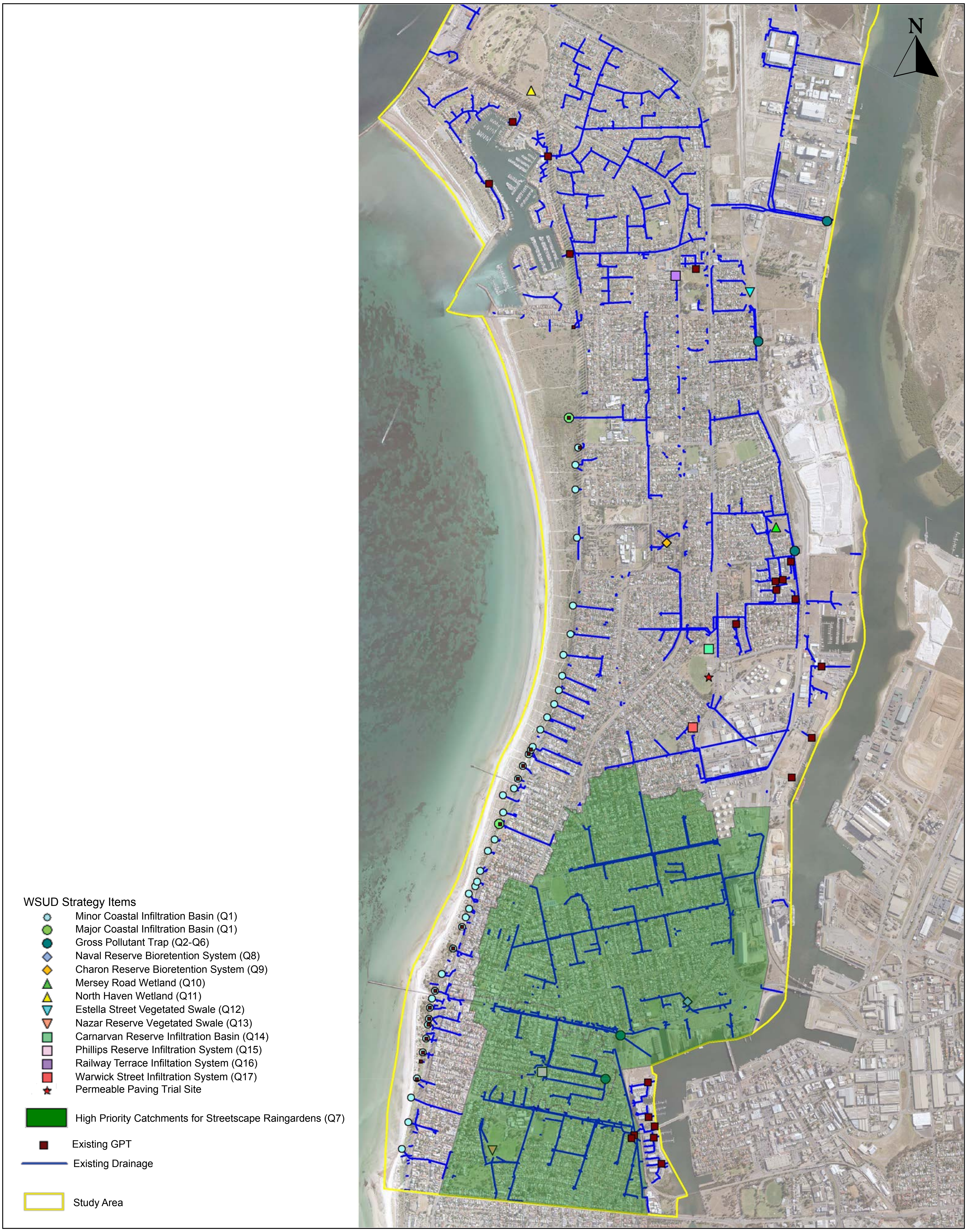
This shall be demonstrated based on modelling procedures which compare the performance of the proposed WSUD strategy for the catchment with an equivalent, untreated catchment. Therefore a WSUD strategy MUSIC model has been compiled to enable comparison to the baseline scenario MUSIC model. This has also enabled preliminary sizing of WSUD elements and budget cost estimation.

The range of WSUD measures that are proposed to be implemented across the Lefevre Peninsula include infiltration basins along the western coastline and within Council reserves, vegetated swales, raingardens (bioretention), constructed wetlands, and Gross Pollutant Traps.

The WSUD strategy has also identified allotment-level and precinct-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, and Aquifer Storage and Recovery (ASR) techniques.

Careful consideration has been given to how the proposed measures will integrate with the local environment in order to develop a WSUD strategy that can be readily implemented. Due to variation in soil and groundwater conditions across the Peninsula, certain WSUD measures that are appropriate at one location may not be feasible at other locations. The following sections provide an overview of the proposed WSUD measures and their geographical limitations.

An overview of all WSUD upgrades is shown in Figure 5.2, and each of the proposed works packages have been assigned a Project ID which corresponds to action summary tables.



Data Sources:
City of Port Adelaide Enfield (Aerial Photograph)
Southfront (Drainage Data)

Lefevre Peninsula
Stormwater Management Plan

southfront

Proposed Water Sensitive Urban Design Sites
Location Plan
Figure 5.2

5.7.1 Coastal Infiltration Basins

The catchments along the western side of the Peninsula, between Semaphore South and Osborne, are typically small residential catchments that drain via conventional 'pit and pipe' systems and discharge flows to shallow depressions at the rear of the coastal dune system, which are above the tidal zone. These depressions are effective at infiltrating stormwater into the natural soil profile, thereby reducing the volume of stormwater (and associated pollutants) that enters the Gulf.

Table 5.3 classifies the coastal outfalls discharging to the dune system based on their catchment size; there are 48 'minor' catchments of less than 5 hectares (including 16 outfalls that cater for the Esplanade and foreshore areas), and 10 'major' catchments of greater than 5 hectares.

Table 5.3—Coastal Outfalls Classified by Catchment Size

Minor Catchment < 5 ha	Major Catchment > 5 ha
Paxton Street, Semaphore South	Arthur Street, Semaphore South
Albert Street, Semaphore	Jervois Road, Semaphore South
South Terrace, Semaphore	Hart Street West, Semaphore
Hall Street, Semaphore	Anthony Street, Largs Bay
Coppin Street, Semaphore	Wigley Street, Largs Bay
Blackler Street, Semaphore	Cheapside Street, Largs North
Newman Street, Semaphore	Seafield Street, Largs North
Semaphore Road West, Semaphore	Gedville Road, Taperoo
Dunn Street, Semaphore	Military Road, Taperoo
Derby Street, Semaphore	Lady Gowrie Drive, North Haven
Jetty Road West, Largs Bay	
Everard Street, Largs Bay	
Union Street, Largs Bay	
Kanowna Street, Largs Bay	
Kalgoorlie Road, Largs Bay	
Hannay Street, Largs Bay	
Ralston Street, Largs Bay	
Alexander Street, Largs Bay	
Musgrave Street, Largs Bay	
Harrold Street, Largs Bay	
Chester Street, Largs Bay	
Roslyn Street, Largs Bay	
Walcot Street, Largs North	
Afric Street, Largs North	
Persic Street, Largs North	
Kybunga Terrace, Largs North	

Minor Catchment < 5 ha	Major Catchment > 5 ha
Charnock Street, Largs North	
Koowarra Terrace, Largs North	
Duntroon Crescent, Taperoo	
Wandana Terrace, Taperoo	
Paringa Street, Taperoo	
Moldavia Walk, Osborne	
16 x Esplanade and foreshore locations	

There are currently 18 outfalls to the coastal dune system that are fitted with Gross Pollutant Trap devices that intercept and capture primary pollutants (eg. anthropogenic waste and debris) from stormwater before it is discharged to these depressions. An example of such an outfall, at South Terrace in Semaphore, is shown in Figure 5.3.

