# Whyalla Stormwater Management Plan

**City of Whyalla**

2 July 2019
Ref: 20160064R005Rev0

Building exceptional outcomes together

# Document History and Status

| Rev | Description | Author | Reviewed | Approved | Date |
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| A | For Client Comment | JDN | SEM | SEM | October 2018 |
| B | Completed draft for Council review | JDN | | SEM | February 2019 |
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# Contents

Project: Whyalla Stormwater Management Plan | Stormwater Management Plan
Client: City of Whyalla
Ref: 20160064R005Rev0

## Tables

## Figures

## Appendices

# Executive Summary

A Stormwater Management Plan has been prepared for the City of Whyalla in accordance with the South Australian Stormwater Management Planning Guidelines (Stormwater Management Authority 2007).

The plan covers the entire developed city area of Whyalla, along with the industrial estate to the north of the Iron Knob Road and the Airport and Mullaquana rural living area to the south of the Lincoln Highway / Broadbent Terrace. The plan considers the impact of flooding from both localised rainfall events, as well as flooding caused by runoff from the large rural catchment of Salt Creek to the north-west of the City.

The document is structured as follows:

- Section 1 Introduction – an overview of previous studies and investigations
- Section 2 Study area – a description of the area covered by the SMP, catchment zones, topography, soils, land use and zoning, the causes of flooding, local climate and receiving waters. This also provides a summary of the existing stormwater infrastructure located within the study area and known stormwater drainage issues and historical flooding events.
- Section 3 SMP objectives – a summary of strategic plans, policies and documents relevant to stormwater management planning in Whyalla followed by the definition of the goals and objectives that this SMP seeks to achieve.
- Section 4 Flooding – background to the modelling undertaken, limitations, an assessment of existing stormwater drainage standard and identification of key flood prone areas and hazards indicated by the floodplain modelling. An assessment of estimated flood damages is also provided
- Section 5 Flood Management Strategies – identification of structural and non-structural strategies or actions to address flooding in key areas, including priorities and estimated costs
- Section 6 Water Quality – an assessment of water quality for the existing catchment and loads of common stormwater pollutants discharging to the gulf, followed by recommended strategies to reduce stormwater pollutant discharges
- Section 7 Stormwater harvesting reuse – a summary of existing water reuse infrastructure within the City and potential yields of stormwater available for harvesting in selected areas
- Section 8 Consultation Summary – a summary of the consultation activities undertaken to communicate the outcomes of the SMP process
- Section 9 Consolidated Stormwater Management Plan – a summary of recommended actions, costs, benefits and priorities along with timeframes for implementation and responsibilities
- Section 10 References – a summary of reference material used in the development of the plan

A number of additional technical reports were prepared as part of the plan's development including:

- Hydrology Summary Paper – summary of the hydrological modelling approach
- Hydraulic Modelling Report - summary of the hydraulic modelling approach
- Water Quality and Water Reuse Discussion paper – a summary of investigations into water quality and reuse potential

Technical detail contained within these reports is generally not reproduced in this SMP document.

A number of key flood risks were identified by the modelling, including:

- Flooding caused by external rural catchments to the north and west of the city, in particular widespread flooding caused by the Salt Creek catchment. The existing flood levee on the western boundary of the city was shown to be inadequate in extent and in need of repair in some areas

- Significant deficiencies in existing stormwater infrastructure either due to insufficient pipe capacity, a lack of stormwater inlets or the complete absence of stormwater drains
- Inadequate capacity within the major stormwater outlet from the City – the 'Airport Drain'

Additionally, the plan highlighted the limited stormwater treatment and reuse infrastructure currently in place, which was not surprising given the arid climate. Despite a lack of stormwater use, treated effluent currently is reused extensively within the city.

A range of strategies and actions have been developed which seek to achieve Council's goals and meet the multi-objective requirements of the SMP planning process. The strategies are aimed at:

- Providing an acceptable level of protection from flooding to the community and public and private assets
- Improving water quality to meeting the requirements for protection of the receiving environment
- Maximising the economic reuse of stormwater for beneficial purposes
- Managing stormwater assets in a sustainable manner
- Achieving desirable planning outcomes associated with new development, open space, recreation and amenity
- Managing stormwater runoff in a manner that protects and enhances biodiversity and the natural environment

Specific strategies identified include:

| Action | Suburb | Priority | Cost |
|---|---|---|---|
| FLOOD MITIGATION | | | |
| Northern levee repair and short extension | Whyalla Jenkins / Whyalla Stuart / Whyalla Norrie | High | $190,000 |
| New 6.2 km extension to northern levee | Whyalla Jenkins / Mullaquana | Medium | $2.58M |
| Airport drain upgrade | Whyalla Stuart / Whyalla Norrie / Mullaquana | Low | $3.18M |
| McRitchie Crescent and Brook Street pipe upgrade | Whyalla Stuart | Medium | $1.88M |
| McLennan Avenue drain upgrades | Whyalla Norrie | High | $6.39M |
| Drainage and detention basin within future Education Precinct | Whyalla Norrie | High | $4.03M |
| Cabin Park levee | Whyalla Norrie | Low | $20,000 |
| Broadbent Terrace culverts | Whyalla Norrie | Low | $1.16M |
| Iron Knob Road detention basins | Whyalla Norrie / Whyalla Playford | Medium | $900,000 |
| McBryde Terrace detention basin | Whyalla Norrie | Medium | $330,000 |
| McConville Street pipe upgrades | Whyalla Playford | Medium | $1.16M |

| Action | Suburb | Priority | Cost |
|---|---|---|---|
| Ocean Eyre development detention basin | Whyalla Jenkins | TBD[1] | $1.74M |
| Sugarwood Crescent detention basin | Whyalla Stuart | Low | $360,000 |
| Farrell Street and Wood Terrace pipe system | Whyalla | High | $810,000 |
| WATER QUALITY IMPROVEMENT | | | |
| Neagle Terrace raingardens and basin | Foreshore | High | $120,000 |
| Dunstone Street infiltration basin | Foreshore | High | $35,000 |
| Cudmore Terrace basin | Foreshore | Medium | $80,000 |
| Roberts Terrace raingardens | Foreshore | Low | $110,000 |
| Education precinct wetland (opportunistic) | Whyalla Norrie | TBD | – |
| Airport Channel erosion and landscape works (opportunistic) | Whyalla Stuart / Whyalla Norrie / Mullaquana | Low | – |
| WATER REUSE | | | |
| Detailed feasibility study into stormwater reuse and distribution potential | All | Medium | $150,000 |

Prior to the implementation of strategies identified there will be a need for additional modelling and investigations to prove the concepts identified. It is also anticipated that some refinement and optimisation will be undertaken as a result of this additional work.

