West Lakes Catchment

Stormwater Management Plan

City of Charles Sturt

CCS045206
5 November 2021
Ref: 20190818R004

Building exceptional outcomes together

Document History and Status

Rev	Description	Author	Reviewed	Approved	Date
A	Draft for initial Council review	MM	OO	OO	7 July 2021
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Client: City of Charles Sturt
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Glossary

AAD	Annual average damage
ACWS	Adelaide coastal waters study
ACWQIP	Adelaide coastal water quality improvement plan
AEP	Annual exceedance probability
ASR	Aquifer storage and recovery
ARI	Average recurrence interval
ARR	Australian Rainfall and Runoff
AUSMAP	Australian Microplastic Assessment Project
BCR	Benefit-cost ratio
BoM	Bureau of Meteorology
DEM	Digital elevation model
DIT	Department for Infrastructure and Transport
EY	Exceedances per year
GP/GPT	Gross pollutant / Gross pollutant trap
HGL	Hydraulic grade line
MAR	Managed aquifer recharge
ODMG	Optimised Decision Making Guidelines
PET	Potential evapotranspiration
RAGC	Royal Adelaide Golf Club
RAM	Rapid appraisal method
RCP	Representative concentration pathway
SES	State Emergency Service
SMA	Stormwater Management Authority
SMP	Stormwater management plan
SSWFE	Southern and South Western Flatlands (East)
TN	Total nitrogen
TP	Total phosphorus
TSS	Total suspended solids
WPW	Waterproofing the West
WSSA	Water Sensitive South Australia
WSUD	Water sensitive urban design

1 Introduction

This draft stormwater management plan (SMP) for the West Lakes catchment has been developed to provide the framework for a coordinated and multi-objective approach to the management of stormwater on a whole of catchment basis. The SMP is aimed at addressing existing problems and identifying opportunities that provide a range of benefits. It is intended that the plan be used as the basis for developing budgets for the works recommended herein. Consistent with the requirements of the Stormwater Management Planning Guidelines (Stormwater Management Authority, 2007), the SMP includes the following catchment-specific details:

- Objectives for managing stormwater in the catchment.
- Actions (both structural and non-structural) required to manage stormwater to achieve beneficial outcomes and meet the specified objectives.
- Justification for any proposed actions.
- Estimates of capital and recurrent costs and identification of priorities and timeframes for each of the actions.
- Obligations of the relevant parties in funding, implementing and communicating the plan.

The plan has been prepared in consultation with staff from the City of Charles Sturt (Council) and other key stakeholders.

2 Catchment characteristics

The study area for the West Lakes SMP consists of eight sub-catchments which discharge to West Lakes ('the Lake'). The study area, which is shown in Figure 2.1, has a total area of approximately 25.4 km^2 and extends along the coast from Semaphore Park in the north to Henley Beach in the south and towards Port Road to the east. The study area is located entirely within the City of Charles Sturt.

The study area is predominantly residential in nature, and most of the area is heavily developed. An extensive underground drainage network services the catchment, conveying stormwater runoff to multiple discharge points within the Lake, either directly or via an open channel.

2.1 Description of sub-catchments

The major sub-catchments within the study area are listed in Table 2.1. The catchment boundaries are shown in Figure 2.2.

Table 2.1 West Lakes SMP sub-catchments

Catchment	Area (km^2)	Outlet location
Henley Grange	6.0	Trimmer Parade (western end)
Meakin	4.4	Trimmer Parade (western end)
Trimmer Parade	4.6	Trimmer Parade (western end)
West Lakes Central	1.0	Various discharge points into West Lakes
West Lakes East	3.5	Adjacent to Sea Lake Court
West Lakes North East	0.8	Adjacent to Lochside Drive and adjacent to Eildon Court
West Lakes South	1.7	Various discharge points into West Lakes
West Lakes West	3.3	Various discharge points into West Lakes

The study area receives overflows from a number of external catchments including Port Road (which discharge into the Lake) and the Torrens East Catchment.

Overflows from the Port Road catchment, which is located to the east of the study area, are discharged into the Lake. The Port Road catchment is not covered by the SMP as it is addressed separately by the Port Road SMP (Connell Wagner, 2007). The Port Road catchment is included in the TUFLOW model so that the impact of these overflows on the study area can be modelled.

The Frogmore Road pump station, which is located in the Torrens East catchment to the southeast of the study area contributes flows to the West Lakes catchment and has therefore the pump station and contributing stormwater catchment has also been included within the modelling. Previous modelling of the broader Torrens East catchment (Tonkin, 2012) shows that aside from in the vicinity of the Frogmore Road pump station, the flows from the Torrens East catchment into the study area are negligible and hence the broader Torrens East catchment is not included in the TUFLOW model.

Flood mapping of the West Torrens catchment (to the south of the study area) was undertaken in parallel (by a third party) with the modelling for the West Lakes SMP. The flood mapping shows water ponding near the boundary of the West Lakes SMP study area in a 1% AEP event. Review of the DEM indicates that this area is a trapped low point and it is not expected that these flows would contribute flows to the West Lakes SMP study area. This catchment is therefore not included within the West Lakes TUFLOW model.

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WEST LAKES STORMWATER MANAGEMENT PLAN
STUDY AREA BOUNDARY

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Figure 2.1

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CITY OF CHARLES STURT

WEST LAKES STORMWATER MANAGEMENT PLAN
MAJOR SUB-CATCHMENT BOUNDARIES

Figure 2.2

2.2 Topography

Situated on the western Adelaide Plains, the West Lakes SMP catchment gradually and uniformly slopes towards the coast.

A digital elevation model (DEM) of the study area was provided by Council. The DEM was extracted from the Adelaide Metro Councils' DEM which is owned by the Department of Infrastructure and Transport. The LiDAR based DEM was flown in April 2018 by Aerometrex using a RIEGL VQ-780i sensor, with a minimum of 8 points per square metre. The original DEM had a grid size of 1 m, however Aerometrex reprocessed the raw data to provide a 0.5 m grid size for the purpose of the SMP.

Review of the digital elevation model shows that the catchment generally falls in a north-westerly direction. Surface elevations of the catchment range from approximately 13 mAHD at its easternmost point in Beverley to approximately 1.5 mAHD at the northern boundary.

The invert of the Lake itself is unknown but based on the outlet structure into the Port River is estimated to have an invert of -3.0 mAHD. The invert of the Lake does not influence the results of the modelling as the Lake never empties. The water level in the lake is controlled by the tidal levels.

Some relatively localised formations in the topography are seen, particularly the dune system that runs along the coastline and the variations in topography introduced by the Royal Adelaide, Grange and West Lakes golf clubs.

The DEM used to define the topography for the study is shown in Figure 2.3.

2.3 Groundwater

The West Lakes SMP area is located within the Urban Torrens groundwater catchment. AWE (2002) reviewed the hydrogeology of the Urban Torrens catchment for the purpose of understanding the potential for aquifer storage and recovery (ASR) schemes within the area. A summary of the groundwater, in the context of implications on the management of stormwater, is provided in the following sections.

2.3.1 Geology

The study area is located within the Adelaide Plains sub-basin which is underlaid by the St Vincent Basin formation. The sediments consist of interbedded Quaternary sands and clays up to 80 m thick which in turn are underlain by shelly limestones and sands of Tertiary age, averaging 150 m in thickness. These sediments overlie basement rocks. The heavily developed nature of the urban catchments combined with the clayey nature of the soils limit direct recharge from rainfall to the shallow aquifers. Recharge to the shallow aquifer does occur from creeks and some reaches of the River Torrens through permeable alluvial sediments. The deeper Tertiary aquifers are recharged only by groundwater flow from the fractured rock aquifers along the faulted Hills Face zone. A summary of the generalised stratigraphy is provided in Table 2.2. Georges (2006) notes that the first Tertiary aquifer (T1) is recognised as the superior aquifer in terms of salinity and yield, and is also the shallowest of the four Tertiary aquifers. It is therefore considered that the T1 aquifer has the greatest potential for stormwater harvesting and reuse schemes.

Table 2.2 Adelaide Plains – generalised stratigraphy (Gerges, 2006)

Age	Lithology	Hydraulic Characteristics
Quaternary	Mainly fluvio-lacustrine clay with minor sands and gravel.	Sands and gravels form thin aquifers, usually high in salinity and low yielding.

Age	Lithology	Hydraulic Characteristics
Tertiary	Fossiliferous, glauconitic, partly carbonaceous sand, sandstone, limestone, chert, marl and shell remains. Thick clay layers and thin lignitic beds.	Sand, sandstone and limestone form aquifers with potential high yields. Clay, chert and marl form leaky confining beds. The late Tertiary sediments contain the better quality and quantity of water.
Precambrian	Slate, phyllite, quartzite and dolomite.	Where highly fractured (near faults) high supplies of low salinity.

2.3.2 Hydrogeology

AWE (2002) defined a number of hydrogeological zones based on the hydrogeological characteristics and the nature of groundwater use. The zones are illustrated in Figure 2.4. It can be seen that the West Lakes SMP study area is largely within Zone 2 and Zone 4.

Zone 2 coincides with the West Lakes irrigation area. In this area the groundwater is used for irrigation of golf courses and other recreational grounds. There is a resultant seasonal effect on the water table in this zone due to large quantities of seasonally extracted groundwater.

Zone 4 contains domestic bores that mostly access the shallow Quaternary aquifers for garden watering.

2.4 Soils

The distribution of soils across the catchment was derived from information contained in Bulletin 46 (Taylor, Thomson, & Shepherd, 1974) and is shown in Figure 2.5.

The catchment is predominantly underlain by red brown earths to the east and estuarine muds and sands to the west. Pockets of dune sands and alluvial soils are also found within the study area.

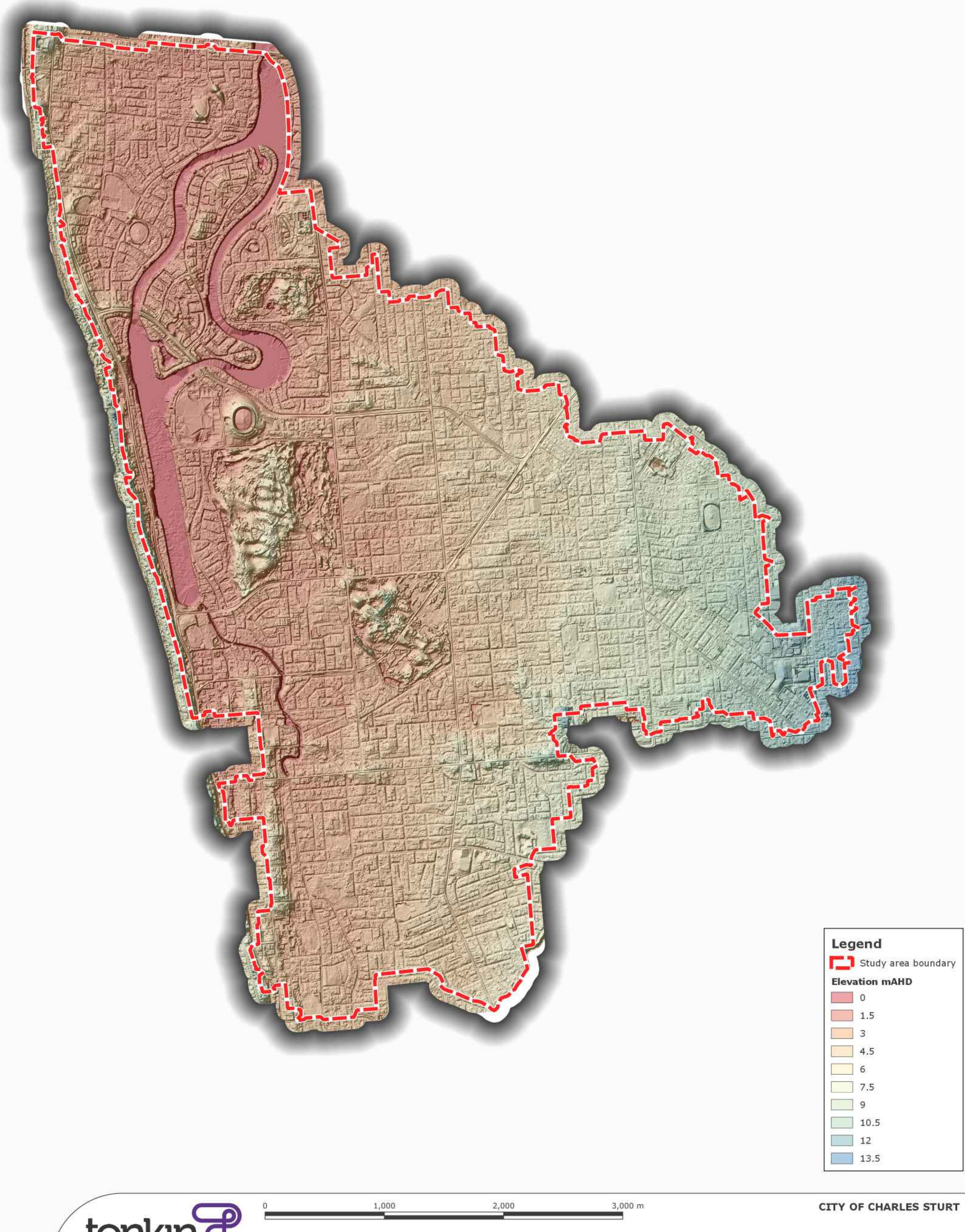
The red brown earths are characterised by brown sandy topsoil overlying red brown sandy clay of indeterminate thickness. This soil type generally experiences low shrinkage or swelling in response to changes in moisture content. The drainage capability of the soil is moderate to high.

Estuarine muds and sands are grey, dark grey or mottled silt and sand deposits with some organics. They generally do not shrink or swell with changes in moisture content, and drainage through them is relatively rapid.

The alluvial soils within the catchment are those deposited along the River Torrens and are generally silty and sandy clays. Internal drainage tends to be rapid and generally they do not undergo shrinking or swelling with changes in moisture content.

The dune sands are remnants from past dune systems along the Adelaide coast. They vary in colour, and are predominantly sand but can contain layers with higher clay content. Generally, they are well drained and stable.

It is considered that all of the soil profiles in the catchment are suitable for stormwater infiltration given the right conditions. This is a result of their low potential for swelling and shrinkage, and their good drainage characteristics.



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Digital terrain model from Aerometrix, 2019

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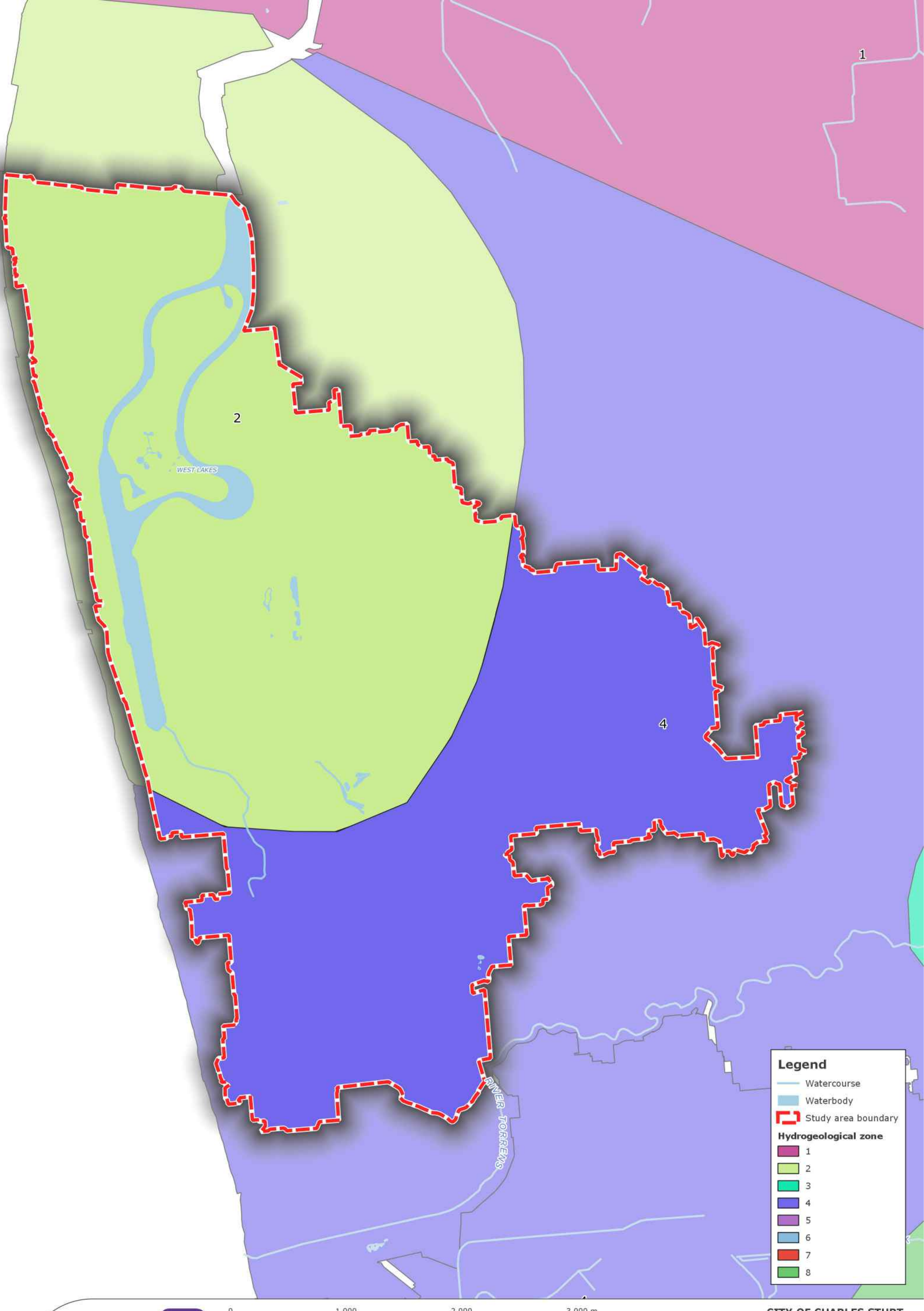
WEST LAKES STORMWATER MANAGEMENT PLAN
STUDY AREA TOPOGRAPHY

Figure 2.3



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Watercourses from Data SA, 2018
Hydrogeological zones from AWE, 2002

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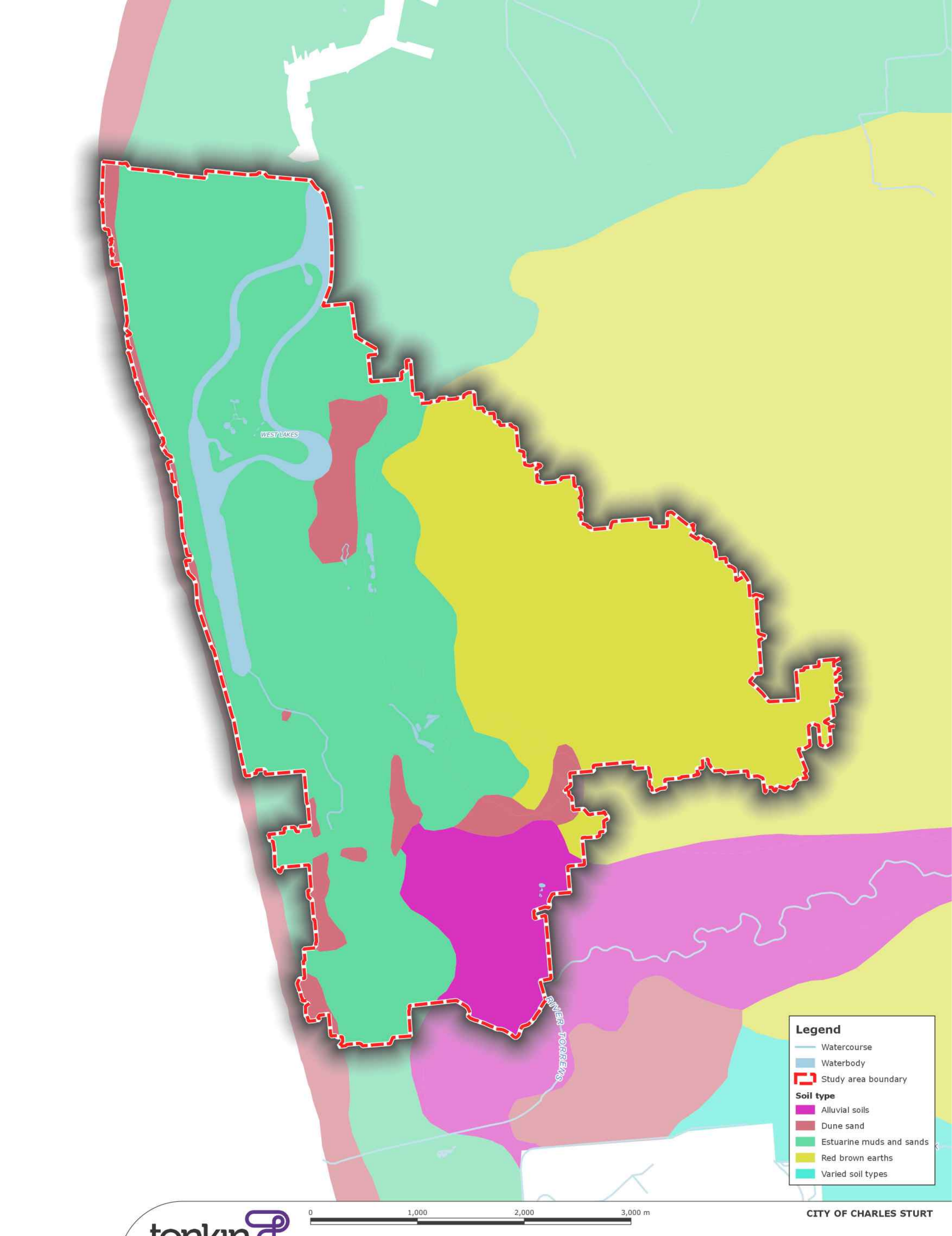
WEST LAKES STORMWATER MANAGEMENT PLAN
HYDROGEOLOGICAL ZONES

Figure 2.4



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Data Acknowledgement:
Watercourses from Data SA, 2018
Soils from Dept. of Mines, 1974

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WEST LAKES STORMWATER MANAGEMENT PLAN
SOILS

Figure 2.5

2.5 Land use and zoning

Current land use in the West Lakes catchment is primarily residential, with small pockets of industrial, commercial and retail use. There are also three golf courses within the study area which cover approximately 8% of the catchment. Maps of existing land use and land development zones are provided in Figure 2.6 and Figure 2.7 respectively. Table 2.3 provides a summary of land use (by area) within the catchment.