Figure 5.3—South Terrace Drainage Outfall, Semaphore

Minor Catchments < 5 hectares

It is proposed to fit the remaining 40 coastal outfalls with GPT devices. For the 'minor' catchments it is proposed to install primary treatment devices such as the Ecosol Net Tech device, which is reported to capture 91% of solids larger than 19 mm and has the added benefit of capturing and retaining these pollutants in their dry state for ease of disposal. The cost of supplying and fitting the NetTech devices within a precast concrete outlet chamber as depicted in Figure 5.2, is estimated to be $20,000 each. This cost estimate assumes that a minimum of 10 devices will be installed at one time, and includes minor earthworks and revegetation to establish the infiltration basins.

It is also proposed to formalise the depressions into infiltration basins that are nominally 1m deep and with a footprint of approximately 15 m^2. Where possible, the footprint of the infiltration basin shall be round or square in shape, rather than elongated. The infiltration rate for these basins is conservatively expected to be in the order of 1000 mm/hr, based on the results of the infiltration testing performed by AGT and allowing for long term blockage of the floor of the basin due to the accumulation of sediments from stormwater inflows. The coastal infiltration basins shall be vegetated with native indigenous plant species and subject to routine maintenance by Council (and community groups) including the removal of accumulated pollutants and weeds, remediation of localised erosion, and care for dune vegetation.

Major Catchments > 5 hectares

Inspection of aerial photography and survey identified that a large infiltration basin has formed in the dune system at Taperoo, which receives stormwater flows from the Military Road drainage system. This is a large drainage system currently servicing a catchment of approximately 60 hectares and discharging to the dunes via a 1050 mm diameter pipe, located between Moldavia Walk and Gedville Road. Based on the natural topography stormwater flows are expected to rarely, if ever, overtop or break out from this infiltration to the beach. Site inspection showed that the dune vegetation is particularly well established at this location as shown in Figure 5.4.

Figure 5.4—Large Infiltration Basin, Taperoo

For the 'major' catchments it is proposed to install new high performing 'wet sump' GPTs on the outfall drains in order to facilitate the capture of suspended sediment as well as anthropogenic waste and debris. The GPTs shall be sized to provide adequate storage in the pollutant holding chambers to ensure that the devices operate effectively for their nominated cleaning frequency (quarterly or bi-annual cleaning).

Upgrades to the drainage systems of these 'major' catchments shall also maximise opportunities for infiltration of stormwater prior to discharge to the dune system, in order to reduce the magnitude and frequency of stormwater flows spilling to other areas of the dune system and the beach. This can be achieved through the inclusion of underground infiltration systems ranging from individual side entry pits with no concrete floor, to larger underground storages constructed using box culvert arches.

Integration with Coast Protection Works

At the southern end of the Peninsula where the coastal dune system is less extensive and sparsely vegetated, the establishment and maintenance of the coastal infiltration basins will also have the added benefits of:

- Reducing the potential for blockage of the drainage outfall, which was observed to currently be occurring at some locations; and
- Protecting the drainage outfall from being exposed and damaged by wave action.

Examples of such drainage outfalls exist at Semaphore South, as shown in Figure 5.5.

Figure 5.5—Drainage Outfalls at Semaphore South, Before and After Wave Action

An allowance of $25,000 shall therefore be made to establish the proposed infiltration basins for the Paxton Street, Jervois Road and Arthur Street drainage outfalls in Semaphore South. This allowance will enable the existing outfall drains to be modified to suit the basin, including construction of a localised rock seawall or Elcorock sandbag system to reinforce the dune and prevent direct discharge of stormwater flows to the beach. It may be desirable to construct these infiltration basins as part of other coast protection measures.

5.7.2 Reserve Infiltration Basins and Vegetated Swales

The flood mitigation strategies for the Lefevre Peninsula include a number of strategically located detention basins with Council reserves. In addition to their flow attenuation benefits, these detention basins also provide opportunities for integration of WSUD measures.

It is proposed that low flow swales be constructed in the floor of the proposed detention basins to ensure that they drain effectively, and to limit the extent of inundation of the basin during minor rainfall events. These swales shall also be vegetated to reduce flow velocity and promote the retention of coarse sediment, and provide opportunities for incorporation of nature play and wayfinding elements as part of Council's broader landscaping strategy for the reserves.

Vegetated swales are proposed to be constructed in the Nazar Reserve and Estella Street detention basins, to treat flows from small ARI events. An appropriate design objective would be to limit the frequency of overtopping of this swale as much as practicable (eg. achieve a 1 year ARI swale capacity) to maximise the treatment performance and minimise impacts on users of the reserves.

Where the underlying soil and groundwater conditions support the infiltration of stormwater, it is also proposed to raise the invert level of the basin outlet pipe up to 1m higher than the floor of the basin. This will enable stormwater to infiltrate into the natural soil profile, thereby reducing the volume of stormwater (and associated pollutants) that enter the Port River.

The infiltration rate for basins located throughout the centre of the Peninsula (between Military Road and Causeway Road/Semaphore Road/Victoria Road) is expected to be in the order of 500 mm/hr, based on the results of the infiltration testing performed by AGT and allowing for long term blockage of the floor of the basin due to the accumulation of sediments from stormwater inflows.

Infiltration basins are not recommended for areas to the east of Causeway Road/Semaphore Road/Victoria Road due to the likelihood of high groundwater in these areas. For example the existing retention basin at the intersection of Victoria Road and Mascotte Street in Osborne (refer Figure 5.6) has no gravity or pumped outfall, and relies entirely on infiltration/evaporation to dispose of stormwater runoff generated by its small contributing catchment. The basin has an invert level of approximately 0.5 mAHD and the observed standing water in this basin would suggest that groundwater levels at the time of observation were close to this invert level.

Figure 5.6—High Groundwater Level in the Mascotte Street Retention Basin

It is proposed that the infiltration basins be vegetated with plant species that are resilient to extended dry spells, infrequent inundation with stormwater, and potentially saline and seasonally variable groundwater conditions. The vegetation will assist in the water quality improvement performance, stabilise the batters of the basin to mitigate erosion, and improve the amenity of the Council reserves.

The proposed infiltration basins shall be integrated with the detention storages at the following locations:

- Carnarvon Reserve;
- Phillips Reserve;
- Victoria Road/Warwick Street; and
- Railway Terrace/Hutley Road.