# 1 Introduction

This Stormwater Management Plan (SMP) provides a framework for a coordinated, multi-objective approach for the management of stormwater within the City of Whyalla. The process that has been undertaken during the development of the plan, and the contents of the plan itself, comply with the requirements of the Stormwater Management Planning Guidelines (Stormwater Management Authority, 2007).

Consistent with the intent of the SMP Guidelines, this plan is founded on an integrated multi-objective approach to stormwater management on a whole of catchment basis. It provides an overview of the existing state of the catchment, including identification of problems and opportunities associated with the management of stormwater. It defines objectives for the management of stormwater and presents structural and non-structural strategies to address the objectives. The plan then defines the priorities, responsibilities and timeframes for the implementation of the works identified by the plan.

The plan has been prepared in consultation with staff from Whyalla City Council (Council) and a dedicated project steering group including representatives from Natural Resources Eyre Peninsula and the Department of Planning, Transport and Infrastructure (DPTI) acting as technical advisers to the Stormwater Management Authority.

## 1.1 Previous studies and investigations

A number of previous studies of relevance to this SMP have been undertaken in recent years. In some cases the previous studies represent early developmental work on this SMP and have provided a basis for the modelling undertaken as part of this project. A brief description of the previous studies and their relevance to this SMP is provided below.

### Preliminary Flood Risk Assessment report (AWE 2009)

In 2009, Australian Water Environments (AWE) were engaged to undertake a flood risk assessment of Whyalla city (AWE 2009). The study investigated the catchment boundaries, catchment properties and estimated major flows through the relevant catchments. The study identified potential flood locations and potential areas of deficient stormwater infrastructure. An assessment of past flooding and future flooding risk was undertaken.

The study also provided a summary of opportunities for 'improved stormwater management' including a high-level assessment of stormwater runoff quality and opportunities for water reuse.

Recommendations within the report included capture of a digital elevation model of the study area and surrounding catchments, development of a comprehensive DRAINS model of the Whyalla stormwater network and more accurate flood modelling to confirm flood risk. These recommendations have formed the basis of the data capture and modelling work undertaken (by others) prior to the commencement of this SMP.

### Whyalla Floodplain Modelling study (AWE 2014)

In 2014, AWE was engaged to undertake floodplain modelling and mapping of the rural areas surrounding the urban area around Whyalla (AWE 2014). Two models were prepared; one covering the area to the south of the city around the airport (Airport model) and another to the north of the city around the industrial area (Industrial model). The study used RORB models to assess external catchment flows and TUFLOW models to undertake the floodplain modelling and mapping. The RORB and TUFLOW models of the airport and industrial areas were used as the basis for the modelling of these catchments undertaken as part of the SMP. Where required, minor amendments to the models were made to more accurately reflect current conditions.

### Whyalla: Reducing stormwater impacts on coast and marine environments (DesignFlow 2010)

The marine environment of the Eyre Peninsula has substantial value to the aquaculture, fisheries, tourism, conservation and recreation sectors (DesignFlow 2010). Stormwater discharges from urban areas have been identified as a risk to marine values. In 2010, DesignFlow was engaged by the Eyre Peninsula Natural Resource Management (NRM) Board to investigate the potential impacts of stormwater outfalls on the marine habitat and to identify measures to reduce the risk of marine pollution from stormwater.

The study recommended WSUD objectives and water quality improvement targets for total suspended solids (TSS) and total nitrogen (TN) consistent with reductions specified by the SA Government WSUD policy. Improvement targets for phosphorus (TP) were not specified as TSS and TN are considered to be the most critical for the marine environment of the Eyre Peninsula (DesignFlow 2010).

Further, the report presented a suite of suitable WSUD systems, locations and preliminary sizing advice for the outfalls in Whyalla aimed at reducing the risk of marine pollution and meeting the recommended targets.

# 2 Study area

## 2.1 Study boundary

Broadly, the study area covers Whyalla's urban centre and residential areas, the industrial areas north of the city and the airport and rural living areas to the south of the city.

The study covers an area of approximately 54 $km^2$, located within the Corporation of the City of Whyalla. The study area boundary is shown on Figure 2.1.

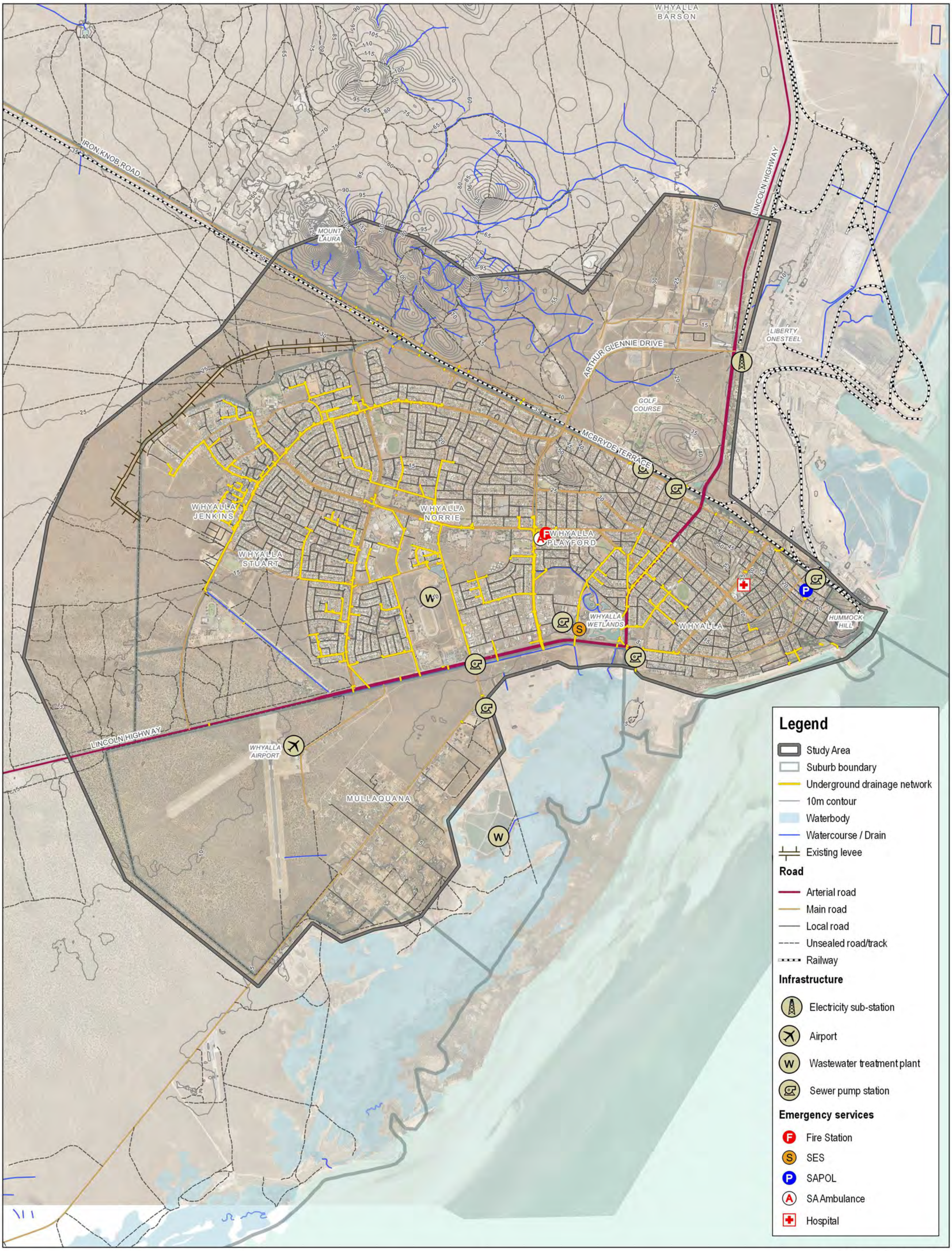
The study area has been broken into three general areas for the purposes of the modelling underpinning the SMP's development:

- the City catchment, bordered by the Lincoln Highway to the south and the Iron Knob Road to the north
- the Industrial area, covering the industrial estate north of the Iron Knob Road
- the Airport and Mullaquana rural living zone, south of the Lincoln Highway.

The Whyalla Steelworks (Liberty Onesteel) area is excluded from the study area.

The City lies within the floodplain of Salt Creek, with a significant rural catchment stretching as far as Iron Knob to the north-west.

The location of the city and the study area in the context of the larger catchment is shown in Figure 2.2.

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**CITY OF WHYALLA**

**WHYALLA STORMWATER MANAGEMENT PLAN**
**STUDY AREA**

Figure 2.1

## 2.2 Description of catchments

### 2.2.1 Major catchments

The study area is covered by two major catchments. The largest catchment, that of Salt Creek, is a 1700 km$^2$ catchment stretching north-west into the Middleback Ranges just beyond Iron Knob. The downstream extent of the catchment covers the majority of the Whyalla city area to the south of the Iron Knob Road and railway line. A small portion of the eastern area of the city is outside the major catchment area and discharges directly to the foreshore area.

A smaller catchment north of Iron Knob Road originates in the ranges on the north-eastern side of Mount Laura and drains through the industrial estate to the west of the steel works. This catchment also includes a small portion of the eastern city area that drains towards McBryde Terrace, discharging under the railway line.

The catchments contributing to the study area are shown on Figure 2.2.