Table 2.3 Land use classification

Land use category	Proportion of total catchment area
Residential	49%
Open space or recreation	15%
Education	2%
Other land uses	14%
Land not in cadastre (including road reserves and the Lake itself)	20%

2.6 Receiving waters

All of the catchments within the study area discharge into West Lakes, which is a man-made lake that was constructed on a tidal swamp as part of the development of the area by Delfin (now Lend Lease communities). The Lake is flushed by seawater and the water quality in the Lake is largely driven by tidal fluctuations which promote circulation and flushing of the Lake. In January 2018, a fish die-off was linked to low levels of oxygen near the Lake inlet, combined with warm temperatures. The underlying cause of the water quality issues was attributed to limited tidal movements.

While stormwater from urban areas is a known source of pollutants including nutrients, heavy metals, pesticides and hydrocarbons, all of which may negatively impact water quality, it is understood that historically stormwater discharges have not significantly impacted on water quality in the Lake.

2.6.1 Lake operations

Flow into the Lake is driven by tide levels in Gulf St Vincent and is controlled by tidal gates which allow water into the southern end of the Lake (near the Trimmer Parade inflow point) at high tide via an intake duct and 3.5 m diameter conduit. This water then flows in a general northerly direction through the Lake.

At its northern extent, the Lake discharges to the Port River through a set of three tide gates. Flows to the Port River are driven by the water level difference between the River and the Lake, with the flap gates preventing any tidal backflow into the flood storage.

The Department for Infrastructure and Transport (DIT) is responsible for water level management in the Lake, including management of inlet and outlet gates. The current operating principles of the Lake are as follows (DIT, 2021):

- Normal Lake level is controlled by the inlet gates at Trimmer Parade.
- The inlet gates are opened automatically to allow seawater to flow into the Lake whenever the Lake is below its pre-set target height and the sea level is above the Lake level at the time.
- The inlet gates close when the Lake reaches its target height or if the sea level falls below the Lake level before the target height is reached.

- When the level in the Port River falls below the Lake level the flap gates at the outlet (at Bower Road) are pushed open and water flows out of the Lake.
- Water will continue to flow out of the Lake until the level in the Port River rises again, causing the flap gates to close.
- If the Lake level falls below the pre-set low level, then the gates will close to prevent further outflows to the Port River. The gates will automatically open once the Port River rises above the Lake level.

The hydraulic design of the Lake aims for the Lake to be flushed twice daily, with complete turnover of water due to tidal flushing every 7-14 days (Read, 1971). This is intended to manage the water quality within the Lake.

2.6.2 Marine habitats

West Lakes is a man-made Lake. National benthic mapping (accessed via NatureMaps, 2021) defines the benthic habitat in West Lakes as "bare sand". No flora or fauna species are identified and the biodiversity values are considered to be limited (AMLR NRM Board, 2008).

Council have implemented a project to improve the fish habitat in the Lake with the installation of 12 artificial reefs. The reefs are expected to promote the health of the Lake and improve the fish habitat in the Lake.

It is considered that the greatest direct impacts of stormwater discharges on the Lake itself are likely to be on the recreational users of the Lake as opposed to the marine habitats. The discharges will also contribute to the total loads of suspended solids and nutrients entering the Port River, and subsequently the Gulf.

2.6.3 Microplastics

Microplastic pollution in aquatic environments is a growing concern world-wide due to its potential impacts on aquatic organisms and ecosystems. Microplastics are defined as plastics that are smaller than 5 mm and originate from many sources.

The Australian Microplastic Assessment Project (AUSMAP) undertakes microplastic surveys at coastal sites around South Australia to help map the extent of microplastic accumulation in our waterways and beaches, and to help improve awareness of microplastics.

The 2019 AUSMAP sampling included three locations around West Lakes, all of which had microplastic loads in excess of 5,000 particles/m^2. In contrast the other sites in the state, including Murray Bridge and metropolitan beaches, had concentrations of less than 11 particles/m^2. A recording of 9,517 particles/m^2 recorded at Towpath Reserve on the shores of West Lakes in 2019 is the highest recorded concentration within Australia.

Over 80% of the recorded microplastics in West Lakes are 'white foam', and the AUSMAP report (2019) concludes that it is difficult to identify the source of such plastics. Sources may include infrastructure associated with the rowing course and materials used in the construction of private pontoons on the Lake. Other sources of microplastics may include certain land uses within the catchments.

It is recommended that more extensive sampling be undertaken to build up a better picture of spatial and temporal variations in microplastics in West Lakes. It is also recommended that targeted sampling occur at stormwater inlets to understand the local catchment contribution.

Once there is more certainty regarding the source of the microplastics, it is recommended that engagement with key stakeholders be undertaken to work towards education and awareness of the issue.

2.6.4 Stormwater quality within the catchment

A water quality gauge is located within the study area at the Kirkcaldy wetland within the watercourse at Nash Street, Grange. A summary of the recorded water quality at this location is provided in Table 2.4 (Water Data Services, 2019). This data has been used to verify the results of the MUSIC model developed as part of the SMP.

Table 2.4 Kirkcaldy wetland water quality summary

Parameter	2013	2014	2015	2016	2017	2018
Annual flow (ML)	971.37	831.95	306.16	1571.96	753.03	620.46
Total phosphorus load (t)	0.16	0.15	0.05	0.33	0.14	0.10
Total nitrogen load (t)	1.78	0.97	0.35	2.71	1.18	1.00
Suspended solids load (t)	63.40	48.64	11.24	136.82	35.93	38.23

2.6.5 Known stormwater risks

Stormwater discharges from the study area flow into West Lakes, which is diluted with sea water and then discharges into the Port River as a result of tidal flushing of the Lake.

Stormwater has been directly linked to negative impacts on the environments of the Adelaide Coastal Waters which, by definition, includes the Port River. The Adelaide Coastal Waters Study (Fox et al, 2001) was undertaken in response to the noticeable decline in coastal water quality and the rapid loss of seagrass meadows. The ACWS concluded that nutrient and suspended solid loads associated with wastewater treatment, industrial and stormwater discharges into Adelaide coastal waters are causing the loss of seagrass. Stormwater discharges were identified as the key contributor of "suspended solid pollution", with the study recommending a 50% reduction in suspended solids.

Habitats in the immediate vicinity of stormwater outfalls are most at risk from direct stormwater impacts. Further away from the outfalls, dilution reduces the concentration of pollutants, thereby reducing the direct impacts on marine habitats. Flows through West Lakes (predominantly tidal flushing) are estimated to be in the order of 600 ML/day (Pfennig, 2008). By comparison, the MUSIC modelling estimates that the annual average volumes of stormwater discharging into the Lake are 3,500 ML/a (based on the existing level of development and historic climate).

Given the lack of natural habitat in West Lakes, and the strong dilution of stormwater with seawater prior to discharge into the Port River, it is considered that the primary risks associated with stormwater discharges into the Lake are:

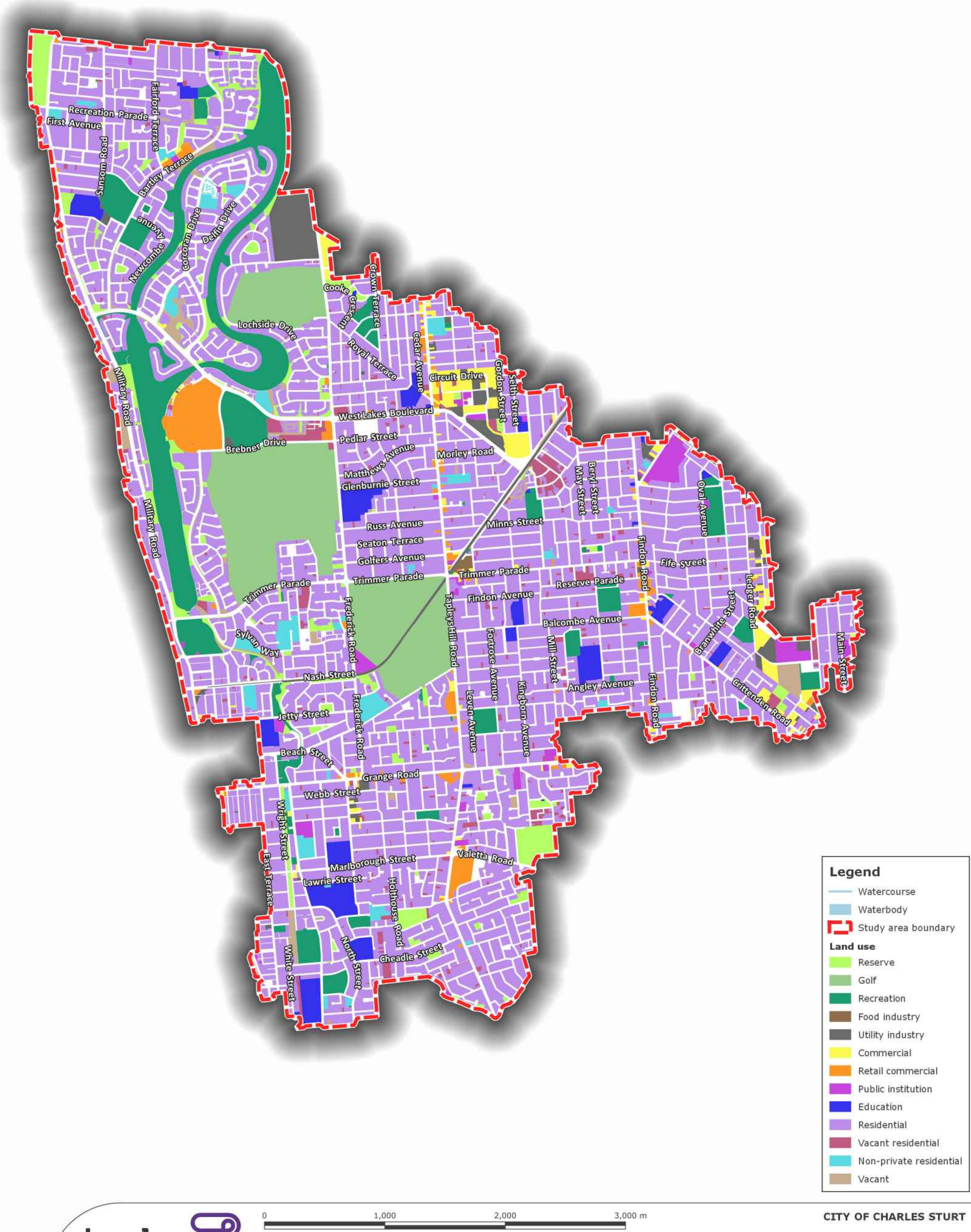
- Impacts on recreational users, particularly following a rainfall event.
- Accumulation of heavy metals and microplastics in marine species in the Lake (which may be consumed by humans).
- Contribution of suspended solid and nutrient loads to the Port River and coastal environments.

On the basis of the above, it is considered that the targets for improved water quality should consider a reduction in average annual loads of nutrients, as opposed to concentration-based water quality targets

2.6.6 Desirable end state values for West Lakes

While the nature of West Lakes means that the biodiversity values within the lake itself of are considered to be limited (AMLR NRM Board, 2008), the lake discharges into the Port River, which forms part of the Adelaide Coastal Waters.

Given the potential stormwater impacts on the Coastal Waters, the desirable end state values for the West Lakes SMP study area are improved water quality through a reduction in suspended solids and nutrients.



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Land use from Data SA, 2017

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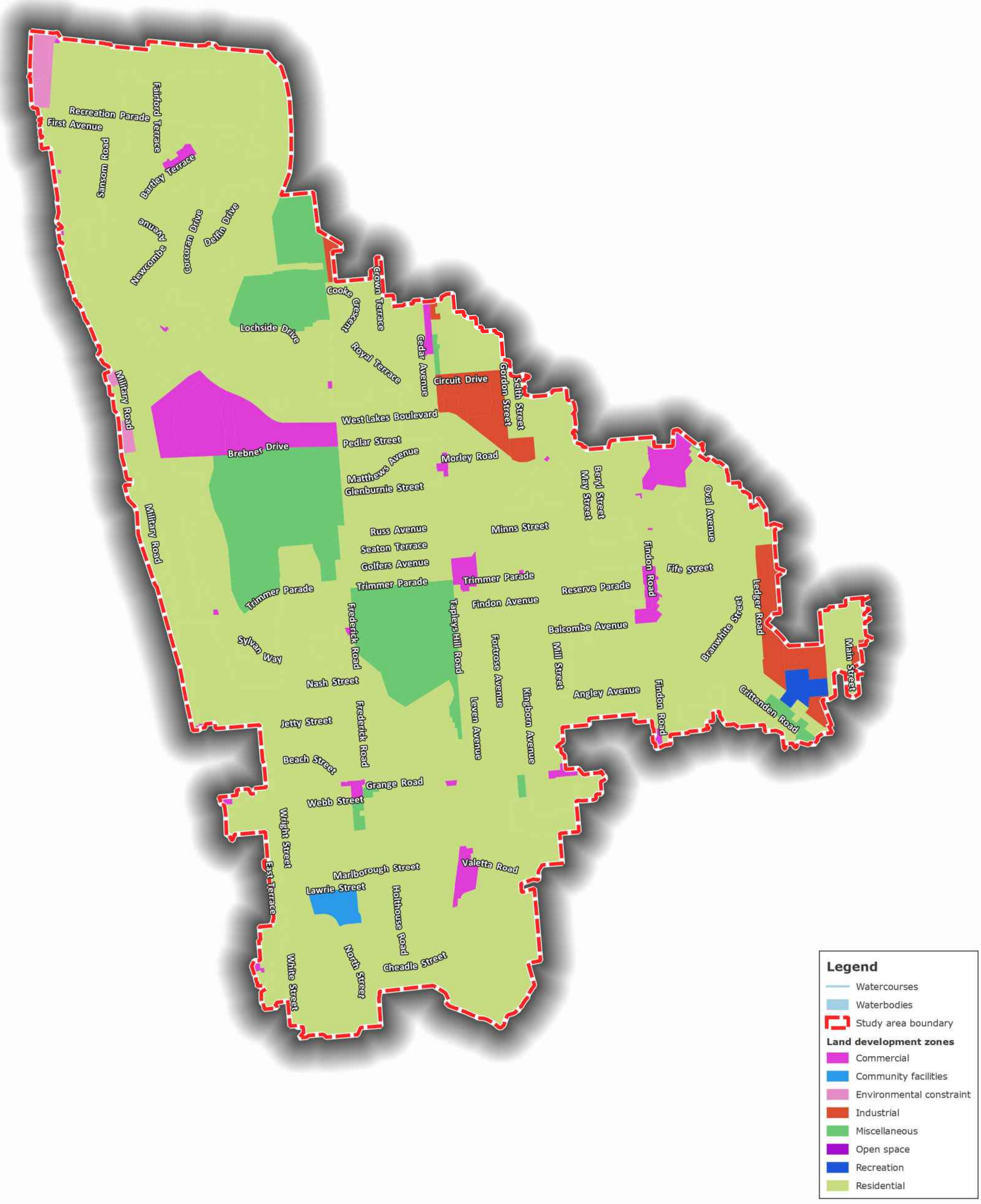
WEST LAKES STORMWATER MANAGEMENT PLAN
EXISTING LAND USE

Figure 2.6



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Watercourses and zoning from Data SA, 2018
Roads and railways from Data SA, 2019

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WEST LAKES STORMWATER MANAGEMENT PLAN
LAND DEVELOPMENT ZONES

Figure 2.7

2.7 Existing stormwater infrastructure

As a heavily developed urban area, extensive underground stormwater infrastructure exists in the West Lakes catchment with over 210 km of pipes and culverts. A summary of the existing stormwater infrastructure within the study area is provided in Table 2.5. The existing stormwater network is also shown in Figure 2.8.

In addition to the stormwater drains, Council is also responsible for the recycled water pipeline associated with the Waterproofing the West stormwater harvesting scheme. Additional information about this scheme is provided in Section 2.8.

Table 2.5 Summary of existing stormwater infrastructure

Asset type	Description	Quantity
Gravity pipes	≤300 mm	9,161 m
	375 - 750 mm	139,614 m
	825-1200 mm	31,007 m
	>1200 mm	17,674 m
	Total	197,456 m
Box culverts	Span < 1.2 m	6,272 m
	Span ≥ 1.2 m	10,217 m
	Total	16,488 m
Recycled water pipeline	Within the West Lakes SMP area	18,326 m
	Total (City of Charles Sturt)	28,003 m
Rising main	Stormwater rising main	3,048 m
Nodes	Side-entry pits	3,992
	Grated inlet pits	441
	Junction box/man hole	1,349
Gross pollutant traps/debris collectors	Number (total)	24

There is a Council owned wetland (which is part of the WPW scheme) within Cooke Reserve. There are also privately owned wetlands within the Grange Golf Club and the Royal Adelaide Golf Club (RAGC).

Additionally, soakage pits have been installed at various locations within the catchment (both within reserves and the road reserve) to promote infiltration of runoff. These locations include Frank Mitchell reserve, Willcocks Reserve, Fraser Street, Surrey Street and Duncan Street. \

2.7.1 Pump stations

The Golfers Avenue pump station is located within the study area. There is also a pump station which diverts flows from Meakin Terrace into the Royal Adelaide Golf Club wetland.

Additionally, the Frogmore Road pump station, while located in the Torrens East catchment (i.e. outside of the SMP study area) is included within the model. The Frogmore Pump Station comprises three pumps with a combined capacity of 1.2 m^3/s. The pumps direct flows from the upstream catchment to the River Torrens. Flows exceeding the capacity of the pump station enter the West Lakes catchment via a pipe in Kidman Road.

2.7.2 Grange Lakes

The Grange Lakes corridor predominantly comprises an open channel than runs between Grange Road and the southern end of West Lakes. The upstream end of the channel takes the form of a natural waterway (Grange Creek), transitioning to a concrete lined open channel in the vicinity of the railway line, approximately 900 m upstream of West Lakes. The Grange Lakes system receives stormwater inflows from the Henley/Fulham Gardens catchment, Meakin Terrace catchment, Grange catchment and the Trimmer Parade catchment, conveying the flows in a northerly direction towards West Lakes. There is also the ability to divert water from the River Torrens into the upstream end of the Grange Lakes system.

The Grange Lakes corridor provides a range of functions including stormwater conveyance, water quality improvement, habitat provision and pathways for recreational purposes.