5.7.3 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 5.7.

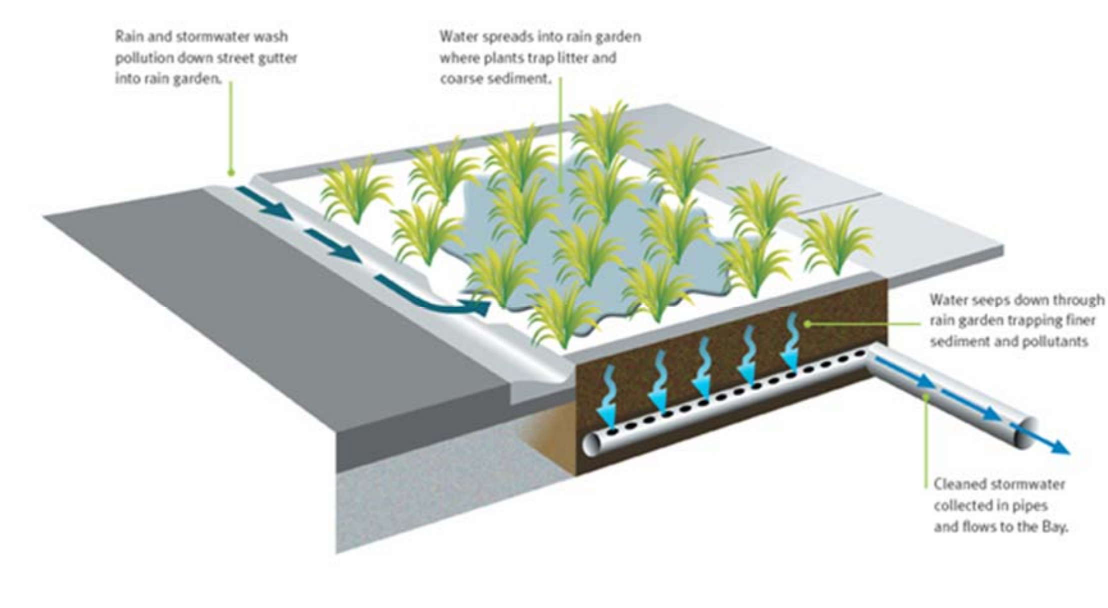


Figure 5.7—Bioretention System Schematic

It is proposed to construct lined bioretention systems at strategic locations across the Lefevre Peninsula, with an emphasis on catchments where infiltration systems are not feasible due to adverse soil and groundwater conditions and/or the close proximity of built forms (eg. roads, buildings).

These locations shall include road reserves that are proposed to be subject to stormwater drainage upgrades and have sufficient width to accommodate raingardens without adversely impacting on other streetscape features such as parking provisions. In these cases raingardens may be used in lieu of traditional side entry pits, to treat the flows from small contribution catchments. MUSIC modelling properties for the proposed streetscape bioretention systems are included in Table 5.4.

Table 5.4—Streetscape Bioretention System Properties

Parameter	Units	Value
Catchment Area	ha	0.5 - 1
High Flow Bypass	L/s	150
Extended Detention Depth	m	0.15
Filter Area	m^2	15
Filter Depth	m	0.5
Submerged Zone Depth	m	0.45

An example of a streetscape bioretention system, in its establishment phase, is shown in Figure 5.8.

Figure 5.8—Bioretention System (Raingarden) Example

Streetscape bioretention systems are suitable for widespread implementation across the Peninsula, and would ideally be delivered in conjunction with Council's road reconstruction program and open space upgrades. The lined streetscape bioretention systems are of particular importance to achieving the target water quality improvement outcomes for catchments that discharge to the Port River, where infiltration systems are not recommended due to the likelihood of high groundwater.

An assessment of the minimum number of streetscape bioretention systems that are required to achieve meaningful water quality improvement in the Port River catchments has been undertaken and summarised in Table 5.5. A more widespread adoption of streetscape bioretention systems would result in enhanced water quality improvement and amenity outcomes. The estimated cost of constructing each raingarden is $25,000 (assuming a footprint of 15 m^2).

Table 5.5—Proposed Streetscape Bioretention System Locations

Catchment	Number
Hargrave Street	8
Semaphore Road East	8
Hart Street	4
Lulu	12
Total	*32*

Bioretention systems are also proposed to be incorporated at two detention basin sites that are to discharge via new pump stations; the Birkenhead Naval Reserve and Charon Reserve. These bioretention systems shall be fully lined and include a submerged zone that will provide a 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 reserve.

Birkenhead Naval Reserve
A new detention basin is proposed to be constructed at Birkenhead Naval Reserve in the Semaphore Road East catchment (refer Section 4.8.3). This detention basin is proposed to discharge to the Port River via a new pump station. It is proposed to install proprietary Gross Pollutant Trap devices on each of the two drainage inlets, which will discharge to lined bioretention systems within the reserve. The underdrain of the bioretention systems shall connect directly to the new pump chamber, enabling treated flows to be discharged to the Port River. The bioretention systems are to have a combined filter area of 500 m^2 and be elevated above the floor of the detention basin such that their maximum depth of submergence is 0.3 metres.

The cost of constructing the bioretention system is estimated to be $445,000, which includes the provision of two proprietary Gross Pollutant Traps. These costs are in addition to the cost of constructing the flood mitigation works proposed for these sites, as described in Section 4.8.3 (including detention basin and new packaged pump station).

Charon Reserve, Taperoo
A new detention basin is proposed to be constructed at Charon Reserve in Taperoo (refer Section 4.8.10). This detention basin is proposed to discharge to the coastal dunes on the western side of the Peninsula via a new pump station. It is proposed to install proprietary Gross Pollutant Trap devices on each of the drainage inlets, which will discharge to a lined bioretention system within the reserve. The underdrain of the bioretention system shall connect directly to the new pump chamber. The bioretention system shall have a filter area of 200 m^2 and be elevated above the floor of the detention basin such that the maximum depth of submergence is 0.3 metres.

The cost of constructing the bioretention system is estimated to be $270,000, which includes the provision of two proprietary Gross Pollutant Traps. These costs are in addition to the cost of constructing the flood mitigation works proposed for these sites, as described in Section 4.8.10 (including detention basin and new packaged pump station).

5.7.4 Rainwater Tanks

The installation of rainwater tanks into new residential development was mandated by the State Government a number of years ago. Currently, this stipulation requires 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.

Council propose to implement a new planning policy whereby new development will be required to provide a minimum 3 kL rainwater tank. Assuming that the rainwater tank caters for an impervious area of 200 m^2, this storage is equivalent to the runoff volume generated by a 15 mm rainfall event (for comparison a 1 year ARI, 2 hour duration event produces 14 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 hence 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 be connected to a daily demand of 200 L/day. The cost of rainwater tanks shall be borne by the homeowner.