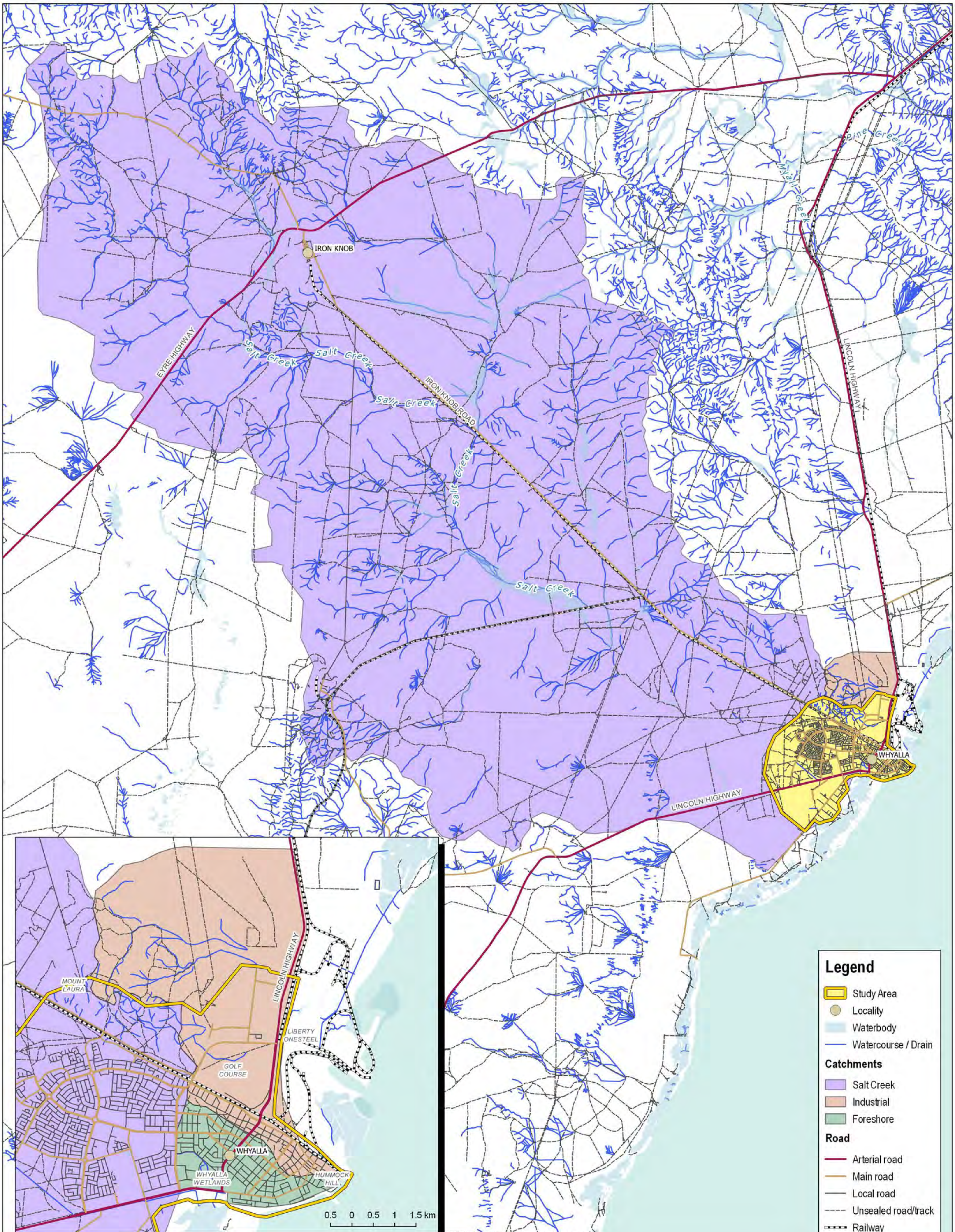
### 2.2.2 City flood zones

Figure 2.3 shows the boundaries of areas draining to the various underground stormwater networks. Due to the way in which the stormwater network has evolved, these areas do not necessarily correspond to the major overland flow paths formed by the natural topography. The stormwater network (and to a lesser extent the road network) distort the usual notion of a 'catchment' across the urbanised parts of the study area. In order to aid discussion of the modelling results, the city has been split into broad zones that approximately follow the primary overland flow paths through the urban areas. The following areas were selected for discussion (and are shown in Figure 2.3 also):

- Valley 1
- Valley 2
- Broadbent Terrace – Ocean Eyre
- McConville Street
- Farrell Street
- Foreshore
- Industrial
- Airport–Mullaquana

Except for the Airport–Mullaquana and Industrial flood zones, the city flood zones are characterised by typical residential and commercial urban development. Pockets of open space exist where schools or public reserves are present. Residential allotments range in size but on average are between 600 and 800 m$^2$.

Runoff is generally dominated by short duration (less than 2 hours duration), high intensity storms that overload the underground drainage network. Peak flows typically occur 20 to 30 minutes after the start of rainfall.

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**WHYALLA STORMWATER MANAGEMENT PLAN**
**MAJOR CATCHMENTS**

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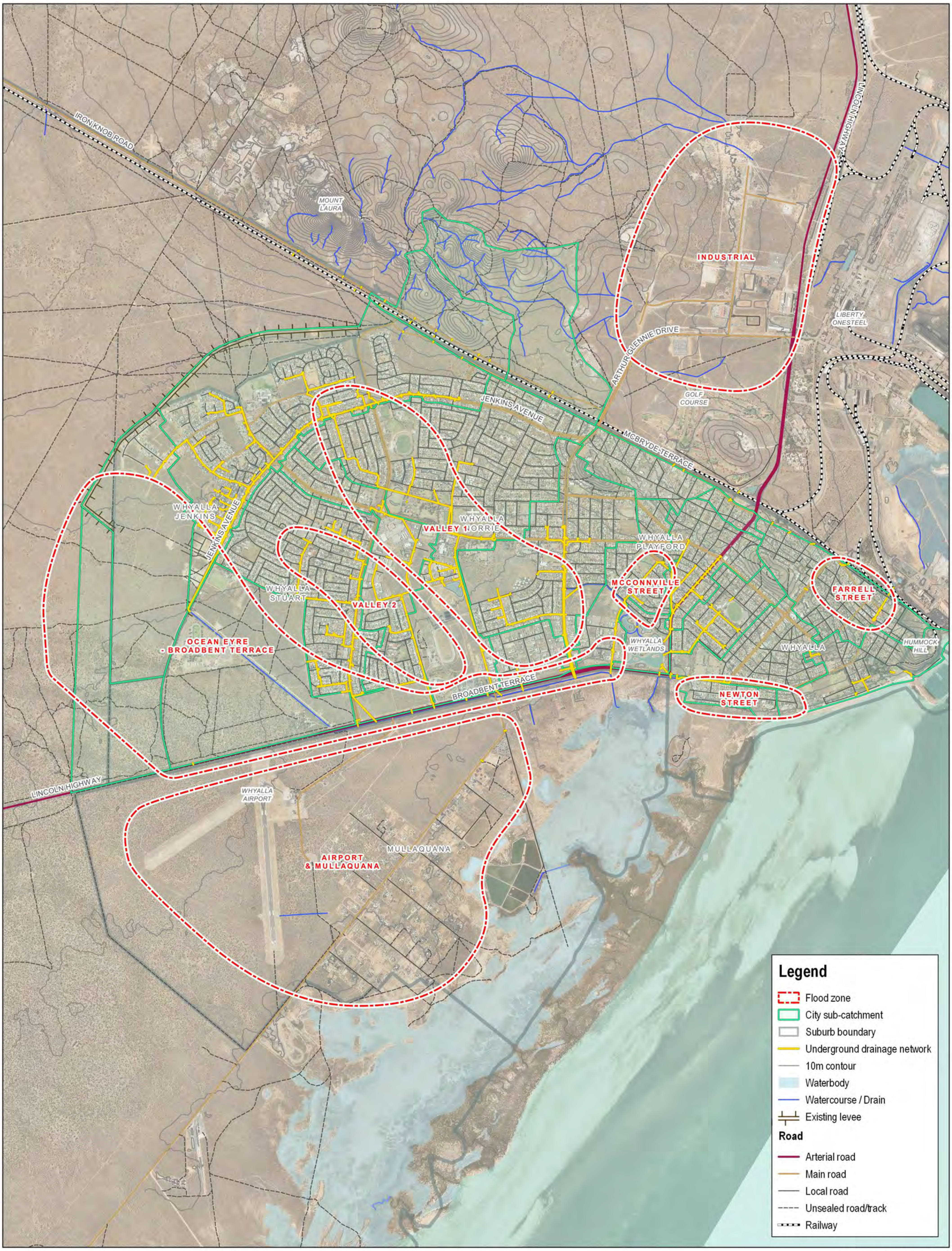
Figure 2.2

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WHYALLA STORMWATER MANAGEMENT PLAN
CITY SUB-CATCHMENTS AND GENERAL FLOOD ZONES

Figure 2.3

### 2.2.3 Topography

The upper Salt Creek catchment has well defined topography drained by a network of gullies and watercourses. In the lower portion of the catchment, to the west of Whyalla city, the topography becomes less defined and the creek likely creates a broad floodplain when in flood. The hills to the north of Whyalla, including Mount Laura drain in a southerly direction towards the north-western portion of the city.