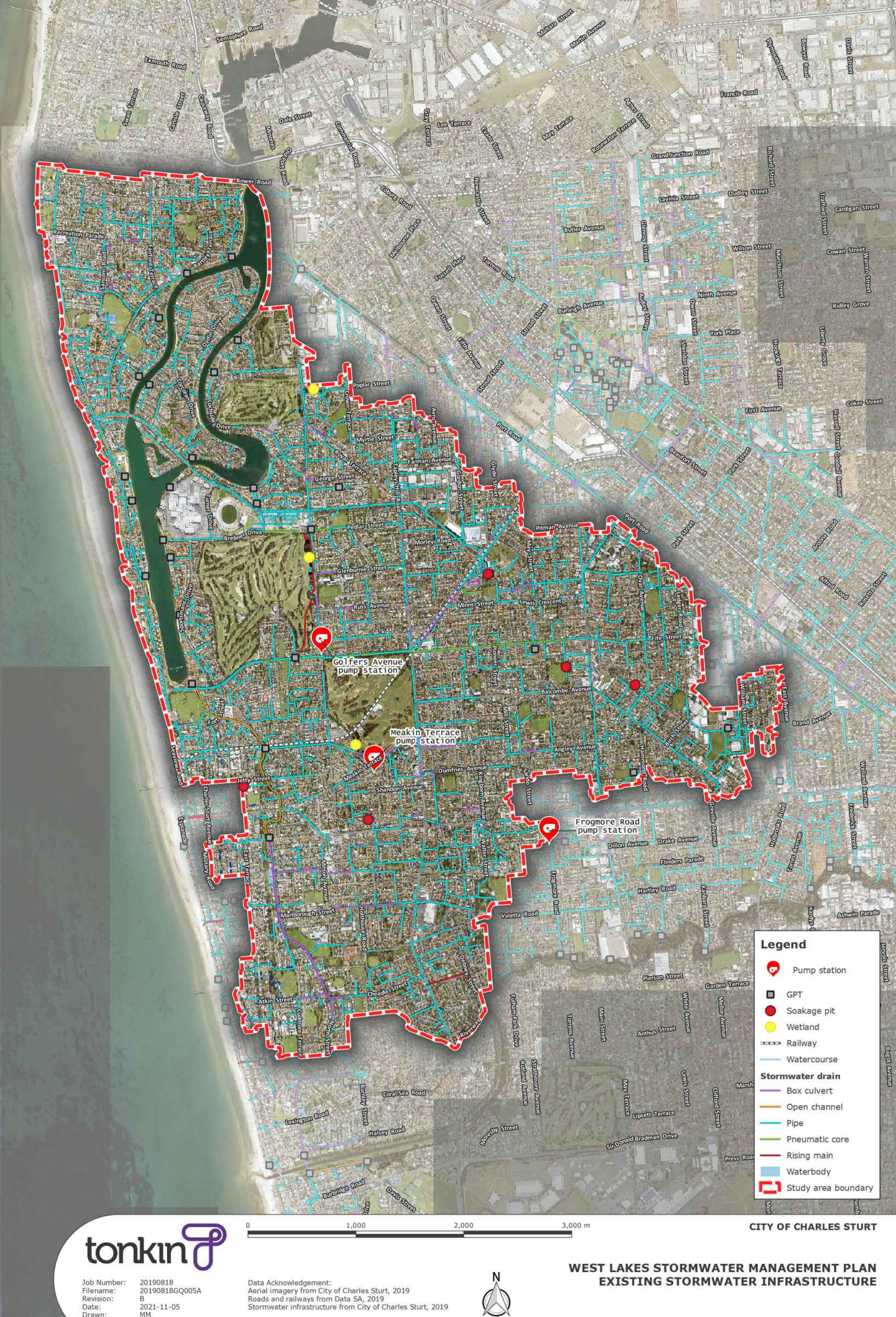
It is considered that there may be opportunities within the Grange Lakes corridor to improve the level of drainage service provided whilst also realising opportunities to provide improved water quality, increased biodiversity, improved aesthetics, increased recreational opportunities, and stormwater harvesting and re-use.

2.7.3 Condition of existing infrastructure

The condition of Council's stormwater infrastructure is reported in the Water Assets Management Plan (AMP), which was last updated in 2020. In the AMP, Council notes that regular condition audits are undertaken for stormwater infrastructure.

Council owns and operates its own CCTV service, and to date has undertaken condition assessments for approximately 70% of its stormwater network. The balance of the network has not yet been assessed to due to a combination of factors including small pipe sizes (the camera cannot fit in drains that are 225 mm or smaller), access issues and the fact that the asset is less than 20 years old.

Based on the data that Council has, it can be concluded that the overall network is generally in good condition, with 62% of assets being classified as being in 'good' or 'very good' condition and 32% of assets having an 'unknown' condition.



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Roads and railways from Data SA, 2019
Stormwater infrastructure from City of Charles Sturt, 2019

CITY OF CHARLES STURT

WEST LAKES STORMWATER MANAGEMENT PLAN
EXISTING STORMWATER INFRASTRUCTURE

Figure 2.8

2.8 Existing water reuse schemes

Council owns and operates the 'Water Proofing the West' scheme which is a region wide scheme that harvests, treats, and stores stormwater in the aquifer prior to distributing water for the purposes of irrigation and other non-potable uses. The scheme, which encompasses a number of sites, includes wetlands and biofilters for treatment, bores for injection and extraction and a distribution network in excess of 50 km long which distributes the water to customers across the Council area.

The scheme has a design harvest capacity of 2,400 ML/year and can harvest a combination of stormwater and water pumped from the River Torrens. While the scheme is not entirely within the SMP study area, two of the wetland sites are (Cooke Reserve and the West Lakes Golf Course) and it is considered that the scheme presents a source of non-potable water within the study area. The extent of the associated non-potable water reticulation network within the study area is shown in Figure 8.1.

In addition to the Council-owned stormwater harvesting scheme, there are two privately-owned stormwater harvesting and reuse schemes owned and operated by golf clubs within the SMP study area. The Grange and Royal Adelaide Golf Clubs both operate schemes which harvest water from Council's stormwater network with treatment via wetlands prior to injection into the aquifer. The water is then extracted during the warmer months and used for irrigation of the golf courses. The Grange Golf Club scheme has a design harvest capacity of 200 ML/a, while the Royal Adelaide Golf Club has a capacity of 324 ML/a. Review of historical data suggest that the typical volumes harvested by the schemes are 50 and 175 ML/a respectively. Further details regarding these schemes, and the reasons why the yields are less than the design harvest capacities are provided in Tonkin (2019).

2.9 Development potential

URPS was engaged by Tonkin to undertake an assessment of the current and potential future levels of development within the study area. The full report is contained within Appendix A. The assessment (URPS, 2019) was made with regard to the planning context provided in the newly released Planning and Design Code and 30 Year Plan for Greater Adelaide.

Three residential zone development scenarios were assessed using the following criteria:

1. Low density development: only sites greater than 900 m^2 are developed.
2. Medium density development: only sites greater than 600 m^2 are developed.
3. High density development: sites greater than 400 m^2 are developed.

The potential increase in the number of allotments by 2070 (Council's nominated timeframe for the assessment) for each of these scenarios is summarised in Table 2.6.

Table 2.6 Potential number of residential allotments (2070)

Sub-catchment	Current residential allotments	2070 high density scenario	2070 medium density scenario	2070 low density scenario
Henley Grange	4,927	12,533	8,152	5,310
Meakin	3,792	9,276	6,126	4,046
Trimmer Parade	4,040	10,057	6,544	4,309
West Lakes Central	843	2,263	1,414	882
West Lakes East	3,017	6,253	4,238	3,122
West Lakes North East	246	677	435	256

Sub-catchment	Current residential allotments	2070 high density scenario	2070 medium density scenario	2070 low density scenario
West Lakes South	261	785	504	290
West Lakes West	2,606	6,127	4,041	2,730
Total	**19,732**	**47,971**	**31,454**	**20,945**

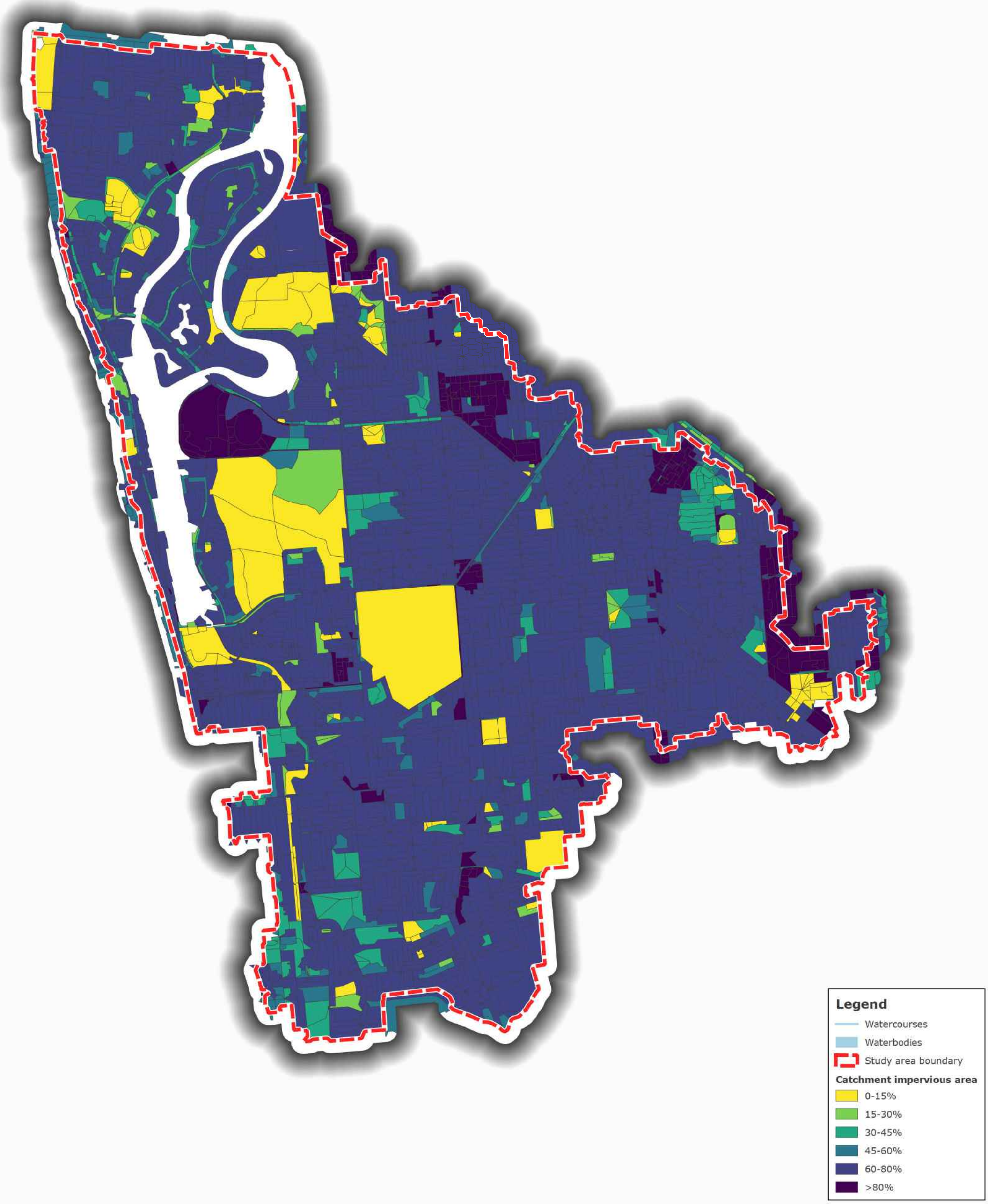
While the URPS study considered the potential increase in the number of allotments based on a range of development scenarios, the focus of the study was on understanding the impacts of development on the proportion of the catchment which is impervious, and hence the impacts on stormwater generation potential.

URPS (2019) noted that even if land is not subdivided to create additional dwellings, the impervious area could increase through activities such as dwelling additions, new verandas or other outbuildings and by an increase in paved/hard surfaces.

The study determined that the area of permeable cover within residential properties could be expected to significantly reduce considering future likely development conditions. It concluded that the impervious area within the catchment would likely be independent of which scenario (high, medium or low density) was adopted.

The modelling undertaken as part of the SMP development therefore assumes that by 2070 all residential land has 80% site imperviousness. The assumption of 80% imperviousness is consistent with the provisions for 'soft landscaping' in the Planning and Design Code.

Based on conversations with Council, the development scenario for 2070 also assumes full development of the SA Water owned land on Frederick Road. The assumed catchment impervious area associated with the 2070 development scenario is shown in Figure 2.9.



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CITY OF CHARLES STURT

WEST LAKES STORMWATER MANAGEMENT PLAN
CATCHMENT IMPERVIOUS AREA
2070 DEVELOPMENT SCENARIO

Figure 2.9

2.10 Climate

The West Lakes study area receives an average of 441 mm of rainfall per year. The mean monthly rainfall for West Lakes (based on rainfall observations at the Adelaide (Seaton) weather station (023034)) is shown in Figure 2.10. Based on historic data, there are on average 70 rain days (>1 mm) per year. Figure 2.10 also shows the mean monthly potential evapotranspiration (PET) for each month, with 10 months of the year experiencing a rainfall deficit. The mean annual PET is 1747 mm per year.

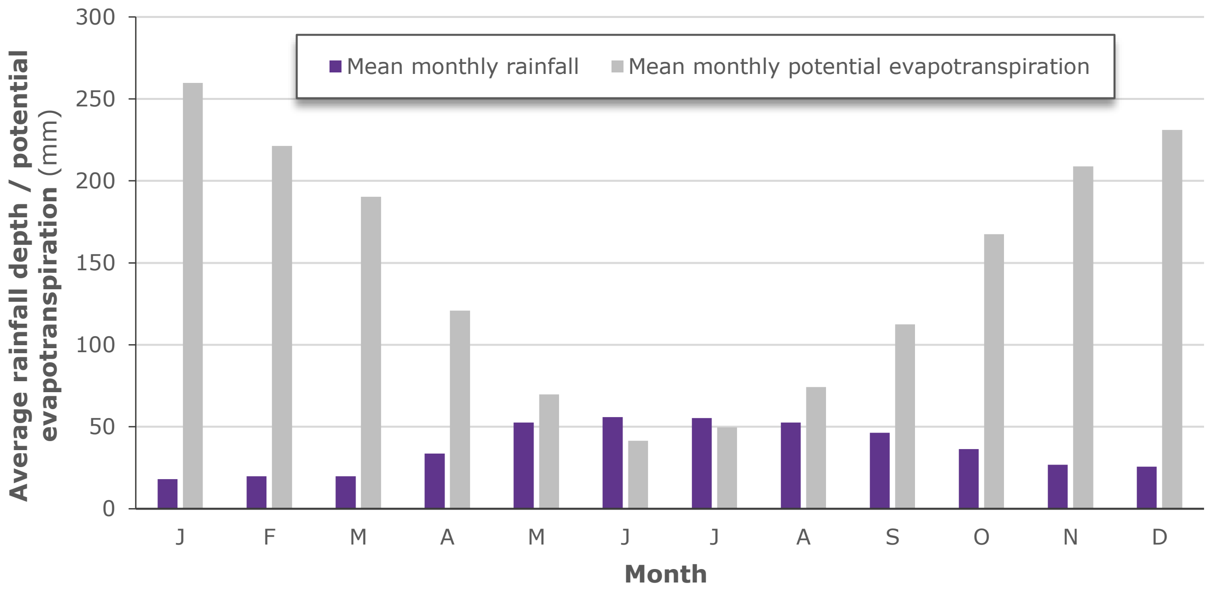


Figure 2.10 Mean monthly rainfall and PET for West Lakes (site number: 023024)

2.10.1 Climate change

The latest available science indicates that the climate is changing. CSIRO (2019) prefaces the latest regional climate change summaries with the following statement:

"Australia's changing climate represents a significant challenge to individuals, communities, governments, businesses, industry and the environment. Australia has already experienced increases in average temperatures over the past 60 years, with more frequent hot weather, fewer cold days, shifting rainfall patterns, and rising sea levels."

Despite global efforts to mitigate greenhouse gas emissions, the momentum of the climate system means that the observed climatic changes will continue with increasing magnitude, for many decades to come.

Projections for West Lakes

Climate Change in Australia (CSIRO and Bureau of Meteorology, 2016) provides climate change projections for selected Australian Cities, including Adelaide. The key climate change projections relevant to the design of stormwater systems for the Adelaide metropolitan area are as follows:

- A continuation of the trend of decreasing winter rainfall is projected with high confidence. Spring rainfall decreases are also projected with high confidence.
- An increase evapotranspiration is projected with high confidence.
- Increased intensity of extreme rainfall events is projected, with high confidence.

- Mean sea level will continue to rise and the height of extreme sea-level events will also increase (very high confidence).

With respect to the management of stormwater within the West Lakes catchment, the key risks associated with the projected changes in climate are as follows:

- A reduced level of service (greater frequency of flooding) due to the higher intensity rainfall events resulting in higher peak flows.
- Higher downstream water levels as a result of rising sea levels.
- Rising groundwater levels as a result of rising sea levels.
- Impacts on the function of existing water harvest and reuse schemes due to changes in rainfall patterns and increasing evapotranspiration.

The projected changes in maximum rainfall intensities (ARR, 2016) for West Lakes are summarised in Table 2.7. Representative concentration pathway (RCP) 4.5 represents a low emissions future and RCP 8.5 represents a high emissions scenario.

Table 2.7 Summary of climate change projections for West Lakes (ARR, 2016)

Year	RCP 4.5		RCP 8.5	
	Temperature	Rainfall intensity	Temperature	Rainfall intensity
2030	0.76°C	3.8%	0.78°C	3.9%
2050	1.18°C	5.9%	1.50°C	7.6%
2070	1.53°C	7.7%	2.34°C	12.1%
2090	1.67°C	8.5%	3.40°C	18.1%

The 2070 median projected sea level rise for the RCP 8.5 scenario for the City of Charles Sturt is 0.4 m (CoastAdapt, 2019). Work previously undertaken by Tonkin (Tonkin,2015) recommended that a mean sea level rise of 0.5 m be adopted for 2070. This is consistent with the Coast Protection Board Policy Document.

AdaptWest

The AdaptWest Climate Change Action Plan (URPS, 2016) was developed collaboratively by the City of Charles Sturt, Port Adelaide-Enfield and West Torrens. Its aims were to identify the regional specific implications of climate change and provide realistic strategies for communities within the region to adapt. The AdaptWest Plan adopts RCP4.5 projections for 2070.

Risk-based approach to climate adaptation

Recognition of the risks associated with climate change is required for better planning for new infrastructure and mitigating the potential damage to existing infrastructure (ARR, 2016). Despite advances in climate science there are still significant uncertainties associated with the projections of future climate, not least of which is patterns of global development and greenhouse gas emissions. A risk-based approach to climate change adaptation is therefore recommended.

Factors to be considered when developing an adaptation approach include:

- The design life of the asset – the impacts of climate change will be greater for assets with a long design life.
- The consequences of failure – if failure is catastrophic then design should be based on the worst-case climate change projection for the end of the asset life. If not catastrophic, design may be based on

climate change projections for the middle of the design life of the asset with acceptance of increased risk of failure towards the end of the asset life.

- Impacts of the projections on system performance – a sensitivity analysis should be undertaken to provide an understanding of what the projected changes mean for system performance.
- Cost of the adaptation measures – no cost or low-cost options should be sought, particularly where the consequence of failure is not severe.

Recommendations for West Lakes SMP

Projections of future climate are inherently uncertain. For the purpose of capturing the potential impacts of climate change on stormwater management within the West Lakes catchment the following has been adopted:

- Consider a 2070 scenario, which is consistent with the approach adopted in the consideration of future development potential and is likely to roughly correspond with the middle of the design life of most stormwater assets (assumed design life of concrete assets is 70-100 years).
- Assume a 10% increase in rainfall intensity. This represents the rough mid-point between the recommendations of the Adapt West project and a RCP 8.5 2070 scenario. Given the highly uncertain nature of climate change, this is considered suitable to inform a risk-based approach to stormwater planning.
- Assume a 0.5 m rise in sea level. While higher than the value provided by Coast Adapt, it is considered prudent to adopt a more conservative approach (the precautionary principle) which is consistent with previous planning documents and studies (e.g. the Coast Protection Board and Tonkin 2015).

2.11 Previous studies and investigations

A number of previous studies of relevance to the SMP have been undertaken within the catchment. These previous studies have provided a basis for the development of the models that will be used to identify issues and opportunities as part of the SMP. A brief description of the key previous studies and their relevance to this SMP is provided below.

2.11.1 Western Adelaide region climate change adaptation plan

The objective of the Western Adelaide region climate change adaption plan (Tonkin Consulting, 2018) was to quantify the impacts of climate change on sea water and stormwater flooding in potentially sensitive costal catchments, including West Lakes. After quantifying these impacts, mitigation options were considered.