5.7.5 Constructed Wetlands

Mersey Road Wetland

A constructed wetland is proposed to be integrated with the detention basin proposed for the Aldinga Street Reserve in the Mersey Road catchment (refer Section 4.8.9). The ground level of this reserve is such that the invert level of the proposed wetland will likely be above the existing invert levels of the adjacent gravity drains. Therefore it is proposed that a new packaged pump system be installed upstream of the existing Mersey Road pump station to direct low flows to the proposed wetland via a new rising main along Mersey Road/Lowana Street/Aldinga Street. A new proprietary Gross Pollutant Trap shall be included to pre-treat flows entering the wetland. It was assumed that the total wetland footprint (including space for macrophyte zone, inlet pond, landscaping, batters etc) could occupy 5,000 m^2 of the reserve.

Treated flows from the wetland may be used for Aquifer Storage and Recovery as described in Section 5.7.6, or alternatively permitted to gravity drain to the existing Mersey Road pump station for discharge to the Port River. Overflows from the wetland would gravity drain to the existing Mersey Road pump station, and it is noted that excess flows from the Mersey Road drainage system shall be permitted to surcharge and fill the wetland site during large storm events, as described in Section 4.8.9. The wetland is proposed to be lined with compacted clay or a proprietary lining system (eg. Geosynthetic Clay Liner). Analysis was undertaken using the MUSIC modelling software to determine the optimum pumping inflow rate in regard to yield and hydrologic efficiency (the ratio of annual volume of treated stormwater leaving the wetland to average total annual inflows), and the assumed wetland properties are summarised in Table 5.6.

Table 5.6—Mersey Road Wetland Properties

Parameter	Units	Value
Pumped Inflows	L/s	60
Extended Detention Depth	m	0.4
Surface Area	m^2	4,000 [1]
Permanent Pool Volume	m^3	1,400
Detention Time	hrs	72

1 Assuming 20% of available wetland footprint will be required for inlet pond/batters/landscaping etc.

The cost of constructing the Mersey Road wetland is estimated to be $1,670,000 which includes the establishment of an Aquifer Storage and Recovery system. These costs are in addition to the cost of constructing the flood mitigation works proposed for this site, as described in Section 4.8.9 (including detention basin and drainage works).

North Haven Wetland

It is proposed that a new packaged pump system be installed near the outfall of the Osborne Road drainage system (refer Figure 5.9) to direct low flows to a proposed wetland adjacent to Lady Gowrie Drive. The Osborne Road drainage system was selected as the preferred harvesting point as the invert level of the system is above 0.5 mAHD and therefore above the adjacent sea level for a majority of the typical tide cycle. However the new pump station will require an electrically actuated gate to prevent seawater ingress during high tides.

Figure 5.9—Location of Proposed Pump Station on Osborne Road Outfall

A new proprietary Gross Pollutant Trap shall be included to pre-treat flows entering the wetland. Should it be desirable for treated flows from the constructed wetland to be used for Aquifer Storage and Recovery as described in Section 5.7.6, it is proposed that the wetland be sited to the north of the North Haven Marina, on land to be acquired by Council in the general vicinity of the golf course. It was assumed that 5,000 m^2 of land would be available for the total wetland footprint (including space for macrophyte zone, inlet pond, landscaping, batters etc). The wetland is proposed to be lined with compacted clay or a proprietary lining system (eg. Geosynthetic Clay Liner). Analysis was undertaken using the MUSIC modelling software to determine the optimum pumping inflow rate in regard to yield and hydrologic efficiency (the ratio of annual volume of treated stormwater leaving the wetland to average total annual inflows), and the assumed wetland properties are summarised in Table 5.7.

Table 5.7—North Haven Wetland Properties

Parameter	Units	Value
Pumped Inflows	L/s	60
Extended Detention Depth	m	0.3
Surface Area	m^2	4,000 [1]
Permanent Pool Volume	m^3	1,400
Detention Time	hrs	72

[1] Assuming 20% of available wetland space will be required for inlet pond/batters/landscaping etc.

The cost of constructing the North Haven wetland is estimated to be $1,895,000 which includes the establishment of an Aquifer Storage and Recovery system.

Alternatively a constructed wetland (or bioretention system) could be established in the reserve adjacent to the proposed pump station on Lady Gowrie Drive. This high profile location would be ideally suited to incorporate opportunities for nature play, wayfinding elements, educational interpretive signage and other landscape elements that are fully integrated and complementary to the other uses for this reserve.

Geotechnical and environmental investigations are required to confirm the feasibility of both proposed wetlands, based on site history and local subsurface conditions. No allowance has been made for site remediation, should this be required to facilitate the works.

5.7.6 Aquifer Storage and Recovery

AGT have reviewed the viability of establishing an Aquifer Storage and Recovery (ASR) scheme at the two constructed wetland sites described in Section 5.7.5. Subject to on-site investigations to determine key hydraulic parameters and groundwater conditions (including depth to water, predicted injection head, transmissivity and aquifer storage capacity) it is considered that ASR may be feasible at these sites using select Tertiary (T) aquifers. The Quaternary (Q) aquifers are not considered appropriate due to their thin and discontinuous nature.

Both the T1 and T2 aquifers are expected to support injection rates in the order of 10 L/s which suggest that a single ASR well may be sufficient to handle the required injection volume at each wetland site (expected injection volume in the order of 30 to 50 ML/yr for the North Haven and Mersey Road wetlands respectively).

The T1 aquifer has lower salinity levels than the T2 aquifer (~1800 mg/L Total Dissolved Solids compared to 3400 mg/L), although these levels still exceed the desirable limit of 1500 mg/L for irrigation. For the proposed of the proposed ASR scheme(s), the salinity of the ambient groundwater is a less important factor than yield/transmissivity and depth to water/injection head considerations. Whilst mixing of injected water with ambient groundwater will occur, ideally after several cycles of injection a sufficiently large injection ‘bubble’ should establish such that injected water will no longer interact with ambient groundwater. However higher ambient groundwater salinities do result in an increase buoyancy force and can reduce ASR recovery efficiency, and for this reason the T1 aquifer if preferred over the T2 aquifer for these ASR scheme(s).

Aquifer Storage, Transfer and Recovery (ASTR) is also unlikely to be favourable due to the elevated salinity of the ambient groundwater, and the limited lateral migration of injectant from the ASR wells. That is, treated stormwater that is injected to the aquifer will need to be recovered at the same location, and then conveyed to the point of use by pipelines.

Of the T1 aquifers, the T1b aquifer is the preferred option because of the ASR viability factors described above (ie. injection capacity, injection head, recovery efficiency), and the fact that recent cessation of extraction from this well by other users (eg. Penrice) has resulted in the recovery of groundwater levels. The T1a aquifer is not considered appropriate due to its bi-modal grain size distribution and problematic nature should remediation for clogging be required.

The North Haven Golf Course has an existing well completed in the T1 aquifer and should the proposed ASR scheme in North Haven proceed, it will be critical to assess various impacts upon existing users, including their ability to withstand potential artesian conditions. Subject to the on-site hydrogeological investigations (drilling, aquifer testing and modelling) and a detailed risk assessment, it is anticipated that Council would be able to obtain the necessary licenses for injection (from the Environment Protection Authority) and extraction (from the Department of Environment Water and Natural Resources).