Elevations within the catchment range from approximately 240 mAHD at the north-western extent of the catchment and 390 mAHD at the highest point within the Baxter Hills to the north of Iron Knob to less than 10 mAHD adjacent the coast.

North of the Iron Knob Road and railway line, the hills surrounding Mount Laura drain in an easterly direction through the industrial estate and steel works. Elevations range from approximately 150 mAHD at the top of Mount Laura to less than 10 mAHD adjacent the coast.

The Whyalla urban area generally grades gently in a south-easterly direction towards the coast, with elevations ranging from 30 mAHD to less than 10 mAHD. The north-eastern portion of the city has some steeper topography, with a band of hills on the southern side of the railway line draining in a southerly direction towards the foreshore. These hills include Hummock Hill at the eastern-most point of the city, with an elevation of 56 mAHD.

A digital elevation model (DEM) of the study area was provided by Council. The DEM was based on data captured by LiDAR, a remote sensing method that uses laser pulses to measure the distance to features in the terrain. Some additional detail was captured to supplement the existing DEM to create a dataset fit for modelling purposes.

The DEM used for the study is shown in Figure 2.4.

### 2.2.4 Soils

Detailed mapping of soils within Whyalla and the surrounding catchment are not available from the Department for Environment and Water (DEW) Soils Database, as the study area is outside of the state's agricultural area for which the mapping is focussed.

Geological information for the catchment and study area was obtained from the South Australian Resource Information Geoserver (SARIG) https://map.sarig.sa.gov.au/. A map showing the surface geology of the area is provided in Figure 2.5. The primary geological units present within the study area are:

- Qha Undifferentiated Holocene alluvial/fluvial sediments.
- Qha7 Holocene talus / scree deposits
- Qpr4 Pleistocene gravel, clay, silt and sand with soft carbonate, overlying nodular/tabular calcrete.
- Qhck St Kilda Formation – Coastal marine sediment: calcareous, fossiliferous sand and mud of intertidal sand flats, beaches and tidal marshes; organic, gypseous clay of supratidal flats.
- Qhks Semaphore Sand Member – Unconsolidated white bioclastic quartz-carbonate sand of modern beaches and transgressive dune fields.
- Lmm Moonabie Formation – Massive grey to purplish volcaniclastic grit with pebble beds and heavy mineral laminae. Bedding rarely visible.
- M-p Pandurra Formation – Sandstone, quartz and lithic, m.g.-c.g., poorly sorted; sandstone, well-sorted, v.f.g.-m.g.; conglomerate, granule to pebble; mudstone; siltstone. Red, brown or purple with reduction spotting or mottling. Fluvial, large-scale cross-bedding and liesegang banding. Maximum deposition 1424±51 Ma (Rb-Sr).

Generally, this indicates that most of the soils within the city's residential area (except the rocky outcrops of the Moonabie and Pandurra Formation) are likely to be clayey, with some sandier materials along the coastal fringe.

The soils are considered typical of the semi-arid regions of Australia – thin red brown, alkaline sand and clay. These are typically fine-grained, subject to wind erosion and of low permeability and area dispersive.

The main topographical feature of the study area is the North Whyalla Hills, stretching from Hummock Hill on the coast in a north-north westerly direction to Wild Dog Hill within the Whyalla Conservation Park, north of the City. This 'hillier' terrain in the north-eastern portion of the city is characterised by relatively shallow rock, which has previously limited the extent of underground stormwater infrastructure. This is likely to limit to the feasibility of large-scale underground stormwater pipe upgrades and may have cost and constructability implications for other flood mitigation and WSUD features such as detention basins. Prior to any detailed design exercise, intrusive ground investigations are recommended to confirm the distribution and depth of rock in any areas being considered for new infrastructure.

Experience in the western parts of Whyalla suggest that some of the near surface clays are susceptible to collapse—sudden (and sometimes large) ground settlement when the ground is brought to around 80% saturation or more. This has the potential to affect the stability and serviceability of any structures where collapse occurs and poses an obvious risk to temporary water storages and nearby areas. Collapse risk will require consideration in detailed design and may require specialised investigation techniques.

Soils within the study area may also influence the feasibility of water sensitive urban design (WSUD) implementation within Whyalla, given the nature of the fine grain, dispersive soils and the shallow saline groundwater system. These soil characteristics limit opportunities for infiltration-type devices and require careful consideration where filtration devices (e.g. raingardens) are being considered. Operational issues at the Whyalla wetlands have highlighted how the design intent could not be achieved due to saline groundwater ingress, soil erosion and difficulties in establishing vegetation.

Soil conditions around the foreshore area are typically associated with coastal sands and are better suited to WSUD treatments than other areas of Whyalla (Design Flow, 2010).