West Lakes was modelled as part of this study to assess the impact of sea level rise, increased rainfall intensity and increasing initial lake water levels associated with climate change. The study concluded that the Lake could be potentially susceptible to climate change impacts on stormwater/seawater interactions. Particularly, under an assumed sea level rise of 1 m, it was found that the Lake would rarely flush due to its dependency on tidal interactions; modelling indicated that 1 m of sea level rise caused an increase in flood depth for the 100-year average recurrence interval (ARI) event of 840 mm.

To mitigate the potential impacts associated with rising sea levels, an increase in the size of the Bower Road outlet was recommended when mean sea level increased by 300 mm. This level corresponds to a peak water level increase in the Lake of around 260 mm.

The study also identified the possibility for pumping for the purposes of water quality management, when the sea level rises to a point that there is insufficient flushing of the lake. The pumps could also be used for drawing down the lake prior to a predicted heavy rainfall event. The study identified that this option would not need to be considered until post 2050.

The amalgamated TUFLOW models developed as part of the climate change adaptation plan will be used as the basis for the floodplain mapping of the West Lakes SMP study area.

2.11.2 West Lakes TUFLOW floodplain modelling

The objective of this investigation (Tonkin Consulting, 2009) was to generate a series of flood maps identifying potential areas of flooding within a portion of the West Lakes catchment for a range of rainfall events (note that the contributing catchment area for the study is less than that for the West Lakes SMP). The modelling considered long-term development, but did not include an allowance for climate change.

Comparison of the results of this modelling, which covers about half of the West Lakes SMP study area, with the results of the modelling undertaken as part of the SMP development shows close general agreement for the long-term development scenario.

Development of the SMP has built upon this previous floodplain modelling.

2.11.3 Henley Fulham catchment initial urban stormwater master plan

As part of this stormwater master plan (Tonkin Consulting, 2005), strategies for managing the high-risk flooding of the Henley Fulham catchment were developed. Strategies included upgrades of some key underground drainage systems in the catchment and provision of detention basins at key points. Suggested upgrades to the underground drainage system included:

- Northern lateral drain (Murray Street)
- Central lateral drain (Marlborough Street)
- Main outfall along Cudmore Terrace north of North Street
- A number of laterals feeding into the Henley-Fulham drain.

Locations suggested for further investigation of detention basins included:

- Fulham Gardens Primary School Oval
- County Street Reserve
- St Michaels College Oval
- Jeanes Street Reserve
- Fulham North Primary School Oval.

Regarding improvement of stormwater quality, the installation of gross pollutant traps (GPT) was recommended. However, it was noted that the grade of pipes in the Henley-Fulham catchment was generally low and, therefore, the hydraulic losses introduced could be significant. As such, the location of any proposed GPTs needs to be investigated to ensure that significant reduction in capacity of the upstream drainage system does not occur.

Since the initial USMP was issued, minor drainage upgrades have occurred within the catchment to address localised flooding areas, including on Marlborough Street. None of the detention basins have been constructed.

2.11.4 Trimmer Parade catchment initial urban stormwater master plan

Previous work by Tonkin (2003a) found that the hydraulic capacity of the Trimmer Parade catchment's stormwater systems was generally inadequate, with the systems as they existed at the time generally having less than a 2-year ARI capacity. Upgrade of the existing drainage systems to increase capacity was not recommended due to high estimated costs. Instead, provision of detention basins and other management strategies (such as on-site retention or detention and monitoring and management of development with consideration of how that development affected the stormwater system) were recommended.

It was noted that the northern end of Frank Mitchell reserve appeared to offer the greatest potential for establishment of a stormwater detention basin. Since this report was prepared, a number of other detention storages have been incorporated into the catchment.

As part of the Renewal SA residential development on Trimmer Parade, located between Cameron Avenue and Field Court, additional underground detention storage tanks have been incorporated within the road drainage system, providing 205 m^3 of storage (Greenhill, 2018).

A new underground drain along the full length of Duncan Street has also since been constructed, with a large detention system in the north eastern corner of Don Klaebe Reserve used to detain flows (Tonkin Consulting, 2014).

A review of the stormwater design models for the Woodville West development (provided by Council) also show a number of basins within the development, including within Frank Mitchell reserve. These basins are captured in the modelling being undertaken for the SMP development.

2.11.5 Meakin Terrace catchment initial urban stormwater master plan

Tonkin Consulting (2003b) previously completed work developing an urban stormwater master plan for the Meakin Terrace catchment. While the construction of underground drainage alone was not suggested at the time due to cost and the potential effects downstream, construction of a new outfall channel was recommended based on the flows from the existing level of development. The suitability of detention basins was also considered, but existing areas of reserves were not suitably located to intercept runoff from large upstream catchments. It was suggested that with further investigation, small detention basins on purchased land could be targeted at areas where more intense redevelopment was likely and where they would have the greatest effect.

Since this study detention has been implemented in a number of locations with the catchment including Willcocks Reserve, Dumfries Reserve and Fraser Street.

2.12 Model development and information gaps

As part of the Stage 1 data investigations, the TUFLOW models previously developed and used for the studies summarised above were revised. Specifically, the following changes were made:

- Drainage elements that have been constructed since the previous models were developed have been incorporated into the model. Approximately 900 drains were added/amended. The new detention basins and underground storages have also been incorporated into the model.
- Council's TUFLOW model of the Port Road drainage upgrade project was added to the model. The Port Road model was assumed to have all recent upgrades included, however, it was found this was incorrect. Lateral systems in Ledger Road, Main Street, Charles Road, William Street did not reflect Council's GIS data. These lateral systems were updated using Council's GIS.
- The Frogmore Pumping station and overflow weir was updated based on Tonkin design drawings. The pump station now has a peak outflow of 1200 L/s and operates according to the design operating rules.
- The Golfers Avenue pump station was added to the model using Council records. Inverts in the Trimmer Parade trunk drain were updated downstream of the pump station using Council GIS data. This will improve the estimate of flooding in the Golfers Avenue sub-catchment. The Trimmer Parade outfall dimensions were also updated from Council GIS. Previously, this parallel pipe system was represented using a single equivalent diameter pipe. The new configuration enables more accurate drain inverts to be used.
- Four large open air GPTs were added to the model to better reproduce hydraulic conditions at the outlet of drains into the Lake. Council provided scans of original design drawings for this exercise. The Trimmer Parade GPT was added using survey as design drawings were not available.
- The schematisation of Grange Lakes was updated to include more representative inverts and channel dimensions. The area south of the Grange railway line was represented in 2D. The area north of Grange railway line was added as a 1D channel to ensure that the correct conveyance of this open drain was captured in the model.

- A new LiDAR derived DEM was integrated. Care was taken to ensure that the underground drainage network was properly linked to the new DEM. On average the new DEM was 100 mm lower than the old DEM, but in places was up to ±500 mm. Therefore, the connection of all inlets to the new DEM was carefully managed to ensure correct connectivity between the 1D and 2D domains. Additionally, all underground drains were checked to ensure they still had appropriate cover compared to the new DEM.
- Multiple soakage basins were added to the model to better replicate infiltration during small events.
- All model elements have been converted to GDA2020 to match the projection of the new LiDAR DEM.

2.12.1 Data gaps and areas for additional improvement

Surface flows from the Torrens East catchment flow into the West Lakes SMP study area when the capacity of the underground network is exceeded. The Torrens East catchment has not previously been included in the West Lakes modelling and it is considered that the impact of the overflows on flood depths in the West Lakes catchment will be localised. Incorporation of the Torrens East catchment into the existing West Lakes TUFLOW model could be considered if Council want to verify the impacts of surface flows from the Torrens East catchment on the West Lakes study areas, however it is considered that this work is beyond the scope of the current SMP.

While the TUFLOW model includes details of outlet structures, based on plans provided by Council, the model does not include representation of the trash nets in the catchment. Based on results of preliminary hydraulic modelling it is not considered that this assumption will significantly impact the modelled water levels during major flow events. They may have localised impacts during smaller flow events.

3 SMP objectives

This section provides details of the objectives underpinning the development of the framework for the whole of catchment approach to the management of stormwater within the West Lakes SMP area.

3.1 Guidelines and policies

Objectives guiding the development of this SMP have been established with reference to a range of guidelines and policy documents relevant to the management of stormwater. Of specific relevance are the following:

- Stormwater Management Authority (SMA) Guidelines
- State WSUD Guidelines
- Planning and Design Code
- Council's Biodiversity Action Plan
- Australian Coastal Water Quality Improvement Plan
- Green Adelaide Draft Regional Landscape Plan

The sections of these plans of specific relevance to this SMP are discussed in the following sections.

3.1.1 SMA guidelines

The key issues to be addressed in the development of any plan for the management of stormwater runoff from an urban catchment include:

- flooding
- water quality
- water use
- environmental protection and enhancement
- asset management.

Catchment specific objectives are set based upon the problems and opportunities identified within the study area. The Stormwater Management Planning Guidelines (SMA, 2007) state that, as a minimum, objectives are to set measurable 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.
- 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 State WSUD guidelines

The Department for Environment and Water's (DEW, formerly DEWNR) Water Sensitive Urban Design (WSUD) Guideline (2013) sets out the South Australian Government's position on WSUD in a local context, provides State-wide WSUD 'targets' for new developments and details the role that Government will play in collaboration with other stakeholders to maximise the use of WSUD approaches.

The aim of WSUD in South Australia is that urban landscapes are planned, designed and managed to be 'water sensitive' and in doing so contribute to the liveability of South Australia's urban environments and the wellbeing of South Australians, both for current and future generations.

The stated objectives of the SA WSUD Guidelines include:

- Encouraging best practice in the use and management of water to minimise reliance on imported water.
- Promoting safe, sustainable use of rainwater, recycled stormwater and wastewater.
- Mimicking a more natural runoff regime.
- Maintaining and enhancing water quality.
- Managing rainfall runoff so that it does not increase the potential for flooding.

A summary of the key performance principles, intents and targets that have been set, and which are considered relevant to the development of this SMP, is provided in Table 3.1

Table 3.1 State-wide WSUD performance principles and performance targets (from DEWNR 2013)

Performance principle	Performance principle intent	State-wide performance target
Runoff quality Positively manage the quality of urban runoff through implementing water-sensitive urban design.	To help protect and, where required, enhance, the quality of runoff entering receiving water environments, in order to support environmental and other water management objectives.	Minimum reductions in total pollutant load, compared with that in untreated stormwater runoff, from the developed part of the site: • Total suspended solids by 80% • Total phosphorus by 60% • Total nitrogen by 45% • Litter/gross pollutants by 90%
Runoff quantity Post-development hydrology should, as far as practical and appropriate, minimise the hydrological impacts of urban built environments on watercourses and their ecosystems.	• Help protect waterways and, where relevant, promote their restoration by seeking to limit flow from development to pre-development levels. • Help to manage flood risk, by limiting the rate of runoff to downstream areas to appropriate levels.	**For flood management:** For development and other relevant infrastructure that will drain runoff to an existing publicly managed drainage system or to a drainage system such as a creek or watercourse on privately-owned land: • the capacity of the existing drainage system is not exceeded • there is no increase in the 5 year ARI peak flow and no increase in flood risk for the 100 year ARI peak flow, compared to existing conditions.
Integrated design That the planning, design, and management of WSUD measures seeks to support other relevant State, regional and local objectives.	Implement WSUD in a way that promotes establishment of 'green infrastructure' and achievement of multiple outcomes, for example: public amenity, habitat protection and improvement, reduced energy use and greenhouse emissions, and other outcomes that	Evidence that relevant stakeholders are engaged at appropriate stages of planning, designing, constructing, and managing WSUD measures so as to maximise the potential for WSUD to contribute to 'green infrastructure' and other relevant State, regional, and local objectives.

Performance principle	Performance principle intent	State-wide performance target
	contribute to the wellbeing of South Australians.	

3.1.3 Planning and Design Code

The South Australian Planning and Design Code includes several provisions to manage stormwater within new developments (of all scales). The code includes provisions associated with the management of hazards associated with flooding and the management of stormwater. The sections of the code that are of relevance to this SMP are summarised below.

Hazards (Flooding) Overlay

The desired outcome of the assessment provisions associated with the Hazards (Flooding) Overlay section of the code is that impacts on people, property, infrastructure and the environment from high flood risk are minimised by:

- retaining areas free from development
- minimising intensification where development has occurred
- appropriate siting and design of development.

Stormwater management requirements

The Planning and Design Code also contains requirements for water sensitive design. The requirements vary depending on the type of development but they typically include measures to manage runoff quality and the volume and magnitude of flows.

For residential developments, the code requires that the '*development is designed to capture and reuse stormwater to maximise conservation of water resources; manage peak stormwater runoff flows and volume; and manage runoff quality.'*

3.1.4 Biodiversity Action Plan

Council's Biodiversity Action Plan (2017) seeks to implement strategies to enhance biodiversity, create diverse and connected open space, promote education and implement strategic drivers. Water quality is identified as one of four key biodiversity action areas for which specific and measurable actions have been developed. These actions include the following:

- Identify significant contributing factors to decreased water quality and develop priority action plans to address these factors.
- Implement WSUD and raingardens/filters in public parks and gardens.
- Engage community and landowners in education programs regarding water quality on private land.

3.1.5 Australian Coastal Water Quality Improvement Plan

The Australian Coastal Water Quality Improvement Plan (ACWQIP), developed by the SA EPA, provides a long-term strategy to achieve and sustain water quality improvement for Adelaide's coastal waters and create conditions to see the return of seagrass along the Adelaide coastline.

The EPA has developed strategies to assist with achieving their target of reducing nitrogen loads by approximately 75% from 2003 levels to halt seagrass loss and create conditions that support seagrass restoration. The strategies that apply to stormwater management include reducing nutrient, sediment and organic matter discharges through the uptake and implementation of WSUD and promoting integrated reuse of wastewater and stormwater (EPA SA, 2013). The ACWQIP targets include:

- The total load of nitrogen discharged to Adelaide's marine environment should be reduced to around 600 tonnes/year (representing a 75% reduction from the 2003 value of 2,400 tonnes). The ACWQIP target for the stormwater contribution is 50 tonnes/year by 2028.
- Steps should be taken to progressively reduce the load of particulate matter discharged to the marine environment. A 50% load reduction (from 2003 levels) would be sufficient to maintain adequate light levels above seagrass beds for most of the time. The reduced sediment load will also contribute to improved water quality and aesthetics.
- The ACWQIP target for the stormwater contribution of suspended solids is 730 tonnes/year by 2028 for discharges into the Barker Inlet. One means of reaching this target is to reduce the volume of stormwater discharging to the Barker Inlet.
- To assist in the improvement of the optical qualities of Adelaide's coastal waters, steps should be taken to reduce the amount of coloured dissolved organic matter in waters discharged by rivers, creeks and stormwater drains.

3.1.6 Green Adelaide

The West Lakes catchment is located within the boundary of the Green Adelaide Board. The Board has recently released the draft regional landscape plan which identifies a number of key focus areas and outcomes across seven priority areas (Green Adelaide, 2021). The goals of the plan that are of relevance to the SMP are listed below:

- Partner and invest in the conservation and restoration of coastal and marine environments.
- Protect, enhance and restore water resources.
- Facilitate and incentivise best practice biodiversity sensitive urban design and WSUD in new developments, major transport corridors, public open spaces and local streetscapes.
- Identify priority locations for improved urban greening.

3.2 Stormwater management goals

With consideration of the guidelines and policies discussed in the preceding sections, the following objectives specific to the management of stormwater within the West Lakes catchment have been developed.

3.2.1 Objective 1: Provide an acceptable level of flood protection.

The SMA states that the priorities for stormwater management should focus on measures that reduce the risks associated with flooding and protect property and human lives. ARR (2019) provides guidance on the design standards for urban stormwater drainage. The design standard is embodied in the major-minor principle, which aims to ensure that development is protected from inundation in a 1% AEP event.

The objectives associated with the provision of an acceptable level of flood protection, outlined below, have been developed with regard to the highly developed state of the catchment and the limitations that this poses on achieving the recommended standard of protection in all areas.

Goal F1: Reduce the risk of flooding to private property through improving the levels of service provided by the drainage infrastructure.

Within existing developed areas:

a. Where practical and economically viable, protect existing habitable buildings from over-floor flooding in a 1% AEP event. A lower standard of protection may be adopted where physical and economic constraints limit the ability to achieve a 1% AEP standard.

b. Where practical, provide a minor drainage system capacity of 20% AEP. A lower standard may be adopted where physical and economic constraints limit the ability to achieve 20% AEP standard and where an overflow route exists.

Within areas of new development:

c. Protect new development from inundation for all events up to and including the 1% AEP event.

d. Provide a minor drainage system capacity of 20% AEP. Where no overflow route is possible, a higher design standard should be adopted.

Goal F2: No private property is subject to high or extreme hazard in a 1% AEP flood event.

Goal F3: Create an informed and more flood resilient community.

3.2.2 Objective 2: Improve water quality to achieve desirable end-state values in receiving waters

To ensure that this stormwater management plan aligns with other strategies and guidelines, stormwater quality targets from other documents have been reviewed. These include the recommendations made in:

- Adelaide Coastal Waters Study (ACWS) (EPA SA, 2007) and Adelaide Coastal Water Quality Improvement Plan (ACWQIP) (EPA SA, 2013).
- Australian Runoff Quality: A Guide to Water Sensitive Urban Design (Engineers Australia, 2006).
- Water Sensitive Urban Design – Creating more liveable and water sensitive cities in South Australia (DEWNR, 2013).

With infill development likely to occur within the catchment, it is imperative that pollutant loadings and concentrations are not increased to a level that would be harmful to the receiving environments. The catchment specific objectives shown below have been set to ensure that the desirable end-state water quality goals are met.

Goal WQ1: Improve the quality of stormwater runoff discharging into West Lakes; aim to achieve the following pollution reduction targets, compared to the 'untreated' case (consistent with the DEWNR (2013) guidelines):

- Total suspended solids: 80%
- Total phosphorus: 60%
- Total nitrogen: 45%
- Gross pollutants: 90%

Goal WQ2: Reduce the concentrations of microplastics in West Lakes to a 'moderate' level (less than 250 mp/m^2).

3.2.3 Objective 3: Maximise the economic use of stormwater runoff for beneficial purposes.

Council currently manages the Waterproofing the West recycled water scheme, which facilitates extensive reuse of harvested stormwater for irrigation within the study area (and beyond).

Consistent with the stated objectives of the State Government's WSUD Guidelines this SMP includes goals to increase the volumes of water that are reused both through expansion of existing schemes, and through development of small-scale schemes. The goals related to the reuse of stormwater are as follows.

Goal RU1: Increase the volumes of stormwater that are harvested and reused within the catchment.

Goal RU2: Increase the delivery of small-scale projects (Council owned and private) which promote the beneficial reuse of runoff.

3.2.4 Objective 4: Achieve desirable planning outcomes associated with new development, open space, recreation, and amenity.

The new Planning and Design Code includes a number of controls relating to the management of stormwater and the management of risk associated with flooding. It is recommended that the outcomes from this SMP, specifically the flood mapping, be used to inform the application of the provisions of the Planning and Design Code for the assessment of development within the SMP study area.

Further, opportunities to leverage off stormwater upgrades to deliver benefits associated with open space, recreation and amenity should be considered. The goals related to planning outcomes, recreation and amenity values are as follows.

Goal RA1: Incorporate flood map outputs from this SMP into the Planning and Design Code.

Goal RA2: Council guidelines for stormwater management should include a requirement to consider opportunities to provide non-flood risk related benefits when developing capital works projects.

Goal RA3: Environmental enhancement of drainage reserves and waterbodies within the study area to promote improved biodiversity and better environmental outcomes.

3.2.5 Objective 5: Sustainable management of stormwater infrastructure

Council owns and operates an extensive network of stormwater infrastructure, with a high capital value. The infrastructure is in varying ages and conditions. Degraded infrastructure will reduce the ability of the drainage system to act as per its original design intent. Without careful planning, structural failure of existing infrastructure may necessitate immediate and expensive rectification. Careful asset management will allow for future planning to determine the timeline for replacement of assets. Goals related to the sustainable management of Council’s stormwater assets are as follows.

Goal AM1: Ensure that Council has asset management plans for all stormwater infrastructure, and these plans consider long-term sustainable management (including consideration of the impacts of climate change).

Goal AM2: Ensure operation and maintenance plans are in place for all WSUD assets. Failure to follow proper operation and maintenance regimes will result in significantly reduced performance of the assets.

4 Identification of flooding

One of the primary objectives of the SMP is the identification of issues associated with flooding within the catchment. To achieve this objective, detailed hydrologic and hydraulic modelling of the study area and surrounding catchments has been undertaken. A single long-term (2070) scenario was modelled which included projections of development, a 10% increase in rainfall and 0.5 m sea level rise.