The cost of implementing an ASR scheme at either site is $385,000, which includes hydrogeological investigations (ie. drilling/aquifer testing/modelling), headworks componentry, pumps, telemetry systems and commissioning. The annual operational costs for such a scheme, including regulatory reporting, are in the order of $40,000/annum.

5.7.7 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.

Aside from the coastal outfalls on the western side of the Peninsula (refer Section 5.7.1), there are currently 7 trash rack or basket type devices and 15 wet sump devices and installed on the drainage systems of the Lefevre Peninsula. In addition to the new GPTs to be installed at the proposed wetlands, bioretention and pump station sites, it is proposed to also install new 'wet sump' GPTs on the following trunk drainage systems:

- The existing 750 mm diameter inlet to the Hamilton Avenue pump station;
- The existing 900 mm diameter outfall for the Carlisle Street drainage system;
- The proposed 1050 mm diameter outfall for the Semaphore Road East drainage system;
- The existing 1650 mm diameter outfall on Vietch Road in Osborne; and
- The existing 1650 mm diameter outfall for the Mersey Road North drainage system.

The cost of the supply and installation of the GPTs proposed for the Hamilton Avenue and Carlisle Street drainage systems is estimated to be $270,000 each. The cost of the supply and installation of the GPTs proposed for the Semaphore Road East, Vietch Road and Mersey Road North drainage systems is estimated to be $425,000 each. These cost estimates have been prepared on the basis the GPTs are installed as a stand-alone works package, and include an allowance for sheet piling and dewatering due to the high likelihood of adverse soil conditions.

The pollutant removal performance predicted by MUSIC is sensitive to the user defined efficiency of proprietary GPTs. Based on a review of available literature and MUSIC modelling guidelines the pollutant removal efficiencies stated in Table 5.8 and a high flow bypass equivalent to the 3 month ARI has been adopted for GPT devices.

Table 5.8—Assumed Gross Pollutant Trap Annual Pollutant Removal Efficiency

Pollutant	Wet Sump Type	Trash Rack or Basket Type
Total Suspended Solids	50%	0%
Total Phosphorous	20%	0%
Total Nitrogen	0%	0%
Gross Pollutants	85%	50%

5.7.8 Permeable Paving

Permeable paving is a load bearing pavement structure that consists of a permeable surface layer overlying an aggregate storage layer. The storage layer is used to temporarily detain stormwater prior to infiltration to the underlying soil or discharge via an underdrain. There is a wide variety of permeable paving types, including surface layers constructed from porous materials or solid segmental pavers that allow the ingress of stormwater via slots or tubes between the pavers.

A simple schematic showing how stormwater is passed through a permeable paving system is shown Figure 5.10, which is an excerpt fromFigure 5.7 *Chapter 7 – Pervious Pavements, Water Sensitive Urban Design Technical Manual for the Greater Adelaide Region* (Department of Planning and Local Government, 2010).

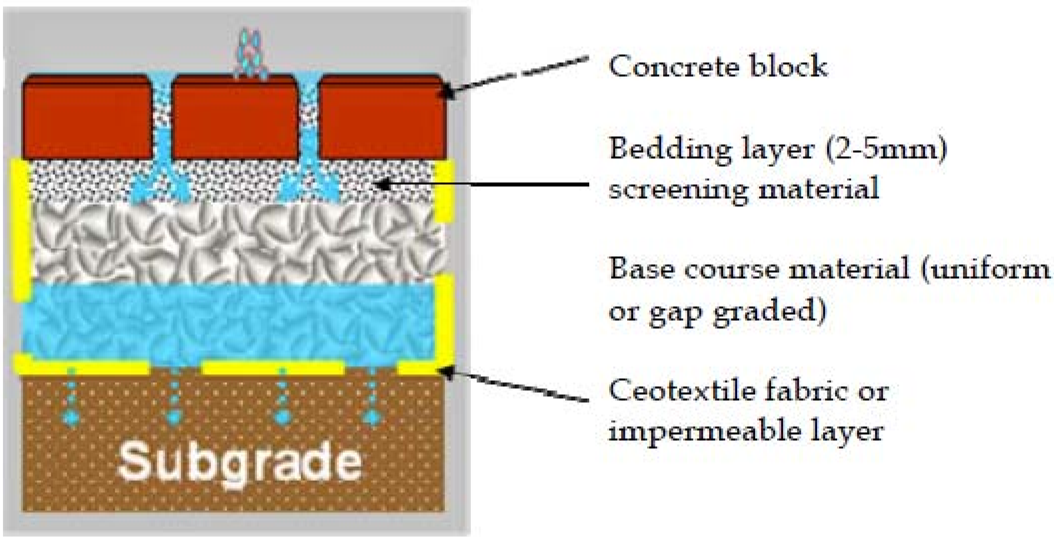


Figure 5.10—Permeable Paving Schematic

Permeable paving is most suitable for locations that are subject to low traffic volumes and light vehicle weights, and is not recommended for areas that have high groundwater levels. Permeable paving requires routine maintenance and cleaning of the surface to prevent clogging by fine sediment, and these maintenance requirements can be exacerbated in coastal locations that are subject to wind-blown or loose sands. Some pervious pavement systems have shown a high failure rate due to clogging by fine sediment and excessive traffic use.

With consideration of these factors, permeable paving would be most suitable across the central zone of the Lefevre Peninsula where infiltration rates are moderate (in the order of 500 mm/hr) and the risk of clogging from wind-blown sands is minimised.

Council already has an existing permeable paving trial site in the carpark at Largs North Reserve. The performance and maintenance requirements of this trial site are being monitored by Council to inform future decisions on whether to incorporate widespread use of permeable paving in footpath and carpark renewal projects on the Peninsula.

5.7.9 Assessed Performance

The baseline scenario MUSIC model was modified for the catchments incorporating various WSUD features described above. The MUSIC model was executed to assess the overall performance of the proposed WSUD strategy under existing climate conditions (average annual rainfall for the period 2002-05 was 420 mm), as summarised in Table 5.9.

Table 5.9—MUSIC Model Results; 'Overall' Upgrade Scenario

Parameter	Sources[1]	Residual	Reduction	Objective
Flow (ML/yr)	2,520	1,740	31%	-
Total Suspended Solids (kg/yr)	483,000	224,000	54%	80%
Total Phosphorous (kg/yr)	1,000	593	41%	60%
Total Nitrogen (kg/yr)	7,170	4,830	33%	45%
Gross Pollutants (kg/yr)	107,000	23,600	78%	90%

1 From Baseline Scenario model.

Model results are also shown below to differentiate between the performance of the WSUD measures that shall be implemented for drainage system discharging directly to the Port River and Gulf St Vincent, respectively.