### 2.2.5 Land use and zoning

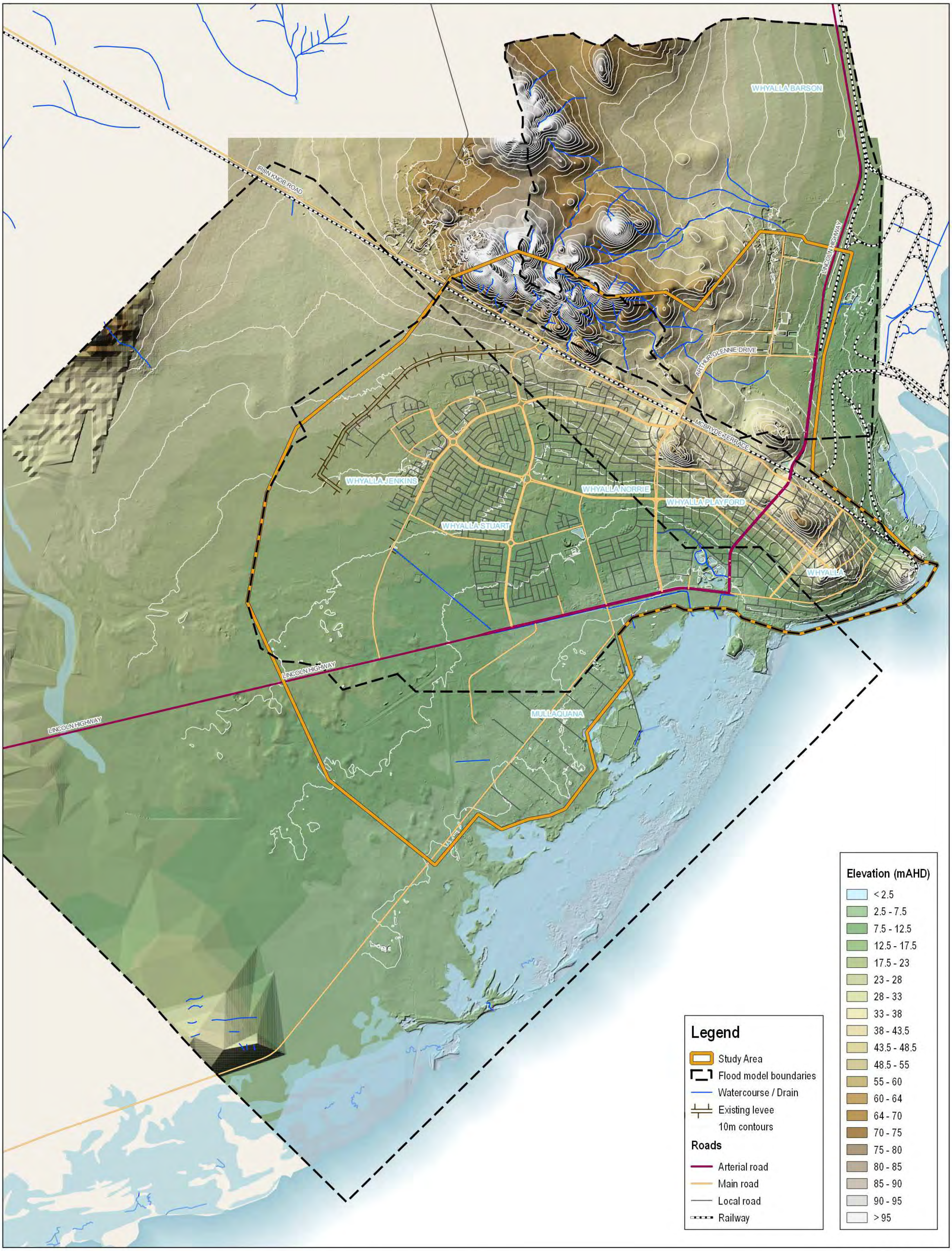
Existing land use within the catchment is shown in Figure 2.6. Within the study area the land use characteristics include:

- The residential areas of Whyalla city, covering the majority of the study area
- Dispersed industrial, commercial, recreational and open space areas within the city
- The Airport, located to the south of the Lincoln Highway
- Rural living, adjacent to the airport, south of the Lincoln Highway
- The large industrial estate at the northern extent of the study area
- The golf course north of the Iron Knob Road.
- The large area occupied by the Whyalla steelworks (Liberty OneSteel) is excluded from the study area.

#### Future development

Current zoning within the study area is shown in Figure 2.7. The map indicates there are some land parcels available for future residential development, predominantly in the north-western corner of the city. Of the available undeveloped residential land, only the area shown as "future residential development" on Figure 2.6 and Figure 2.7 has been considered within this SMP, as agreed with Council. This area is likely to be developed within the timeframe of the SMP implementation, as the 'Ocean Eyre' development expands.

A single development scenario, representing the existing state of the catchment area (but assuming the Ocean Eyre development is fully developed) has been considered in this plan.

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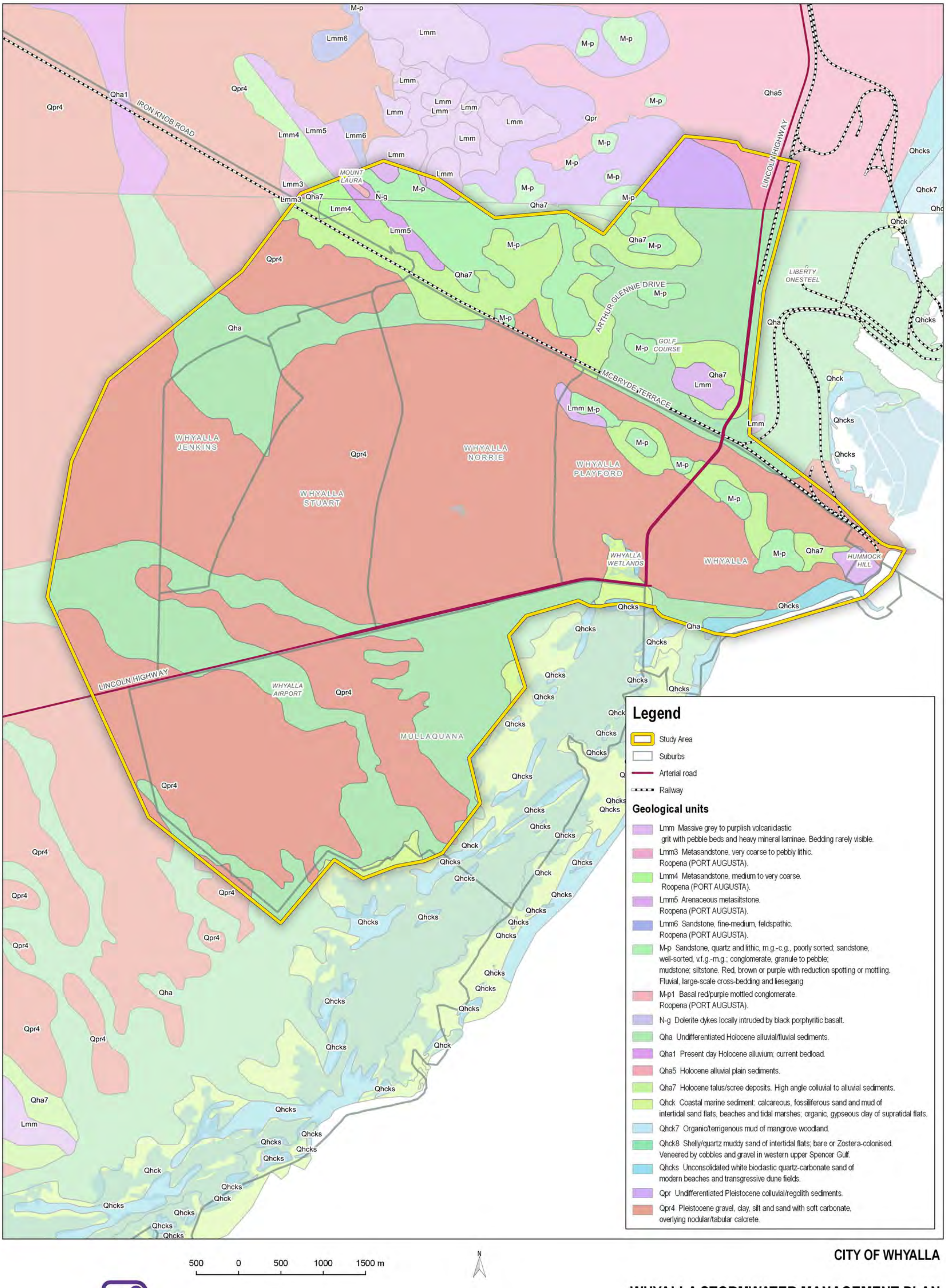
CITY OF WHYALLA