The primary purpose of the modelling was to define the extent and magnitude of flooding during events of differing annual exceedance probabilities (AEP) and to identify areas of significant inundation relevant to the preparation of the SMP. The risk to public safety ('flood hazard') was also categorised for the 1% AEP event. Flood hazard uses the depth and velocity of floodwater to categorise the risk of harm to individuals from floodwater. For example, shallow but swift moving floodwater might be categorised as hazardous to individuals because of the potential for that individual to lose their footing and be pulled downstream by the floodwater.

Details of the hydrologic and hydraulic modelling are provided in Appendix B.

4.1 Assessment of stormwater drainage system standard

The results of the hydraulic modelling were used to estimate the level of service ('drainage standard') provided by the existing drainage network within the study area. The pipe standard was defined by assessment of the freeboard at each pit. The capacity of a drain was deemed to have been exceeded during a particular storm event if the modelling results indicated that the freeboard at the upstream pit was less than 150 mm during that event. Capacity limitations may be associated with inlet capacity or the capacity of the pipe network itself.

Figure 4.1 shows the colour-coded results of the capacity assessment. Drainage systems highlighted in red have a standard of less than 63% AEP (1 EY) and potentially require upgrading to reach the desired standard of protection. Many of the upstream (eastern) drains were identified as having a very low standard.

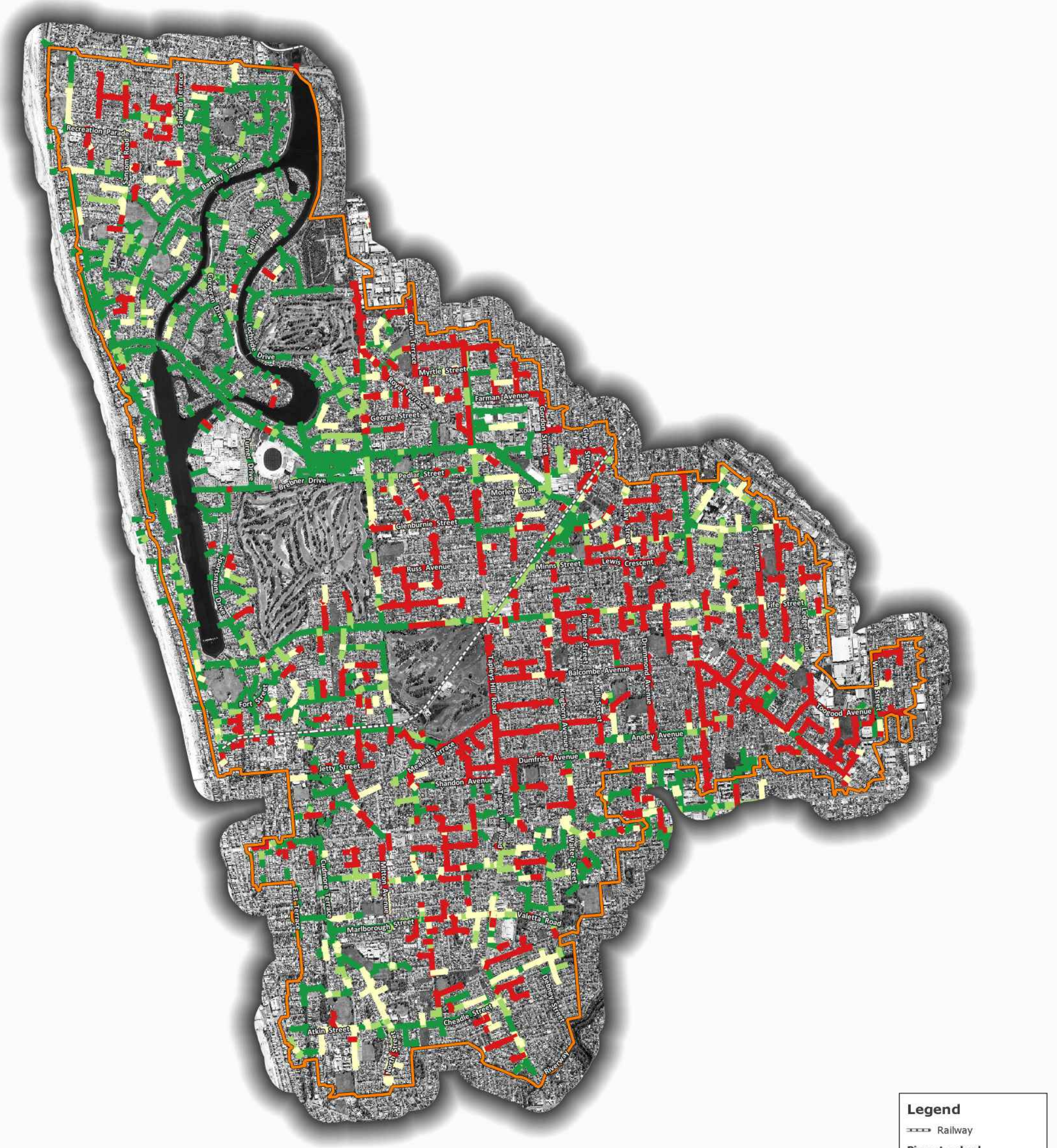
4.2 Key flood prone areas

This section describes the nature and cause of the most prominent flooding issues identified by the flood modelling. For each location the predominant flood behaviour is described, and the main causal mechanisms are defined where possible. An overview showing the relative location of each of the key flood prone areas discussed is provided in Figure 4.2. For each area, a figure showing the modelled inundation for the 20% AEP and 1% AEP events is provided. A full set of flood inundation maps can be found in Appendix C.

The general design standard for underground stormwater networks is conveyance of all flows for events up to the 20% AEP event. The modelling of the West Lakes catchment indicates that in some areas, the underground network has insufficient capacity for the frequent events (up to and including the 20% AEP event). This results in stormwater ponding and/or flowing within the road reserve, with ingress of floodwaters into private property in some locations.

Results of the 1% AEP event show widespread areas of inundation across the catchment, both within the road reserve and private property. Given the assumed level of development and increases in rainfall intensity associated with climate change, this level of inundation would be expected, and it is unlikely to be practicable to upgrade the stormwater systems to provide flood protection to all private property.

The identification of key flood prone areas, which underpins the development of flood mitigation options in this SMP, has therefore been based on identification of areas of significant flooding of private property that occurs in events more frequent than the 1% AEP event. Consistent with the objectives of this SMP, the proposed flood mitigation solutions at these locations aimed to provide protection to private properties in a 1% AEP event.



0 1,000 2,000 3,000 m

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Roads and railways from Data SA, 2019

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WEST LAKES STORMWATER MANAGEMENT PLAN
PIPE DRAINAGE STANDARD
2070 DEVELOPMENT WITH CLIMATE CHANGE

Figure 4.1

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WEST LAKES STORMWATER MANAGEMENT PLAN
KEY FLOOD PRONE AREAS

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Figure 4.2

4.2.1 Meakin Terrace / Leven Avenue

The most widespread area of modelled inundation within the West Lakes catchment is located within the area surrounding Meakin Terrace, to the south of the Grange railway line and the Royal Adelaide Golf Club (RAGC), as shown in Figure 4.3. Information provided by Council indicates that a number of properties within this area reported flooding as a result of the heavy rainfall events that occurred in 2016.

The area shown in Figure 4.3 is served by two primary underground drainage networks. Most of the eastern area drains towards an 1800 mm x 900 mm RCBC within Meakin Terrace. A pump station is used to divert a portion of the runoff within this drain into the RAGC water reuse scheme. A 1050 mm pipe conveys the remaining runoff to the Grange Lakes, along an alignment following the railway line. The western area (to the west of Frederick Road) is directed towards a 525 mm trunk main within Jetty Street, before also discharging to the Grange Lakes.

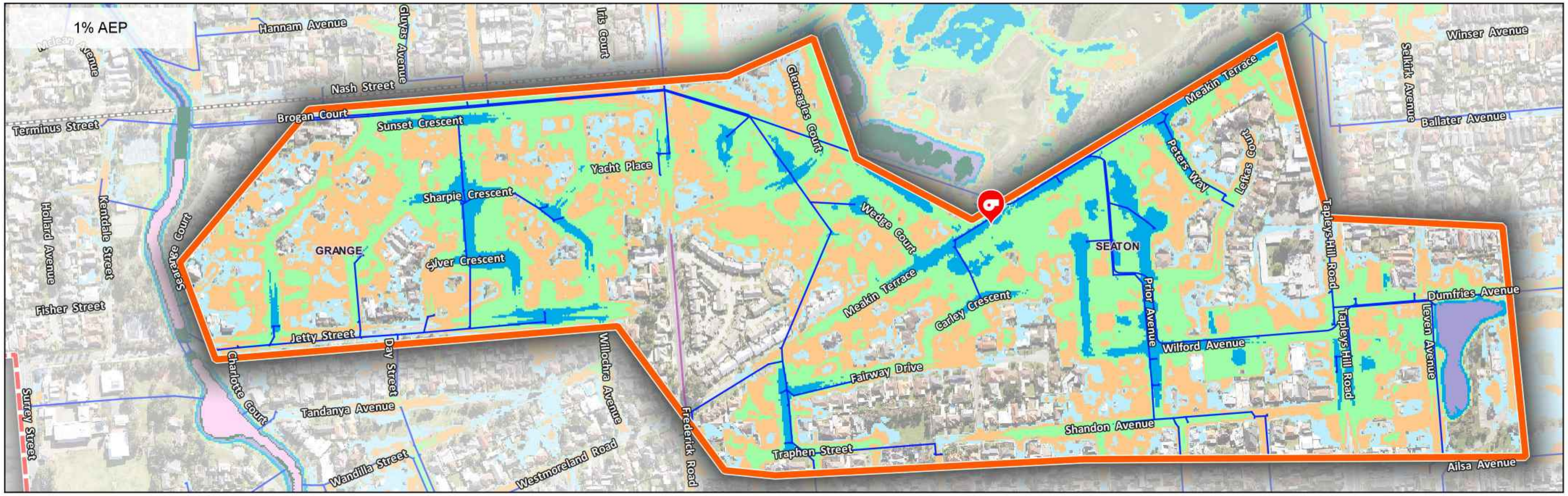
Review of the pipe standards map (Figure 4.1) shows that the drainage network within the eastern catchment does not have capacity to convey flows from the 1 EY event. Similarly, the collector drains within the catchment to the west of Frederick Road also have a standard of less than 1 EY. As such, even in minor events there is upwelling from the pits within this area.

In the 1 EY and 0.5 EY events, flows appear to be contained within the road corridor. For events larger than this, however, the capacity of road network is exceeded, resulting in inundation of a large number of residential properties.

This is first observed during the 20% AEP event within the properties to the south of the RAGC and within Leven Avenue and Tapleys Hill Road. During the 1% AEP event, deep ponding (up to 0.85 m) is observed within the Prior Avenue cul-de-sac. Similarly, flood depths of up to 0.70 m are observed within trapped low spots along Tapleys Hill Road, Meakin Terrace, and Sharpie Crescent during the 1% AEP event.

It should be noted that Prior Avenue, Peters Way and Wilford Avenue are subject to depths of flooding within the road of up to 0.30 m during the 1 EY event (i.e. significant nuisance flooding). Few other areas within the catchment reach this depth of flooding during the 1 EY event.

Overflows from the Frogmore Road pump station (within the Torrens East catchment) also contribute to this area via the pipe along Kidman Avenue. Modelling shows that, in a 20% AEP event, these flows are negligible and do not contribute to the flooding of private property observed within the 20% AEP event.



Legend

- Pump station
- Pipe
- Railway
- Flood zone
- Study area boundary
- Suburb

Depth of inundation

- Less than 0.025m (not shown)
- 0.025m to 0.10m
- 0.10m to 0.25m
- 0.25m to 0.50m
- 0.50m to 1.0m
- 1.0m to 1.5m
- 1.5m to 2.5m
- 2.5m to 5.0m
- 5.0m and more

0 100 200 300 m

N

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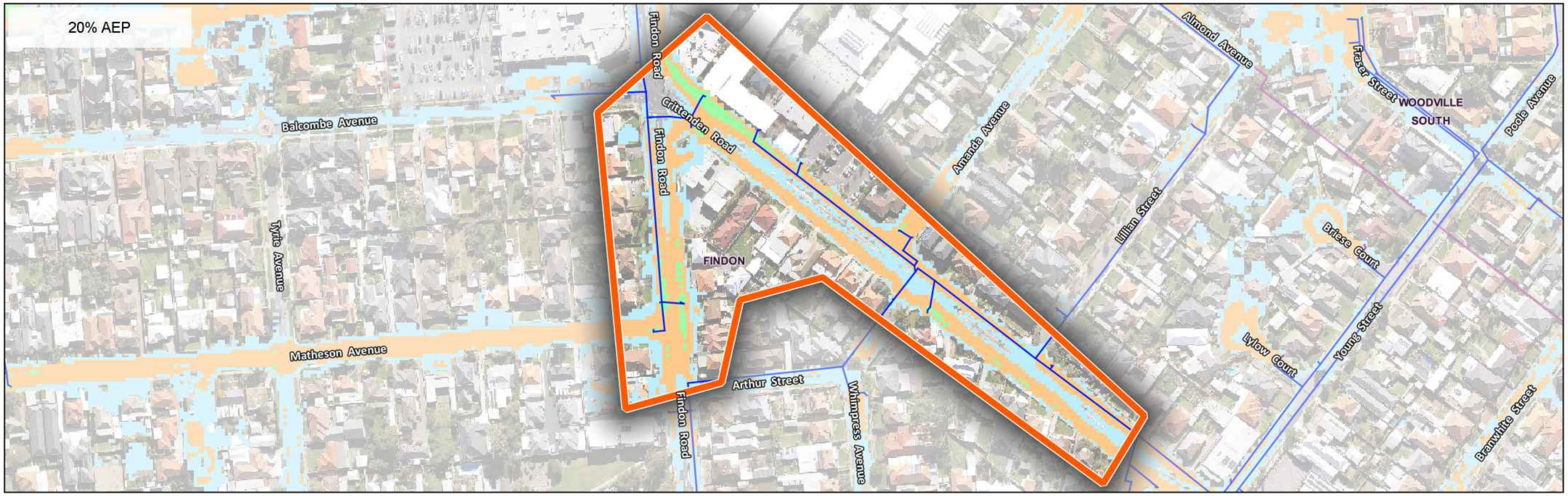
WEST LAKES STORMWATER MANAGEMENT PLAN
FLOODING SURROUNDING MEAKIN TERRACE

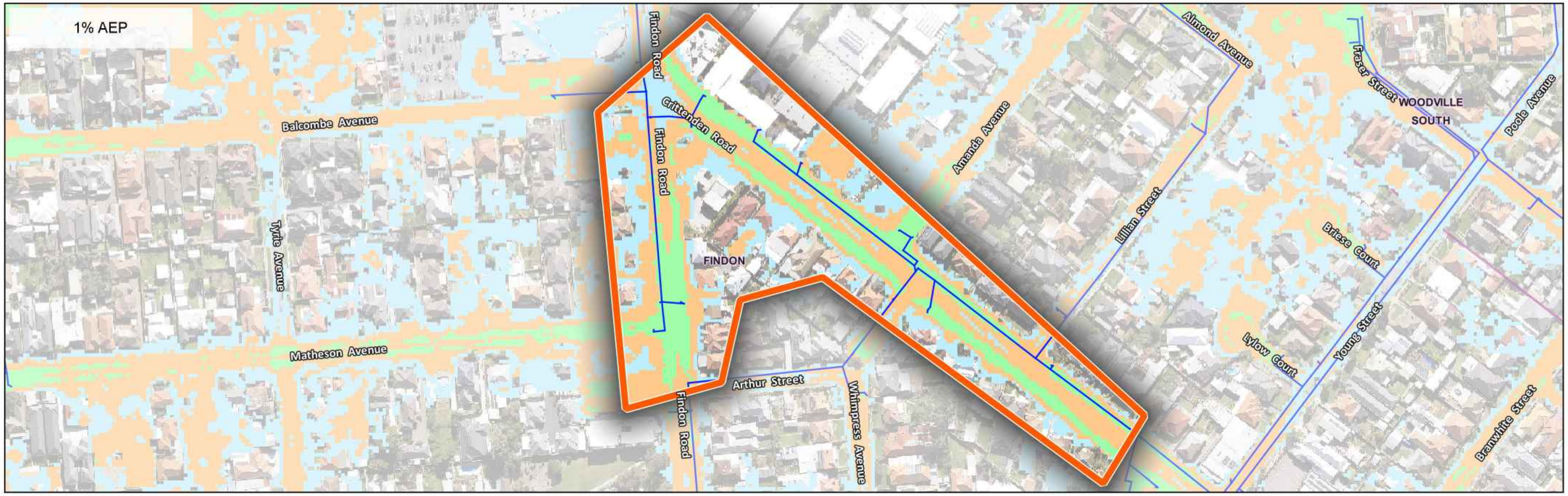
Figure 4.3

4.2.2 Findon/Crittenden

The intersection of Findon Road and Crittenden Road is a low point within the catchment, and is a known flooding hotspot. The modelling confirms that surface flooding along these roads is expected during all events. Between Matheson Avenue and Balcombe Avenue, Findon Road is served by a 300 mm diameter drain, which the modelling indicates has a standard of less than 1 EY. The trunk drain within Crittenden Road has a larger diameter (450 mm to the west of Amanda Avenue), however the drainage standard is also estimated to be less than 1 EY. The flooding within these roads is therefore attributed to a lack of capacity within the underground drainage network. A map of the 20% AEP and 1% AEP flood inundation depths is shown in Figure 4.4.

In addition to the flooding within Findon Road and Crittenden Road, Council has also reported flooding within a nearby local street (Briese Court) to the east; this is consistent with the flood mapping for the 20% AEP event.