Table 5.10—MUSIC Model Results; 'Port River' Upgrade Scenario

Parameter	Sources[1]	Residual	Reduction	Objective
Flow (ML/yr)	1,680	1,300	23%	-
Total Suspended Solids (kg/yr)	321,000	160,000	50%	80%
Total Phosphorous (kg/yr)	664	434	35%	60%
Total Nitrogen (kg/yr)	4,760	3,600	24%	45%
Gross Pollutants (kg/yr)	70,400	17,400	75%	90%

1 From Baseline Scenario model.

Table 5.11—MUSIC Model Results; 'Gulf St Vincent' Upgrade Scenario

Parameter	Sources[1]	Residual	Reduction	Objective
Flow (ML/yr)	848	440	48%	-
Total Suspended Solids (kg/yr)	162,000	64,300	60%	80%
Total Phosphorous (kg/yr)	336	159	53%	60%
Total Nitrogen (kg/yr)	2,400	1,230	49%	45%
Gross Pollutants (kg/yr)	36,200	6,200	83%	90%

1 From Baseline Scenario model.

Table 5.12 presents the median concentrations and pollutant loads on a catchment basis for the Upgrade Scenario, providing a direct comparison to the Baseline Scenario presented in Table 5.2.

Table 5.12—MUSIC Model Results; Upgrade Scenario Concentrations and Loads by Catchment

Guideline[1]:	TN		TP		TSS	
	0.2 (1)		0.025 (0.1)		3	
Region	Median (mg/L)	Total load (kg/yr)	Median (mg/L)	Total load (kg/yr)	Median (mg/L)	Total load (kg/yr)
GSV	2.08	1,230	0.142	159	7.78	64,300
Port River	2.1	3,600	0.137	434	7.33	160,000
Catchment	90th percentile (mg/L)	Mean daily load (kg/day)	90th percentile (mg/L)	Mean daily load (kg/day)	90th percentile (mg/L)	Mean daily load (kg/day)
North Haven	2.83	2.69	0.357	0.334	134	128
Hamilton Ave	2.76	0.275	0.295	0.029	86.9	9.05
Mersey Rd	2.78	1.15	0.315	0.142	103	54.4
Centre St	2.74	1.06	0.323	0.131	105	48.8
Lulu	2.74	1.23	0.319	0.145	98.3	50.3
Hargrave St	2.73	1.01	0.307	0.116	93	40.1
Carlisle St	2.77	0.255	0.305	0.028	90.9	8.68
Hart St	2.77	0.961	0.327	0.111	116	40.1

1 90th percentile TN and TSS water quality objectives from the ACWQIP (McDowell and Pfennig 2011), TP from Pfennig (2008). Default TN and TP trigger values for south central Australia – low rainfall area – slightly disturbed habitats (ANZECC and ARMCANZ 2000a) are shown in brackets.

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 10-15% reduction to the current mean annual rainfall (average annual rainfall for the period 1984-85 was 384 mm), as summarised in Table 5.13. The relative performance of the WSUD strategy is shown to improve with reductions to the mean annual rainfall, as predicted due to climate change.

Table 5.13—MUSIC Model Results; 'Overall - Climate Change' Upgrade Scenario

Parameter	Sources[1]	Residual	Reduction	Objective
Flow (ML/yr)	1,980	1,290	35%	-
Total Suspended Solids (kg/yr)	381,000	153,000	60%	80%
Total Phosphorous (kg/yr)	792	426	46%	60%
Total Nitrogen (kg/yr)	5,620	3,560	37%	45%
Gross Pollutants (kg/yr)	98,000	19,500	80%	90%

1 From Baseline Scenario model.

The modelling indicates that while the works identified in this Plan would contribute significantly towards the improvement in stormwater quality discharged from the catchment, the overall water quality improvement targets are not achieved for the Peninsula.

The key constraints to the achievement of the water quality improvement targets are:

- The high degree of imperviousness of the catchments, coupled with the limited amount of public open space within the lower reaches of many catchments which limits opportunities to establish precinct-scale stormwater harvesting and quality improvement measures; and
- The presence of clay bands on the eastern side of the Peninsula that can lead to the creation of perched watertables and potential water logging of soils, which limits opportunities to establish WSUD measures that promote infiltration of stormwater to the soil profile.

Further measures would need to be implemented in order to ultimately achieve all pollutant reduction targets, particularly for catchments discharging directly to the Port River. The opportunity for further measures primarily exist at the street level, such as WSUD measures incorporated into road reconstructions (eg. raingardens), and on private property. Actions have been identified in this Plan through which these additional opportunities can be identified and integrated into other capital works programs.

5.7.10 Non-structural Measures

An action identified in this Stormwater Management Plan is for Council 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 also recommended that Council seek to maximise the uptake of WSUD measures on private property through community education and 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 manage the stormwater runoff generated by their property in an environmentally responsible manner, including the use of rainwater tanks, soakage systems and raingardens. Initiatives may include articles in Council newsletters, street corner meetings, community group meetings, website updates, brochures and school education.

Integration of water quality improvement objectives for new development currently occurs through Council's existing development assessment processes, with reference to the Natural Resources General Section of the City of Port Adelaide Enfield Development Plan which requires development to be consistent with the principles of water sensitive design, including:

> *Development sited and designed to:*
> *(a) protect natural ecological systems*
> *(b) achieve the sustainable use of water*
> *(c) protect water quality, including receiving waters*
> *(d) reduce runoff and peak flows and prevent the risk of downstream flooding*
> *(e) minimise demand on reticulated water supplies*
> *(f) maximise the harvest and use of stormwater*
> *(g) protect stormwater from pollution sources*

5.8 WSUD Strategy Action Summary

A consolidated summary of the WSUD strategies across the study area is presented in Table 5.14. The costs of establishing infiltration systems and vegetated swales in the proposed detention basins, and the costs of installing Gross Pollutant Traps as part of pump station upgrades, are included in the flood mitigation strategy cost estimates in Table 4.25. 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.

Table 5.14—WSUD Strategy Action Summary

Project ID	Project Location / Activity	Catchment	Precursor Project	Budget Estimate	Description
Q1	Coastal Outfall Infiltration Basins (various locations)	Semaphore Shore / Largs Bay Shore / Largs North Shore / Taperoo Shore	Nil	$875,000	Upgrade or establishment of forty (40) coastal infiltration basins. Minor outfalls to include a primary treatment device and a nominal basin footprint of 15 m^2 (including three basins with rock/sandbag coastal protection). Major outfalls to include a high performance GPT, and an optional underground storage for infiltration that is located upstream of the outfall.
Q2	Hamilton Avenue GPT	Hamilton Avenue	Nil	$270,000	New 'wet sump' GPT installed on existing 750 mm diameter drain
Q3	Carlisle Street GPT	Carlisle Street	Nil	$270,000	New 'wet sump' GPT installed on existing 900 mm diameter drain
Q4	Semaphore Road East GPT	Semaphore Road East	Semaphore Road – Drainage	$425,000	New 'wet sump' GPT installed on proposed 1050 mm diameter drain
Q5	Mersey Road North GPT	Mersey Road	Nil	$425,000	New 'wet sump' GPT installed on existing 1650 mm diameter drain
Q6	Veitch Road GPT	Mersey Road	Nil	$425,000	New 'wet sump' GPT installed on existing 1650 mm diameter drain
Q7	Streetscape Raingardens (various locations)	Various	Nil	$800,000	Thirty-two (32) streetscape raingardens, each with a filter zone footprint of 15 m^2
Q8	Naval Reserve Bioretention System	Semaphore Road East	Naval Reserve - Detention, Pump Station	$445,000	Two proprietary GPTs and a lined bioretention system with a filter zone footprint of 500 m^2
Q9	Charon Reserve Bioretention System	Taperoo Shore	Charon Reserve – Detention, Pump Station	$270,000	Two proprietary GPTs and a lined bioretention system with a filter zone footprint of 200 m^2
Q10	Mersey Road Wetland	Mersey Road	Aldinga Street Reserve – Detention	$1,670,000	Packaged pump station and rising main to deliver low flows to a constructed wetland, including establishment of an Aquifer Storage and Recovery system