WHYALLA STORMWATER MANAGEMENT PLAN
STUDY AREA TOPOGRAPHY

Figure 2.4

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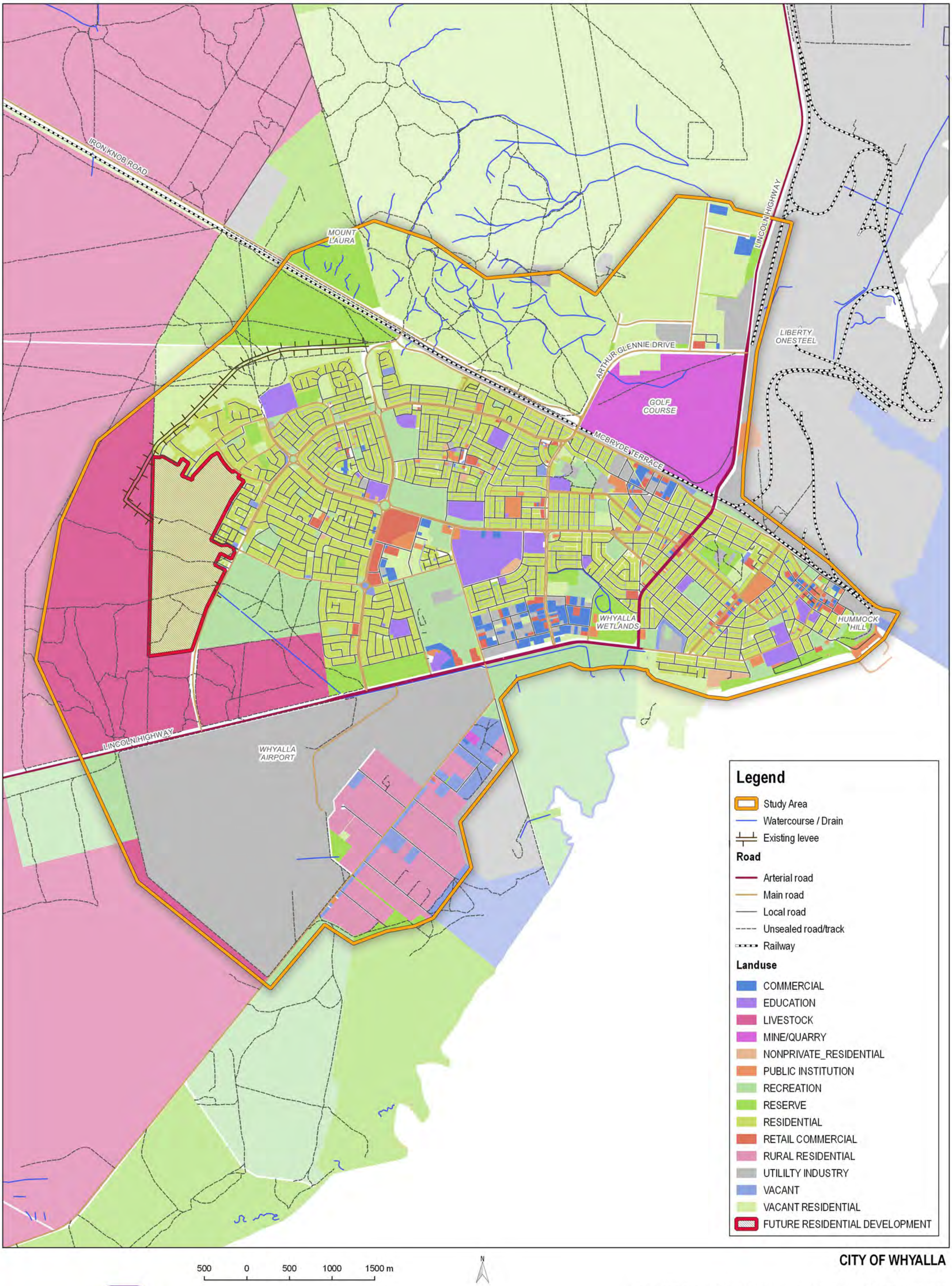
**WHYALLA STORMWATER MANAGEMENT PLAN**
**SOIL TYPES**