Legend

- Pipe
- Flood zone
- Suburb

Depth of inundation

- Less than 0.025m (not shown)
- 0.025m to 0.10m
- 0.10m to 0.25m
- 0.25m to 0.50m
- 0.50m to 1.0m
- 1.0m to 1.5m
- 1.5m to 2.5m
- 2.5m to 5.0m
- 5.0m and more

0 100 200 300 m

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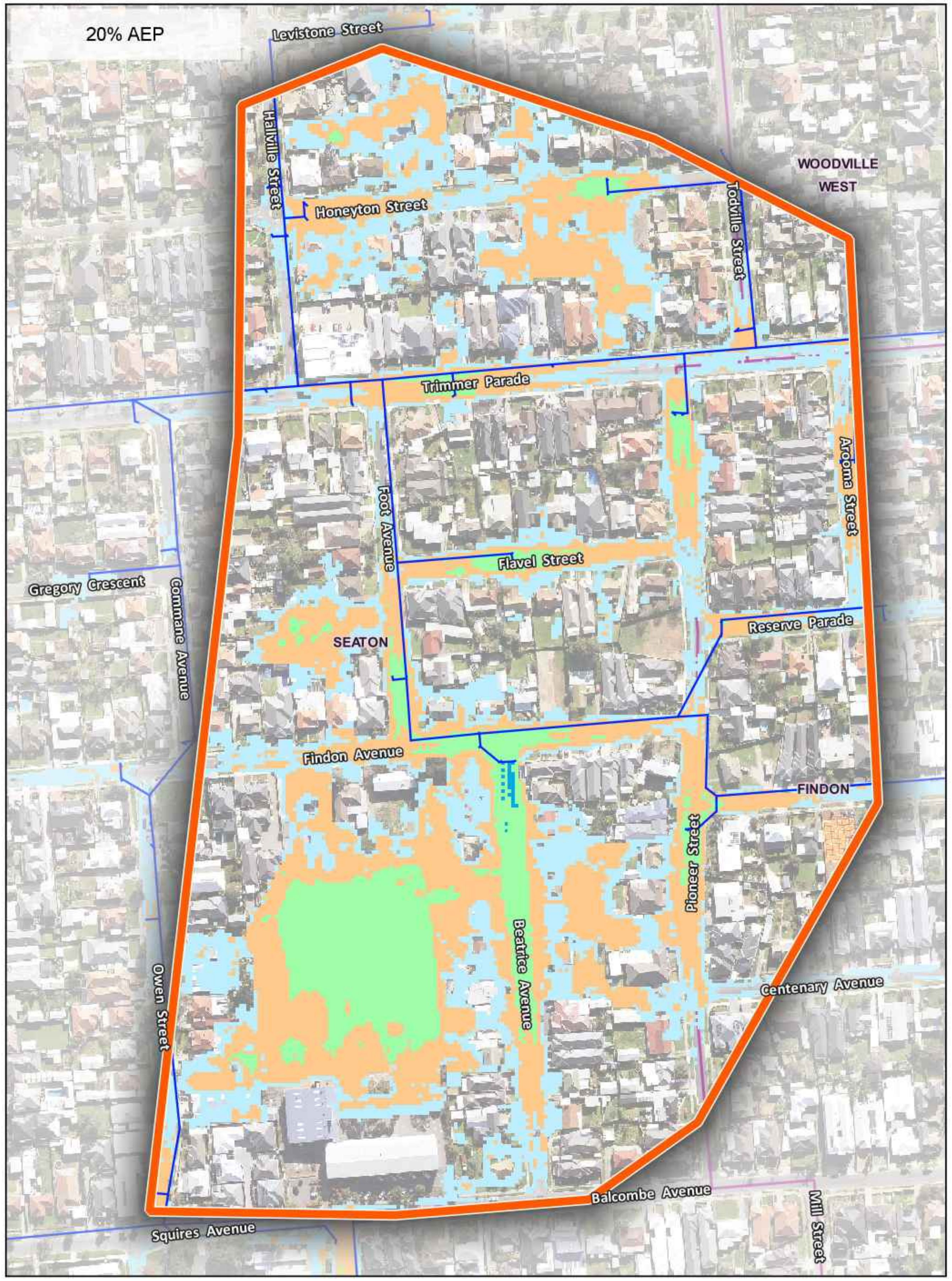
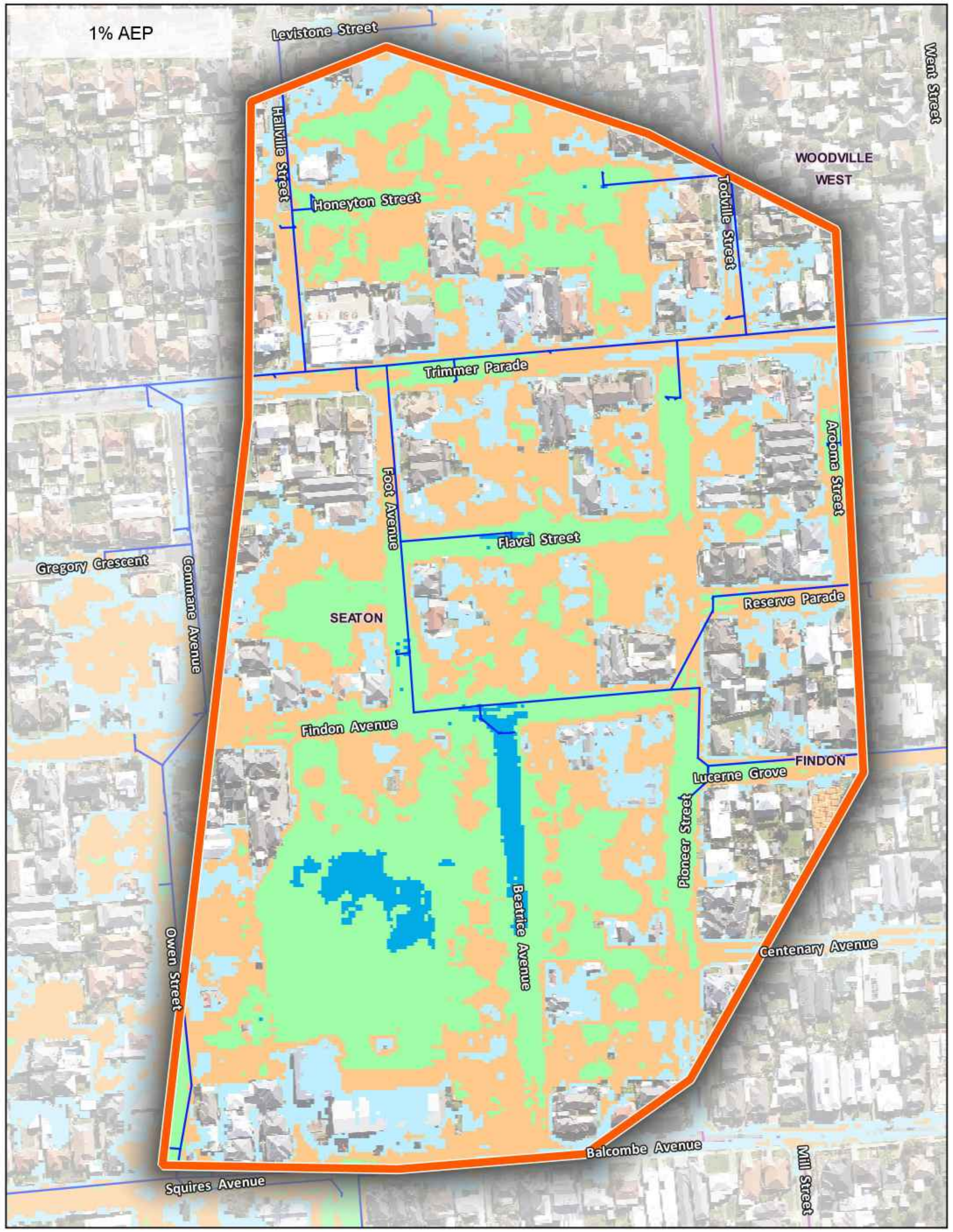
WEST LAKES STORMWATER MANAGEMENT PLAN
FLOODING WITHIN FINDON ROAD AND CRITTENDEN ROAD

Figure 4.4

4.2.3 Beatrice Avenue

The modelling indicates that the underground drainage system servicing the area surrounding Beatrice Avenue (to the south of Trimmer Parade) has a standard of less than 1 EY. Runoff from Beatrice Avenue is collected via pits and pipe (300 mm) at the northern end of the street. As a result of the low underground drainage standard, flood depths within Beatrice Avenue are as high as 0.45 m during the 1 EY event. In larger rainfall events the modelling predicts widespread inundation within the roads and private properties to the north and south of Trimmer Parade. The modelled extent of inundation for the 20% AEP and 1% AEP events is shown in Figure 4.5.





Legend

- Pipe
- Flood zone
- Suburb

Depth of inundation

- Less than 0.025m (not shown)
- 0.025m to 0.10m
- 0.10m to 0.25m
- 0.25m to 0.50m
- 0.50m to 1.0m
- 1.0m to 1.5m
- 1.5m to 2.5m
- 2.5m to 5.0m
- 5.0m and more

0 100 200 300 m

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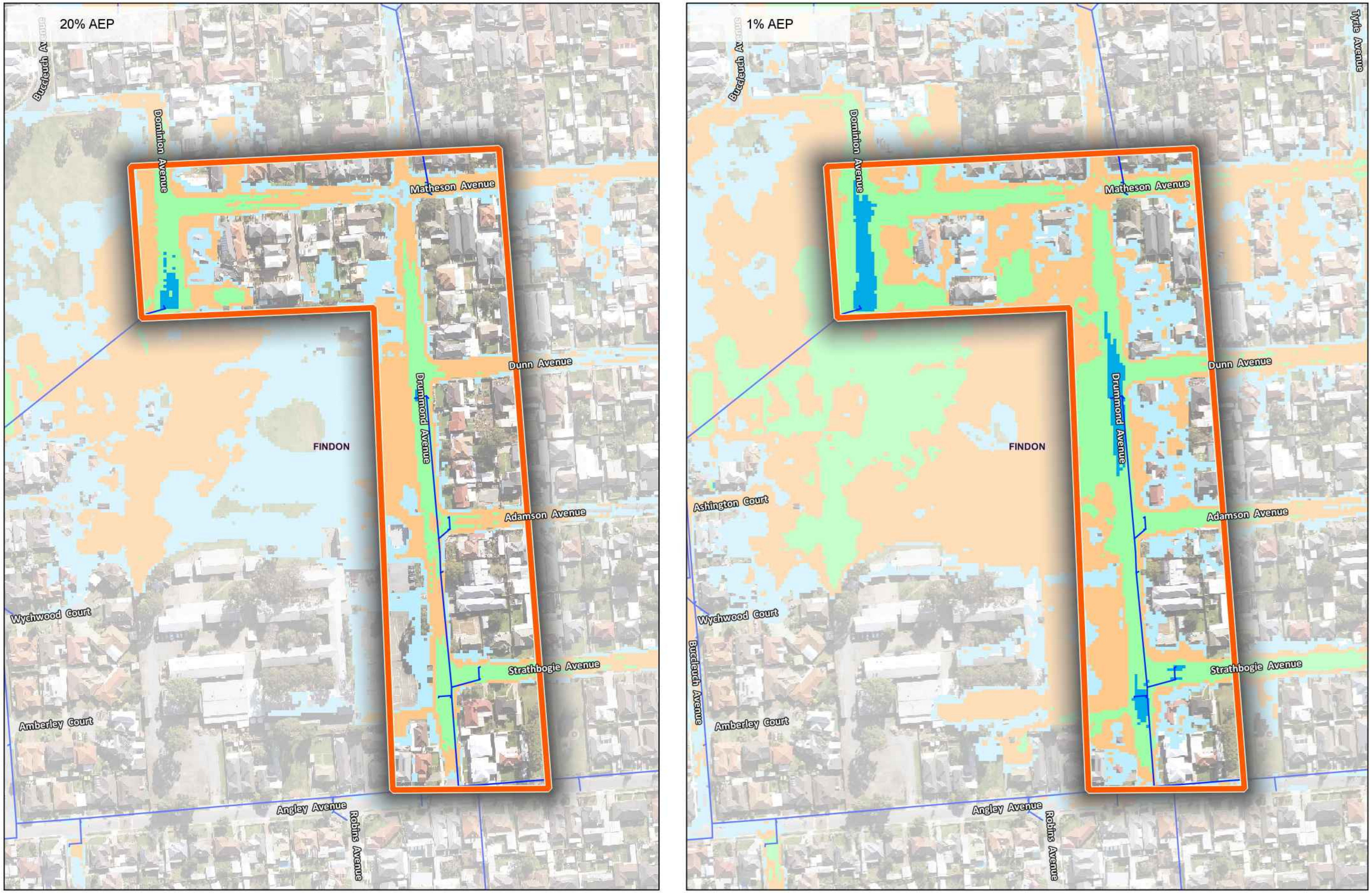
WEST LAKES STORMWATER MANAGEMENT PLAN
FLOODING SURROUNDING BEATRICE AVENUE

Figure 4.5

4.2.4 Drummond Avenue

The modelling results show significant depths of inundation within Drummond Avenue and Dominion Avenue during frequent rainfall events. For the 1 EY event the depth of flooding within Drummond Avenue near Dunn Avenue (a sag location) is up to 0.43 m. At the southern end of Dominion Avenue the flood depth is as high as 0.50 m. These areas therefore represent locations of significant nuisance flooding. The pipe standards map indicates that the drains within each of these streets have a standard of less than 1 EY.

While some inundation of private properties within this area is expected during the 20% AEP and 1% AEP events, the flood depths are typically less than 0.2 m. A map of the 20% AEP and 1% AEP flood depths is provided in Figure 4.6.



Legend

- Pipe
- Flood zone
- Suburb

Depth of inundation

- Less than 0.025m (not shown)
- 0.025m to 0.10m
- 0.10m to 0.25m
- 0.25m to 0.50m
- 0.50m to 1.0m
- 1.0m to 1.5m
- 1.5m to 2.5m
- 2.5m to 5.0m
- 5.0m and more

0 100 200 300 m

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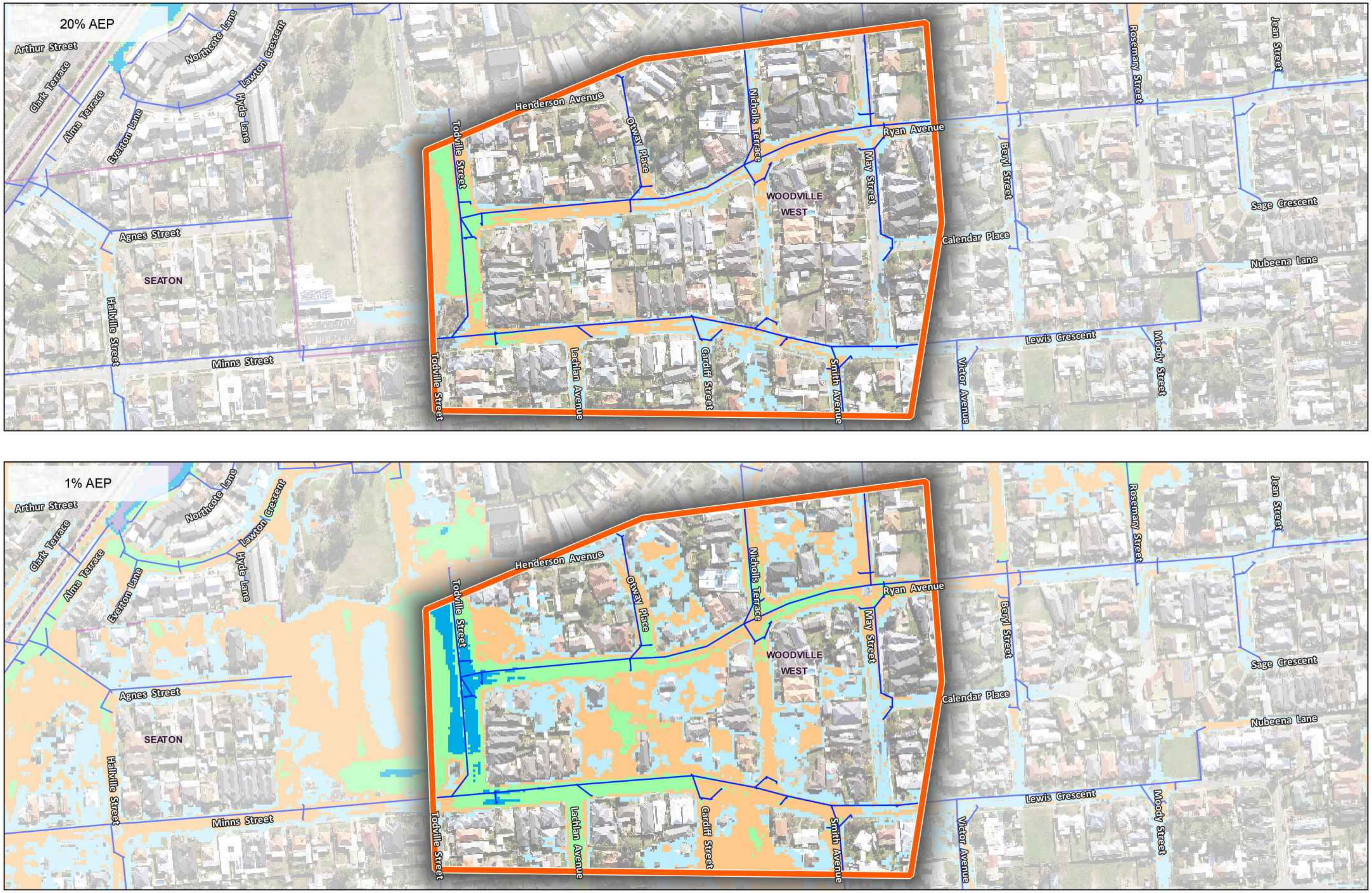
WEST LAKES STORMWATER MANAGEMENT PLAN
FLOODING SURROUNDING DRUMMOND AVENUE

Figure 4.6

4.2.5 Frank Mitchell Reserve

Council has identified flooding issues to the east of Frank Mitchell Reserve. This has been confirmed by the flood modelling for the 1% AEP event, which shows significant flooding within the road reserves of the adjacent streets (Figure 4.7). Depths of inundation of up to 0.65 m are expected within Todville Street. Floodwaters encroach into private properties within Ryan Avenue and Lewis Crescent, typically to depths less than 0.2 m. Flooding of the road reserve within these streets is also expected during the 20% AEP event.

Review of the pipe standards map shows that the pipe network within this area has less than a 1 EY standard.



Legend

- Pipe
- Flood zone
- Suburb

Depth of inundation

- Less than 0.025m (not shown)
- 0.025m to 0.10m
- 0.10m to 0.25m
- 0.25m to 0.50m
- 0.50m to 1.0m
- 1.0m to 1.5m
- 1.5m to 2.5m
- 2.5m to 5.0m
- 5.0m and more

0 100 200 300 m

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WEST LAKES STORMWATER MANAGEMENT PLAN
FLOODING SURROUNDING FRANK MITCHELL RESERVE

Figure 4.7

4.2.6 York Avenue

Localised flooding issues have been identified within the area surrounding York Avenue. Due to a trapped low spot within the road, modelled flood depths of up to 0.3 m are shown along York Avenue in the 20% AEP event. In events with a magnitude greater than the 5% AEP event, flood waters spilling from both York Avenue and Ford Crescent result in inundation depths of greater than 0.2 m within private properties. In a 1% AEP event, the modelled depth of inundation on private property is up to 0.5 m, with depths in excess of 0.5 m expected in the road reserve.

Extracts from the flood modelling for the 20% and 1% AEP events are provided in Figure 4.8.

Legend

- Pipe
- Flood zone
- Suburb

Depth of inundation

- Less than 0.025m (not shown)
- 0.025m to 0.10m
- 0.10m to 0.25m
- 0.25m to 0.50m
- 0.50m to 1.0m
- 1.0m to 1.5m
- 1.5m to 2.5m
- 2.5m to 5.0m
- 5.0m and more

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Date:	2021-07-28
Drawn:	MM

0 50 100 150 m

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WEST LAKES STORMWATER MANAGEMENT PLAN
FLOODING SURROUNDING YORK AVENUE

Figure 4.8

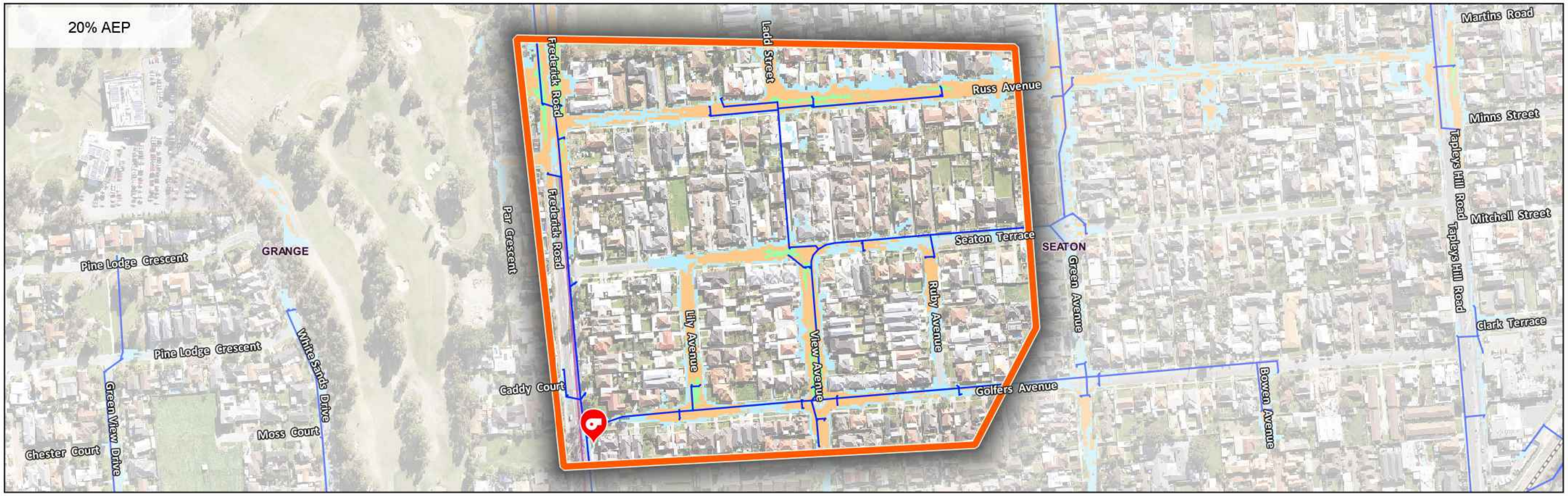
4.2.7 Golfers Avenue

Inundation of private property is observed to the north of the RAGC within the area surrounding Golfers Avenue, as shown in Figure 4.9. Information provided by Council indicates that there were reports of flooding of residential properties within this area during the 2016 heavy rainfall event.

This residential precinct is predominantly served by a single underground drainage network, beginning in Russ Avenue (450 mm x 225 mm RCBC), travelling through private property in a drainage easement to Seaton Terrace, before transfer via pump station at the western end of Golfers Avenue. Review of the standards mapping shows that within this precinct, the underground drain has a standard of less than 1 EY, with upwelling from pits occurring during each modelled event. This is attributed to capacity of both the pipes and the pumps.

The modelling shows that floodwaters would be expected to pool in low spots within the road corridor. This first occurs within View Avenue and Russ Avenue, with modelled flood depths of up to 0.2 m during the 1 EY event. This is consistent with historical observations of regular, nuisance flooding in this area.