Project ID	Project Location / Activity	Catchment	Precursor Project	Budget Estimate	Description
Q11	North Haven Wetland	North Haven	Nil	$1,895,000	Packaged pump station and rising main to deliver low flows to a constructed wetland, including establishment of an Aquifer Storage and Recovery system
Q12	Estella Street Vegetated Swale	Hamilton Avenue	Estella Street Basin - Detention	Included	Vegetated low flow swale to be constructed in the floor of the detention basin
Q13	Nazar Reserve Vegetated Swale	Hart Street	Nazar Reserve – Detention	Included	Vegetated low flow swale to be constructed in the floor of the detention basin
Q14	Carnarvon Reserve Infiltration System	Mersey Road	Carnarvon Reserve – Detention	Included	Promote infiltration by raising the invert level of detention basin outlets above the floor of the basin
Q15	Phillips Reserve Infiltration System	Carlisle Street	Phillips Reserve – Detention	Included	Promote infiltration by raising the invert level of detention basin outlets above the floor of the basin
Q16	Railway Terrace Infiltration System	Taperoo Shore	Railway Terrace – Detention	Included	Promote infiltration by raising the invert level of detention basin outlets above the floor of the basin
Q17	Warwick Street Infiltration System	Jetty Road	Warwick Street – Detention	Included	Promote infiltration by raising the invert level of detention basin outlets above the floor of the basin
Q18	Rainwater Tanks	Various	Nil	N/A	A requirement for installation of 3 kL rainwater tanks for new dwellings
Q19	Business Plan Integration	Various	Nil	N/A	Ongoing integration between the proposed stormwater upgrade works and other capital programs (roads, open space)
Q20	Community WSUD Education	Various	Nil	N/A	Community education and promotional activities to maximise the uptake of WSUD measures on private property
Q21	Permeable Paving	Mersey Road	Existing Site	N/A	Monitor existing permeable paving trial site in the carpark at Largs North Reserve and consider further applications on the Peninsula

Project ID	Project Location / Activity	Catchment	Precursor Project	Budget Estimate	Description
					where/if appropriate
			TOTAL	**$7,770,000**	

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;
- 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 (represented in a technical review capacity by staff from the Department of Planning, Transport and Infrastructure).

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 15 and 18 July 2015 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 on the Peninsula, 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:

- Eight people attended;
- Key points of interest with attendees included long term solutions to flooding issues around Peterhead, allotment level stormwater management (benefits of rainwater tanks), and the unique nature of the Peninsula and environs;
- Two particularly interested groups were the Port Adelaide Residents Environment Protection Group and the Port Adelaide Environment Forum; and
- The key take home message was that a range of stormwater management techniques will be required for different locations across the Peninsula.

6.3 Consultation on the Draft Stormwater Management Plan

6.3.1 Approach to Consultation on the Draft Plan

The draft Plan was placed on consultation from 15 August to 12 September 2016. The availability of the draft Plan for review and comment was publicised via:

- Corflute signage established on Semaphore Road, the Esplanade at Largs Bay, Hargrave Street at Peterhead and Swan Terrace at Glanville advertising the availability of the draft Plan, dates and times for the open house drop-in sessions, and inviting feedback;
- Direct mailed letters to identified major landowners/land managers on the Lefevre Peninsula;

- Direct mailed letters to identified stakeholders including government agencies, service providers, educational institutions and Members of Parliament;
- Direct mailed letters to identified community groups;
- Information station at the Civic Centre (including availability of information brochure, fact sheets and feedback from);
- Council's website;
- Advertisements in the Messenger newspaper;
- Facebook posts; and
- Twitter.

Opportunities to provide feedback on the draft Plan comprised:

- Attendance at an open house, drop-in session;
- Completion of an online feedback form on Council's website;
- Completion of a hard copy feedback form available at Council's Port Adelaide offices and the Semaphore Library;
- Provision of a written submission; and
- Invitation to interested groups to meet with project team to hear about the draft Plan and provide feedback.

6.3.2 Participation in the Consultation Process

The following participation in the consultation on the draft Plan was recorded:

- A meeting was held with the Port Adelaide Environment Forum which was attended by more than 30 people;
- A workshop with Council's Elected Members was undertaken which included a presentation, opportunities for questions of the project team, and interactive, small group discussions;
- 3 written submissions were received;
- 3 people attended the open house sessions; and
- No feedback forms were completed.

6.3.3 Key Messages from the Consultation Process

The key messages from the consultation process included:

- The Lefevre Peninsula is a unique ecological system. Water quality in the Port River is a significant issue and the estuary is an important ecosystem that needs to be protected;
- Increased stormwater runoff from infill development is a key issue for stormwater management on the Peninsula;
- There are concerns over the lack of open space in the Peterhead/Largs/Birkenhead area and the limitations that this places on the available stormwater management options;
- There is strong support for using infiltration systems to reduce the volume of stormwater being discharged to the Port River and Gulf St Vincent;

- There is strong support for stormwater projects that provide a water quality improvement function;
- Community education is required to promote the implementation of WSUD on private property, including rainwater tanks, soakage systems and raingardens;
- There was a high level of interest in the interaction between stormwater and groundwater, in particular the sustainability of groundwater resources and the potential for impervious areas to limit traditional groundwater recharge; and
- A major business has reported that drainage issues have the potential to impact their operations.

7 Stormwater Management Plan

7.1 Prioritisation and Timeframes

The actions outlined in this Stormwater Management Plan will require implementation to be scheduled across many years, in order to be accommodated sustainably within the City of Port Adelaide Enfield's budget 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 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 the consultation workshops, 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 Lefevre Peninsula 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 Lefevre Peninsula.

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 the City of Port Adelaide Enfield 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 (100 year ARI)	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 (100 year ARI)

The flood mitigation strategies for each catchment have been grouped together and prioritised based on a ratio of estimated reduction in flood damages (100 year ARI) against the budget estimate for the corresponding capital works. 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 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.

- Reduced Property Inundation

These values (number of properties) were obtained through reference to the 100 year ARI floodplain mapping of the ultimate scenario.