Flows appear to spill out of the road reserve and into private property during the 10% AEP event (although flood depths within private property for this event do not exceed 0.2 m). Figure 4.9 indicates that almost all properties within this area will be subject to some degree of inundation during the 1% AEP event. Additionally, flood depths of up to 0.6 m within the road corridor are expected within View Avenue, Lily Avenue and Frederick Road in this event.



Legend

- Pump station
- Pipe
- Beatrice Avenue
- Suburb

Depth of inundation

- Less than 0.025m (not shown)
- 0.025m to 0.10m
- 0.10m to 0.25m
- 0.25m to 0.50m
- 0.50m to 1.0m
- 1.0m to 1.5m
- 1.5m to 2.5m
- 2.5m to 5.0m
- 5.0m and more

0 100 200 300 m

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CITY OF CHARLES STURT

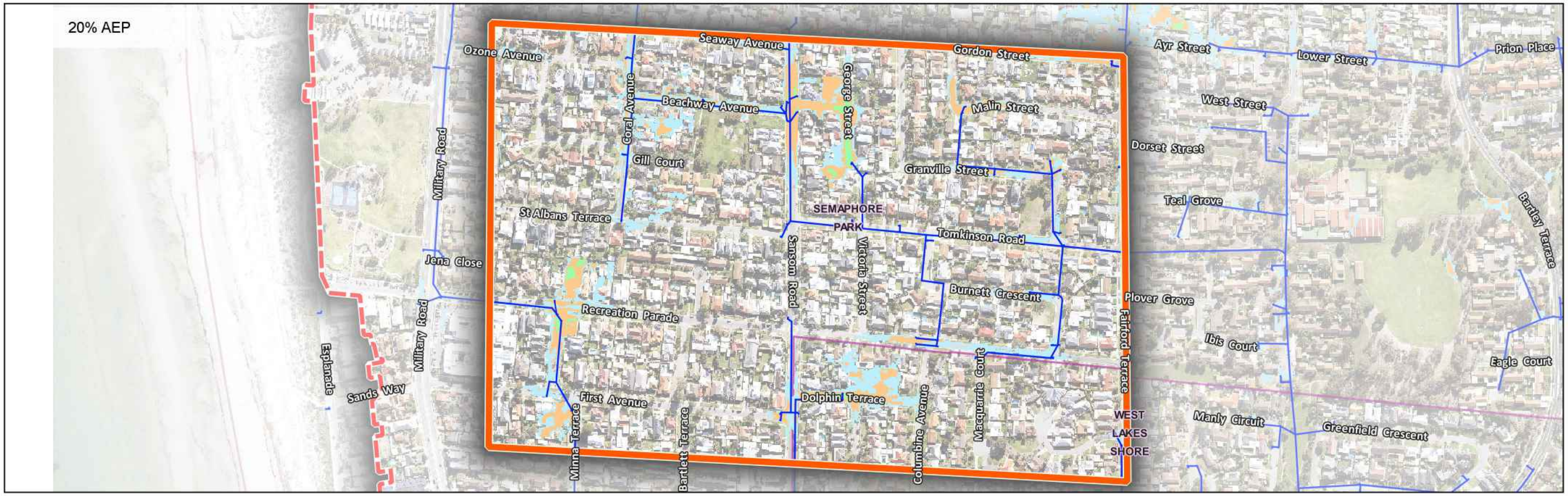
WEST LAKES STORMWATER MANAGEMENT PLAN
FLOODING SURROUNDING GOLFERS AVENUE

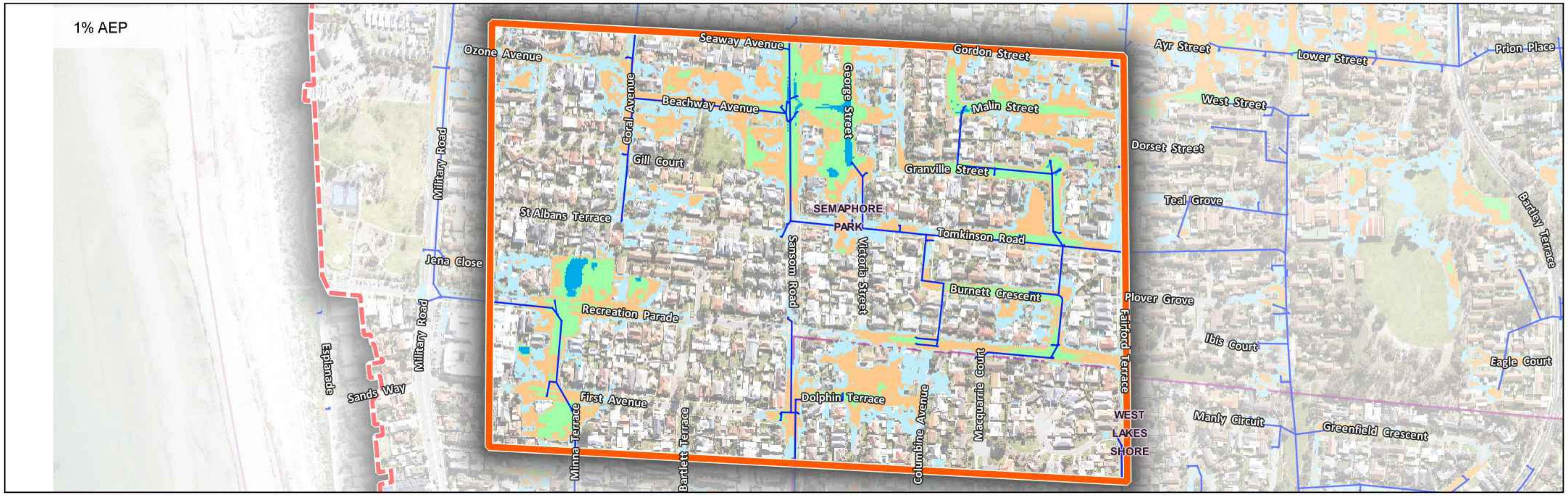
Figure 4.9

4.2.8 Sansom Road

The residential precinct surrounding Sansom Road is served by an underground drainage network that discharges directly to the Lake. Review of the standards mapping shows that the section of drain within Sansom Road, George Street and Granville Street has a drainage standard of less than 1 EY, resulting in ponding of water within the road during frequent events. Of particular concern is the modelled flooding within the southern portion of George Street, which reaches a depth of up to 0.45 m during the 20% AEP, due to insufficient capacity within the 300 mm diameter pipe.

Flooding within this area during the 20% AEP and 1% AEP events is shown in Figure 4.10. There are multiple areas of deep (up to 0.7 m) flooding within the road reserve, as well as multiple instances of ingress of floodwaters into private properties, with depths exceeding 0.2 m.





Legend

- Pipe
- Flood zone
- Study area boundary
- Suburb

Depth of inundation

- Less than 0.025m (not shown)
- 0.025m to 0.10m
- 0.10m to 0.25m
- 0.25m to 0.50m
- 0.50m to 1.0m
- 1.0m to 1.5m
- 1.5m to 2.5m
- 2.5m to 5.0m
- 5.0m and more

0 100 200 300 m

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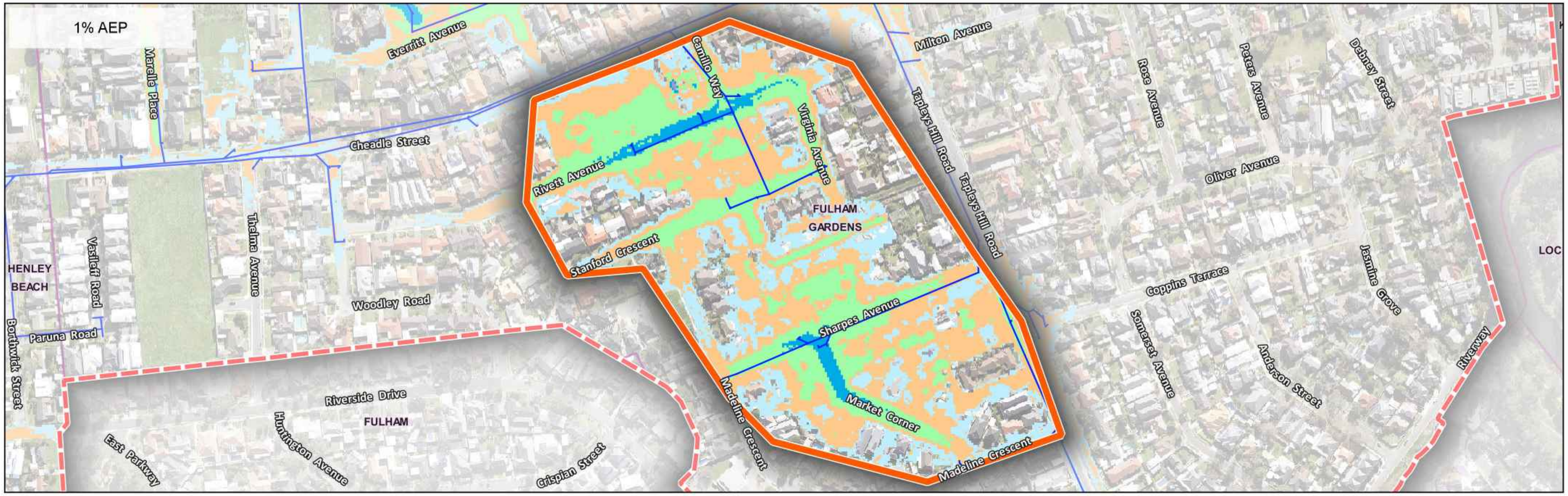
WEST LAKES STORMWATER MANAGEMENT PLAN
FLOODING SURROUNDING SANSOM ROAD

Figure 4.10

4.2.9 Market Corner

Flooding within the area surrounding Market Corner is expecting during the 20% AEP and 1% AEP event, as shown in Figure 4.11. Flood depths at localised depressions within the road are greater than 0.5 m at Rivett Avenue and 0.65 m at Market Corner, resulting in potentially unsafe driving conditions along these roads. The capacity of the aboveground drainage system is exceeded at most locations within this area, resulting in widespread inundation within private properties during the 1% AEP event.

Of particular note is the flood depth at the northern end of Market Corner (a sag location), which exceeds 0.3 m in the 0.5 EY (frequent) event, and is therefore a location of nuisance flooding. Runoff is collected via pits and pipe (375 mm), however review of the standards mapping indicates that this system (Market Corner and Sharpes Avenue) has a standard of less than 1 EY. The frequent ponding of runoff within the road at this location is therefore primarily caused by a lack of capacity in the underground drainage system.



Legend

- Pipe
- Flood zone
- Study area boundary
- Suburb

Depth of inundation

- Less than 0.025m (not shown)
- 0.025m to 0.10m
- 0.10m to 0.25m
- 0.25m to 0.50m
- 0.50m to 1.0m
- 1.0m to 1.5m
- 1.5m to 2.5m
- 2.5m to 5.0m
- 5.0m and more

0 100 200 300 m

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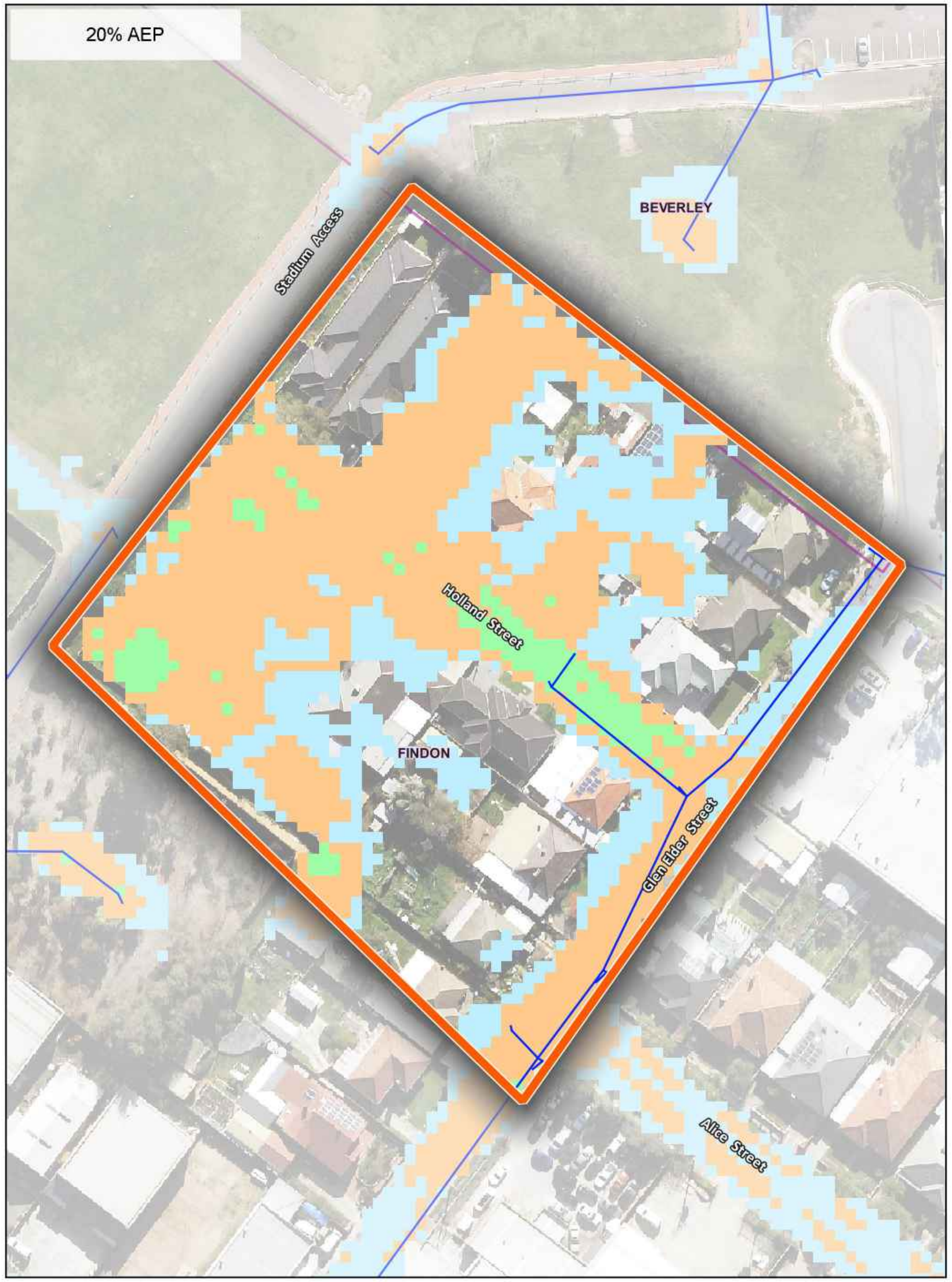
CITY OF CHARLES STURT

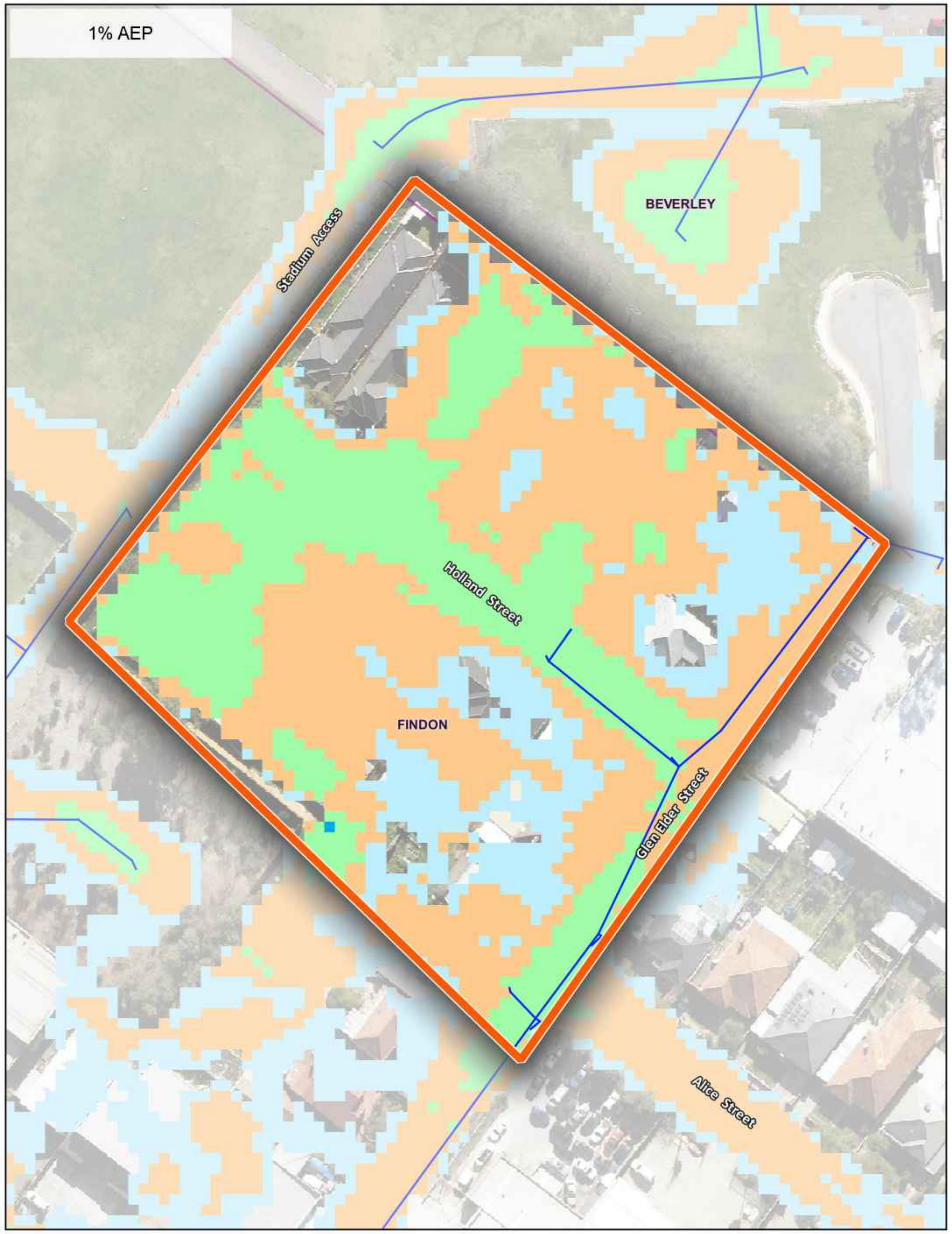
WEST LAKES STORMWATER MANAGEMENT PLAN
FLOODING SURROUNDING MARKET CORNER

Figure 4.11

4.2.10 Holland Street

The road reserve as well as a number of properties within Holland Street are subject to inundation during all events. Inlets located at a sag point towards the eastern end of the street are used to direct runoff to the underground drainage network. The standard of the network within this area is less than 1 EY. Ponding at the sag reaches depths of up to 0.3 m during the 20% AEP event and 0.45 m in the 1% AEP event. The 20% AEP and 1% AEP inundation depths are shown in Figure 4.12.