- Street Nuisance

This value was assigned based on judgement of the improvements demonstrated by the 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 in consultation with the Project Steering Committee (refer Appendix E) 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

Strategy / Project	Weighted Score
Hughes Street - Drainage & Naval Reserve Basin - Detention, Pump	3.97
Anthony Street - Drainage	3.85
Hargrave Street - Lateral Drainage	3.53
Semaphore Road - Drainage	3.33
Phillips Reserve Basin - Detention	3.32
Kolapore Avenue - Drainage & Carnarvon Reserve Basin - Detention	3.25
Aldinga St Reserve Basin - Detention	3.15
Railway Terrace Basin - Detention, Pump	3.15
Carlisle Street - Drainage & Nazar Reserve Basin - Detention	3.15
Charon Reserve Basin - Detention, Pump	3.13
Goldsworthy Road - Drainage	3.10
Lulu - Drainage, Pump	3.05
Jetty Road - Drainage, Pump & Warwick Street Basin - Detention	3.00
Deslandes Street - Drainage	2.83
Midlunga Railway Station - Pump	2.83
Largs North - Conversion to Gravity Drainage	2.60
Estella Street Basin - Detention	2.57

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 or Gulf St Vincent (annual average)	$13\frac{1}{3}$	>10 tonnes	5-10 tonnes	2-5 tonnes	1-2 tonnes	<1 tonne
Stormwater Reuse or 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	Create new	Improve existing	Restore existing	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*					

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

- 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 in consultation with the Project Steering Committee (refer Appendix E) 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

Strategy / Project	Weighted Score
Estella Street Basin - Vegetated Swale	4.37
Carnarvon Reserve Basin - Infiltration System	3.93
Streetscape Raingarden	3.67
Anthony Street Drain - Infiltration System	3.67
Aldinga Street Reserve Basin - Wetland & ASR	3.47
North Haven Wetland	3.33
Coastal Outfall Infiltration Basin	3.30
Nazar Reserve Basin - Vegetated Swale	3.23
Phillips Reserve Basin - Infiltration System	3.20
Railway Terrace -Infiltration System	3.07
Naval Reserve Basin - Bioretention System	3.23
Warwick Street Basin - Infiltration System	3.07
Carlisle Street GPT	2.87
Hamilton Avenue GPT	2.87
Mersey Road North GPT	2.83
Veitch Road GPT	2.83
Charon Reserve Basin - Bioretention System	2.83

7.2 Strategy Action Costs, Benefits and Priority Summary

A consolidated list of prioritised actions is presented in Table 7.5, together with a brief description of the benefits realised 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

The City of Port Adelaide Enfield is responsible for implementation of all activities identified within this Plan. It is expected that the Council will continue to liaise with relevant State Government departments and agencies to satisfy a variety of regulatory requirements, including the Adelaide and Mount Lofty Ranges Natural Resources Management Board and Department of Environment, Water and Natural Resources.

7.4 Implications for Adjoining Catchments

There are no significant implications for stormwater management within the Lefevre Peninsula Stormwater Management Plan area on adjoining catchments. However any future flood study of the adjacent West Lakes catchment should have regard to the potential for receiving minor spills across Bower Road from the Hart Street catchment at the southern end of the Lefevre Peninsula.

Table 7.5— Stormwater Management Plan Actions Summary

Priority	Project Location	Activities	Catchment	Project ID	App D Sheet	Flood Mitigation Benefit	Water Quality Benefit	Runoff Volume Benefit	Capital Cost	SMA Eligible
High	Kolapore Avenue / Carnarvon Reserve	Drainage, Detention, Infiltration	Mersey Road	D12, Q14	06	✓	✓	✓	$1,310,000	✓
High	Anthony Street	Drainage, Infiltration	Largs Bay Shore	D9, Q1	05	✓	✓	✓	$1,175,000	
High	Hughes Street / Naval Reserve	Drainage, Detention, Pump Station, Bioretention	Semaphore Road East	D6, Q8	04	✓	✓		$2,270,000	
High	Semaphore Road	Drainage, GPT	Carlisle Street / Semaphore Road East	D5	08 / 08a	✓	✓		$2,405,000	
High	Various	Raingarden	Various	Q7	N/A		✓		$800,000	
High	Hargrave Street	Lateral Drainage	Hargrave Street	D7	N/A	✓			$1,675,000	
High	Various	Rainwater Tanks	Various	Q18	N/A	✓		✓	N/A	
High	N/A	FloodSafe Program	Various	D18	N/A	✓			N/A	
High	N/A	Floor Level Survey	Various	D19	N/A	✓			N/A	
High	N/A	Business Plan Integration	Various	Q19	N/A	✓	✓	✓	N/A	
High	N/A	Community WSUD Education	Various	Q20	N/A		✓	✓	N/A	
High	Largs North Reserve	Monitor Permeable	Mersey Road	Q21	N/A		✓	✓	N/A	

Priority	Project Location	Activities	Catchment	Project ID	App D Sheet	Flood Mitigation Benefit	Water Quality Benefit	Runoff Volume Benefit	Capital Cost	SMA Eligible
		Paving								
Medium	Aldinga Street Reserve	Detention, Wetland and ASR	Mersey Road	D13, Q10	01	✓	✓	✓	$2,610,000	✓
Medium	Warwick Street / Jetty Road	Drainage, Detention, Pump Station, Infiltration, GPT	Jetty Road / Centre Street	D11	02	✓	✓	✓	$13,210,000	✓
Medium	Lulu	Drainage, Pump Station, GPT	Lulu	D8	10	✓	✓		$14,235,000	✓
Medium	Railway Terrace	Detention, Pump Station, Infiltration	Taperoo Shore	D16, Q16	14	✓	✓	✓	$285,000	
Medium	Phillips Reserve	Detention, Infiltration	Carlisle Street	D4, Q15	09	✓	✓	✓	$305,000	
Medium	Goldsworthy Road	Drainage, GPT	Hart Street	D3	03	✓	✓		$580,000	
Medium	Estella Street	Detention, Vegetated Swale	Hamilton Avenue	D17, Q12	17	✓	✓		$840,000	
Medium	Various	Coastal Infiltration	Semaphore / Largs Bay / Largs North / Taperoo Shores	Q1	05 / 11 / 12		✓	✓	$875,000	
Medium	Carlisle Street / Nazar Reserve	Drainage, Detention, Vegetated Swale	Hart Street	D2, Q13	15 / 16	✓	✓		$1,715,000	
Medium	North Haven	Wetland and ASR	North Haven	Q11	18		✓	✓	$1,895,000	
Low	Hamilton Avenue	GPT	Hamilton Avenue	Q2	N/A		✓		$270,000	

Priority	Project Location	Activities	Catchment	Project ID	App D Sheet	Flood Mitigation Benefit	Water Quality Benefit	Runoff Volume Benefit	Capital Cost	SMA Eligible
Low	Carlisle Street	GPT	Carlisle Street	Q3	N/A		✓		$270,000	
Low	Deslandes Street	Drainage	Hart Street	D1	N/A	✓			$340,000	
Low	Mersey Road North	GPT	Mersey Road	Q5	N/A		✓		$425,000	
Low	Veitch Road	GPT	Mersey Road	Q6	N/A		✓		$425,000	
Low	Midlunga Railway Station	Pump Station	Taperoo Shore	D15	13	✓			$1,185,000	
Low	Charon Reserve	Detention, Pump Station, Bioretention	Taperoo Shore	D14, Q9	07	✓			$1,360,000	
Low	Various	Conversion from Soakage System to Gravity Drainage	Largs North Shore	D10	11 / 12	✓			$2,975,000	
								TOTAL	**$53,435,000**	

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