Legend

- Pipe
- Flood zone
- Suburb

Depth of inundation

- Less than 0.025m (not shown)
- 0.025m to 0.10m
- 0.10m to 0.25m
- 0.25m to 0.50m
- 0.50m to 1.0m
- 1.0m to 1.5m
- 1.5m to 2.5m
- 2.5m to 5.0m
- 5.0m and more

0 25 50 75 m

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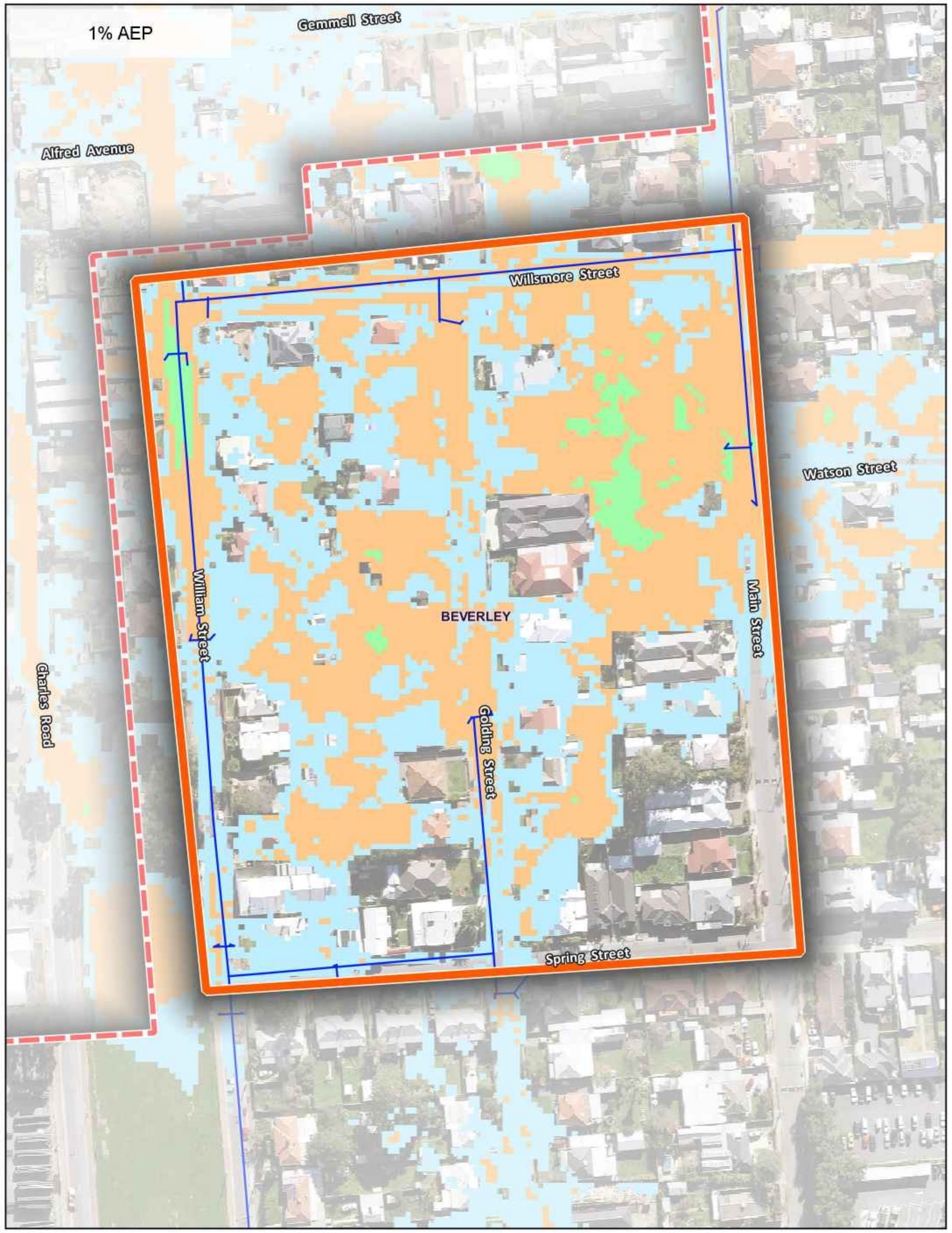
WEST LAKES STORMWATER MANAGEMENT PLAN
FLOODING SURROUNDING HOLLAND STREET

Figure 4.12

4.2.11 Main Street

Runoff within Main Street is directed to an underground drain (300 mm diameter) at a sag location adjacent to Watson Street. Review of the pipe standards map shows that this drainage run has less than a 1 EY standard. This is consistent with the flood mapping which shows ponding of water within the road to a depth of up to 0.15 m during the 1 EY event. As such, flooding within this area is likely due to a lack of capacity within the underground drainage network.

Additionally, ingress of floodwaters into private property along the western side of Main Street is expected for all events. The extents of inundation for the 20% AEP and 1% AEP events are shown in Figure 4.13. Deep ponding (up to 0.35 m) is observed within a localised depression near the intersection of William Street and Willsmore Street during the 1% AEP event.



Legend

- Pipe
- Flood zone
- Study area boundary
- Suburb

Depth of inundation

- Less than 0.025m (not shown)
- 0.025m to 0.10m
- 0.10m to 0.25m
- 0.25m to 0.50m
- 0.50m to 1.0m
- 1.0m to 1.5m
- 1.5m to 2.5m
- 2.5m to 5.0m
- 5.0m and more

0 50 100 150 m

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Roads and railways from Data SA, 2019

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CITY OF CHARLES STURT

WEST LAKES STORMWATER MANAGEMENT PLAN
FLOODING SURROUNDING MAIN STREET

Figure 4.13

4.3 Flood hazard

Flooding is a hazard which has the potential to cause damage to the property and a risk to life. Given the nature of the West Lakes SMP area, it would be expected that flood waters would typically be shallow and slow moving. Deep, fast moving flows may occur in open channels such as Grange Lakes.

Flood hazard mapping assists with identifying the relative degree of hazard in a floodplain. This allows for effective floodplain management and emergency response planning.

Flood hazard maps for the West Lakes catchment were produced using the combined flood hazard threshold curves developed by Smith et al (2014), as shown in Figure 4.14. The combined flood hazard curves are divided into a number of hazard classifications that are based on thresholds for the stability of people, vehicles and buildings in floods. These thresholds are influenced by a number of factors, predominantly the velocity and depth of floodwaters.

The flood hazard map for the 1% AEP event (long term development (2070) with climate change) is included with the flood depth maps in Appendix C.

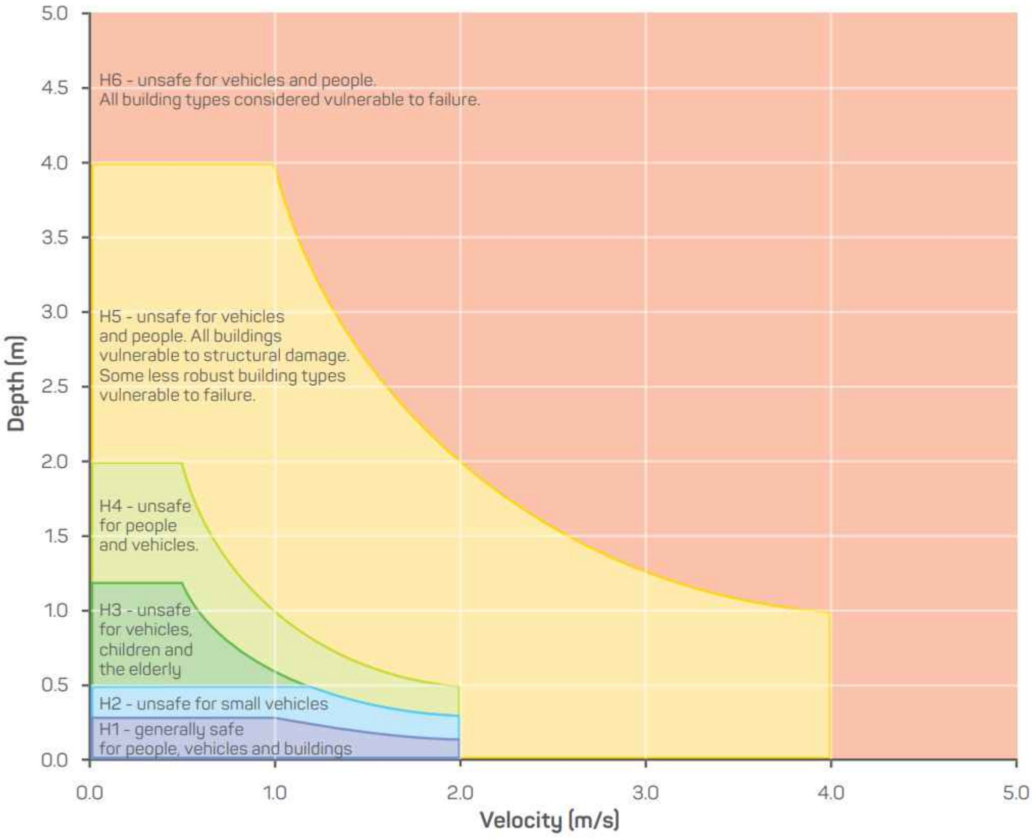


Figure 4.14 Combined flood hazard curves (Smith et al. 2014)

Review of the 1% AEP hazard map shows that despite the extensive inundation across large areas of the study area, the shallow and slow moving nature of the flows means that in most areas within the catchment, the associated hazard will be low (H1). This means that safe evacuation will generally be possible and the direct risks to life and structural damage to buildings will be generally life. Other impacts to the community including psychological impacts and damage to property may still occur.

Areas of higher hazard generally occur at areas of deep ponding within the roads. Each of the key flood prone areas identified in Section 4.2 contains a segment of road with a hazard classification of H3. These areas should be noted when preparing flood response management plans.

5 Flood damages

Floods can have large social, economic and environmental consequences for communities and individuals. Within the West Lakes catchment, the most likely immediate consequence of a flood will be damage to property, although loss of life may also occur.

The cost of damages caused by a flood provides important information that can be used to prioritise flood mitigation or prevention measures. It can indicate the magnitude of damage caused by a design flood event of given annual exceedance probability.

The magnitude of the damages is dependent on a number of factors, including the extent of flooding, property value, property size and the preparedness of the community affected by flooding (i.e. whether they are prepared to respond to a flood threat). These factors and others have been included in the damage calculation process.

Flood damages have been estimated using the Rapid Appraisal Method (RAM) developed by the Victorian Department of Natural Resources and Environment (DNRE, 2000). This approach allows for a rapid and consistent evaluation of floodplain management measures in a cost-benefit analysis framework.

The assessment includes consideration of damage to residential and non-residential properties. In the absence of surveyed floor levels, it has been assumed that the floor level is 150 mm above ground level at the centroid of the allotment for residential buildings, and 100 mm above ground level for non-residential buildings. Damage to public infrastructure, such as roads, has not been included in the analysis as it has been assumed that these damages would be small.

The estimates of damage also include consideration of direct damages and indirect damages (costs that are incurred by a community during and after a flood event that are not related to damage of property).

Further details regarding the methodology are provided in Appendix D.

5.1 Damage results

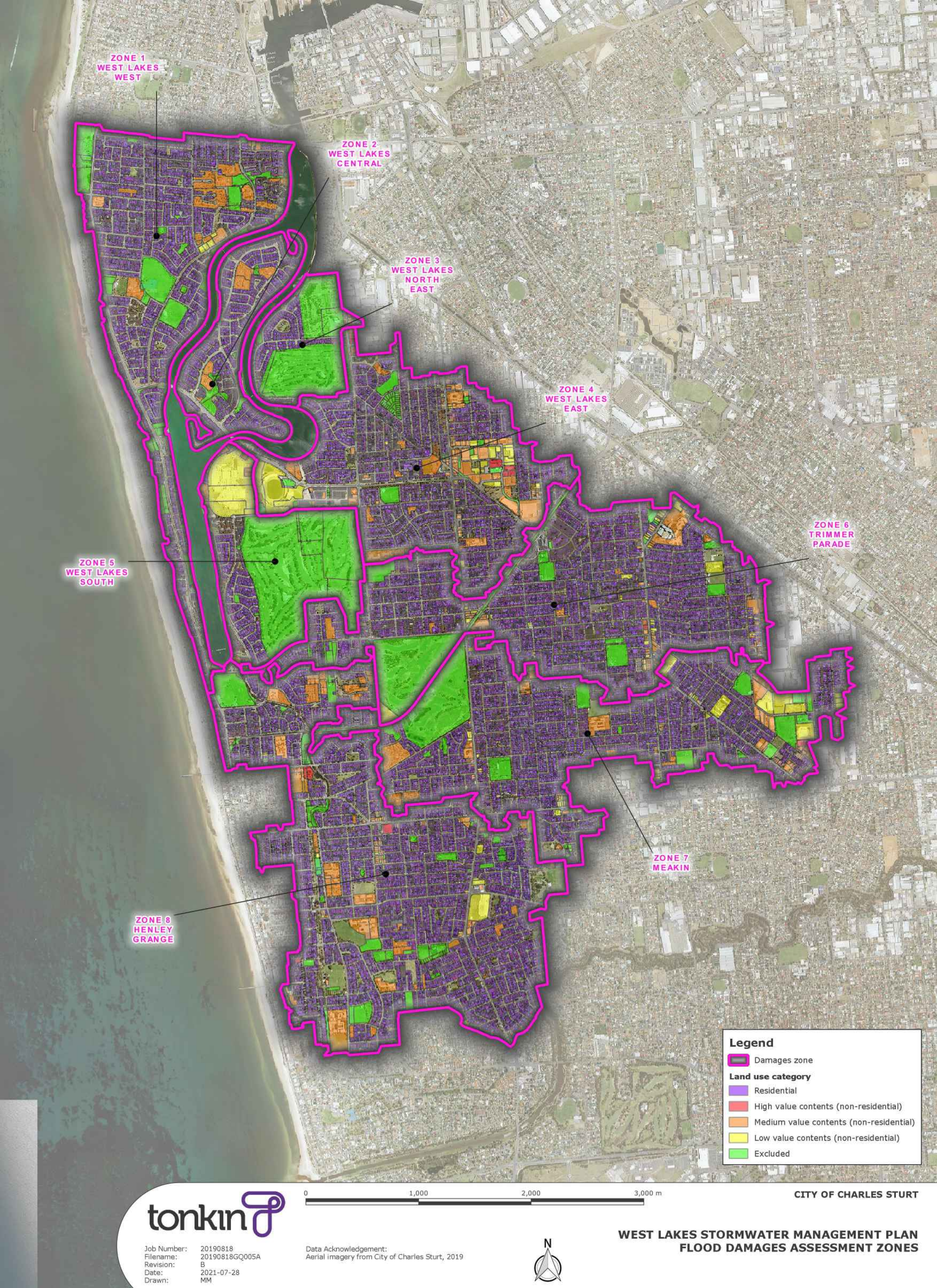
Damages across the study area have been calculated for the full range of modelled flood events (63% to 0.2% AEP). The damages were categorised based on the following zones, representative of the major sub-catchments:

- Zone 1 – West Lakes West
- Zone 2 – West Lakes Central
- Zone 3 – West Lakes North East
- Zone 4 – West Lakes East
- Zone 5 – West Lakes South
- Zone 6 – Trimmer Parade
- Zone 7 – Meakin
- Zone 8 – Henley Grange.

The boundaries of each zone, as well as the land use type used to quantify the damages, are shown in Figure 5.1.

The flood damages across these zones are summarised in Table 5.1 for each of the modelled flood events. The annual average damages (AAD) are presented in Table 5.2. The AAD were calculated based on the assumption that there are no damages in a 12 exceedances per year (EY) storm event.

It can be seen that the greatest damages occur within Zones 6, 7 and 8, as a result of flooding to residential properties along shallow natural valleys within the landscape. There is minimal damage within Zones 2 and 3. These areas are relatively small catchments, discharging directly to the Lake.



tonkin

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CITY OF CHARLES STURT

WEST LAKES STORMWATER MANAGEMENT PLAN
FLOOD DAMAGES ASSESSMENT ZONES

Figure 5.1

Table 5.1 Flood damages ($ million) (future climate and development, existing stormwater infrastructure)

Zone	Annual exceedance probability							
	63%	39%	20%	10%	5%	2%	1%	0.2%
1 West Lakes West	0.07	0.11	0.37	0.57	1.38	3.02	4.43	11.06
2 West Lakes Central	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09
3 West Lakes North East	0.01	0.01	0.01	0.01	0.01	0.02	0.03	0.11
4 West Lakes East	0.08	0.19	0.29	0.59	1.45	3.32	6.18	12.50
5 West Lakes South	0.24	0.34	0.49	0.66	0.89	1.19	1.80	3.76
6 Trimmer Parade	0.09	0.31	1.17	2.49	5.26	12.08	18.91	39.75
7 Meakin	0.19	0.67	2.25	4.70	8.45	15.20	20.64	31.49
8 Henley Grange	0.05	0.12	0.34	0.97	3.26	8.08	14.19	33.73
Total	**0.74**	**1.74**	**4.92**	**9.98**	**20.70**	**42.92**	**66.18**	**132.50**

Table 5.2 Annual average damages (future climate and development, existing stormwater infrastructure)

Zone	AAD ($)
1 West Lakes West	$340,000
2 West Lakes Central	$0
3 West Lakes North East	$8,000
4 West Lakes East	$381,000
5 West Lakes South	$359,000
6 Trimmer Parade	$1,231,000
7 Meakin	$1,833,000
8 Henley Grange	$718,000
Total	**$4,870,000**

Interrogation of the flood modelling results has been undertaken to identify the number of flood-affected properties for each storm event. A flood affected property is defined as any property that has some water at the centroid. It should be noted that these numbers are based on existing cadastre and do not take into account future subdivision of land. They are considered a suitable measure for comparative purposes (pre and post-mitigation).The results are summarised in Table 5.3. The number of residential properties with above floor flooding (based on existing cadastre)are summarised in Table 5.4.

It is expected that almost 900 residential properties would be subject to over floor flooding during a 1% AEP event.

Table 5.3 Number of flood-affected properties (future development and climate change with existing stormwater infrastructure)

Zone	Annual exceedance probability							
	63%	39%	20%	10%	5%	2%	1%	0.2%
1 West Lakes West	27	40	59	89	126	220	300	633
2 West Lakes Central	0	0	0	0	0	1	2	4
3 West Lakes North East	3	4	4	4	4	9	13	49
4 West Lakes East	16	33	59	95	147	292	428	715
5 West Lakes South	3	4	8	9	11	14	24	63
6 Trimmer Parade	36	72	157	274	476	858	1203	1814
7 Meakin	58	107	250	395	560	750	952	1364
8 Henley Grange	13	16	48	109	284	573	816	1408
Total	**156**	**276**	**585**	**975**	**1608**	**2717**	**3738**	**6050**

Table 5.4 Number of flood-affected properties (future development and climate change with existing stormwater infrastructure)

Zone	Annual exceedance probability							
	63%	39%	20%	10%	5%	2%	1%	0.2%
1 West Lakes West	0	0	5	7	21	48	69	178
2 West Lakes Central	0	0	0	0	0	0	0	0
3 West Lakes North East	0	0	0	0	0	0	0	0
4 West Lakes East	0	1	1	3	9	28	61	131
5 West Lakes South	0	0	0	0	0	0	5	12
6 Trimmer Parade	0	2	12	30	70	171	272	646
7 Meakin	1	8	25	49	98	203	283	439
8 Henley Grange	0	0	0	2	38	108	206	510
Total	**1**	**11**	**43**	**91**	**236**	**558**	**896**	**1916**

6 Flood management strategies

The management strategies presented here address the key SMP objective of providing an acceptable level of flood protection (Goals F1, F2 and F3). They target the key flood prone areas identified in Section 4.2. Both structural (capital works) and non-structural strategies (such as education and awareness) are discussed.

6.1 Structural mitigation strategies

A set of flood maps showing the post-mitigation inundation and hazard is available in Appendix C. The post-mitigation maps show the effects of implementing the structural mitigation strategies. Change maps showing the difference in flood depth between the pre- and post-mitigation scenarios are also included. Figure 6.1 shows the location of the structural mitigation options investigated.

The structural flood mitigation strategies include a combination of pipe upgrades and detention storage options. Modelling has demonstrated that, from a hydraulics perspective, in most locations the temporary storage of runoff can either be achieved either within a detention basin or an underground tank. Most of the open spaces within the study area are heavily utilised by the community. On this basis, the SMP generally recommends underground storage tanks.

Further consideration, including community consultation, should be given to the selection of an underground storage tank or an open basin during the design development stages of the relevant mitigation strategies. Typically, the underground tanks will have a higher cost than an open basin option.

6.1.1 Gleneagles Reserve underground tank

Underground detention within Gleneagles Reserve was identified as a recommended standalone solution to mitigate flooding in the area surrounding Meakin Terrace and Leven Avenue. The reserve is upstream of the Leven Avenue flooding hotspot, and therefore provides an opportunity to capture and detain surface runoff prior to it being conveyed through the problem area. Underground detention, as opposed to an open basin has been recommended due to the high levels of use of the reserve.

Consideration of upgrading the Frogmore Road pump station to reduce overflows into the area was also considered during the options development, but it was not found to provide effective flood reduction.

An underground detention tank with a storage volume of 30,000 m^3 is proposed for the ultimate state of development. The modelling assumes a surface area of 15,000 m^2 (i.e. approximately half of the area of the reserve) and depth of 2 m, although alternative configurations are feasible. In practice, the detention may be constructed as a number of smaller tanks built progressively, allowing Council to adapt to increased runoff as a result of increased infill development in addition to projected increases in rainfall intensities due to climate change.

The tank will receive inflows via diversion of the underground drainage networks within Leven Avenue (DN675) and Dumfries Avenue (1200 x 600 RCBC). An outlet from the storage (DN375) will connect into the drain on Dumfries Avenue. A schematic concept design for this option is provided in Figure 6.2.

The resultant reductions in flooding for the 20% AEP and 1% AEP events are shown in Figure 6.3 and Figure 6.4, respectively. It can be seen that the tank provides a significant reduction in the flooding of private property downstream.

During the detailed design process, opportunities to incorporate infiltration (subject to site geotechnical conditions) and/or storage and reuse to provide water for irrigation of the reserve may be considered to increase the benefits associated with construction of the storage.