Figure 2.5

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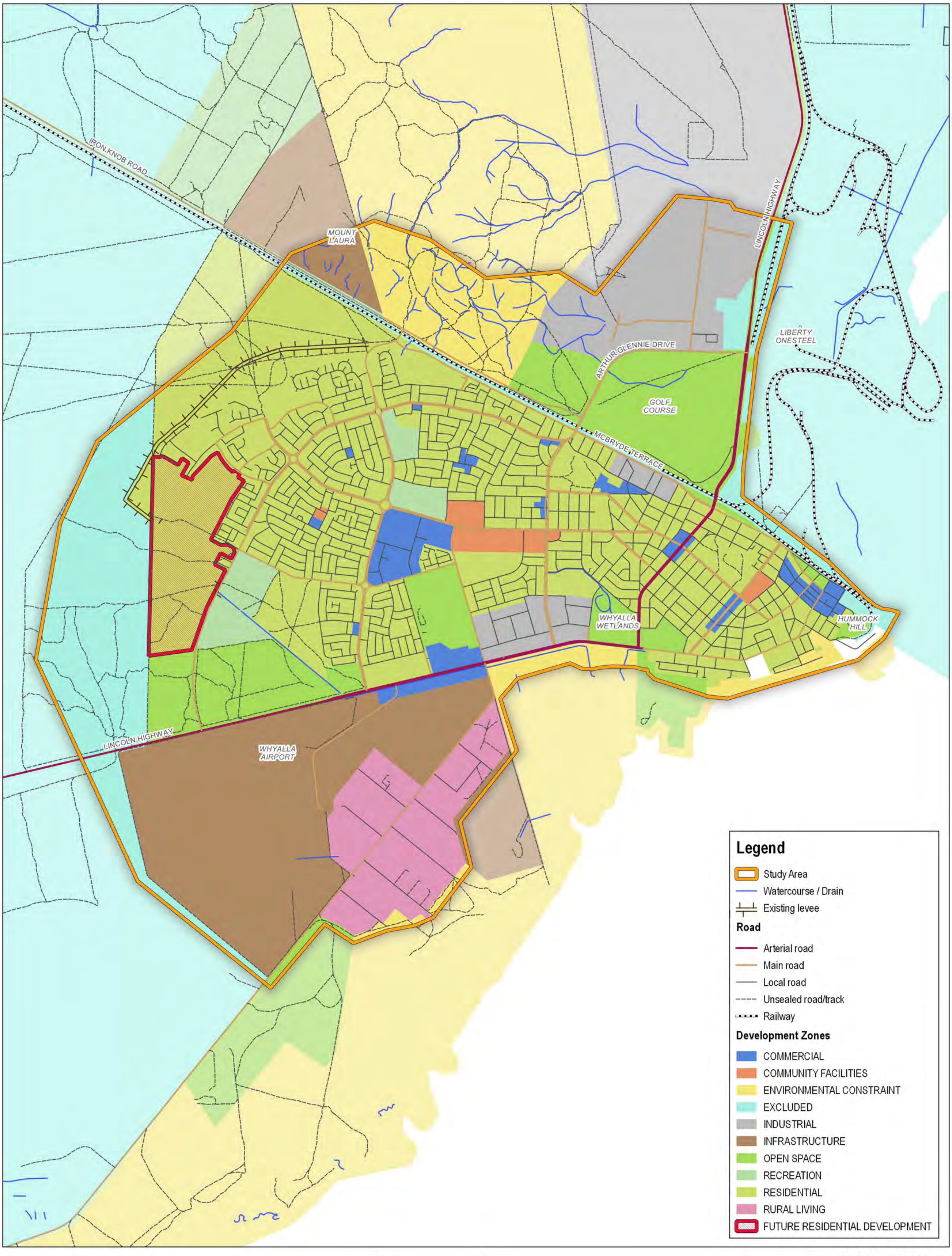
CITY OF WHYALLA

**WHYALLA STORMWATER MANAGEMENT PLAN**
**EXISTING LAND USE**

Figure 2.6

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CITY OF WHYALLA

**WHYALLA STORMWATER MANAGEMENT PLAN**
**DEVELOPMENT ZONING**

Figure 2.7

## 2.3 Cause of flooding

Situated at the eastern end of the large Salt Creek catchment and to the south of the Mount Laura range, Whyalla is subject to both fluvial and pluvial flooding. Fluvial flooding, or 'riverine' flooding, is caused by floodwater leaving a defined watercourse, such as a river or creek, and inundating areas within the floodplain. Pluvial flooding, or 'stormwater' flooding, is caused by intense rainfall that creates a flood event independent of an overflowing water course. A common cause of pluvial flooding is rain falling on hillsides that are unable to absorb the water such as in urban areas where the ground is covered by roads and other hard surfaces.

Modelling was used to quantify the effects of both types of flooding.

## 2.4 Receiving waters

The Upper Spencer Gulf Marine Park, which is located within the Northern Spencer Gulf, is considered to be the receiving waters for discharges from the Whyalla SMP study area. The area contains large areas of seagrass meadows, mangrove forests, mudflats and salt marshes that support a wide range of animals and plants. It is an important nursery and feeding area for many fish, molluscs and crustaceans, including commercially and recreationally important species (EPA 2018).

The Marine Park includes a number of sanctuary zones that provide habitat for species of international importance. Every year between the months of May and August, thousands of Giant Australian Cuttlefish congregate on the rocky coastline between Fitzgerald Bay and False Bay, north of Whyalla, to spawn. North of the city the coastline also includes the heritage listed Fitzgerald Bay Stranded Shingle Ridge. The shingles, which were deposited almost 12,000 years ago are largely undisturbed and extremely rare, with only two other comparable examples in the world.

Stormwater from the study area does not directly discharge into these areas of significance and it is considered unlikely that discharge from the SMP study area would impact directly on the marine environment at these locations.

Whilst Whyalla's stormwater is not discharged directly to the gulf, a significant proportion of the city's stormwater is directed through the intertidal samphire flats, which act as a buffer to filter the stormwater before discharging into the marine environment. The presence of weeds, soil disturbance and water erosion within the samphire flat area, primarily at the airport drain outfall, indicate that the current stormwater discharge points have had an impact on these intertidal areas. The ability of this area to continue to be the interface and filter the stormwater relies on the health and stability of the ecosystem. However, the capacity of the samphire flat area to provide these functions has not yet been determined. The Eyre Peninsula Natural Resource Management Board has recommended that investigations be carried out to determine the impact of current and future stormwater (including proposed infrastructure) on the samphire flat area prior to implementing any new stormwater management measures that may affect this area.

The Eyre Peninsula Natural Resources Management Region's Strategic Plan (EPNRM 2017) identifies coastal and marine degradation as a key challenge to be addressed within the Spencer Gulf sub-region. The plan identifies an opportunity to "Partner with Local Government to undertake urban stormwater planning and implementation focussing on water sensitive urban design that reduces water quality impacts."

The Eyre Peninsula Coastal Action Plan, which aimed to develop management and conservation priorities, concluded that the waters in the immediate vicinity of Whyalla have a 'medium to high' threat level. The identified threats include weed infestation, dune erosion, marine debris and industrial expansion.

## 2.5 Existing infrastructure

### 2.5.1 City centre and residential area

The urbanised area of the city relies on extensive underground stormwater drainage systems. The vast majority of the systems are relatively long and drain to an open channel on the southern boundary of the city. In total there is 49 km of underground drains of various sizes.

There are eleven stormwater basins spread across the study area which are used for a variety of purposes.

Three small basins located in recently redeveloped residential areas are used to attenuate runoff from the developed areas. This helps to mitigate the increased runoff caused by a higher density of development.

Two basins located on the northern side of Civic Park are used to capture runoff that would otherwise collect in McLennan Avenue. These basins are relatively shallow in nature and are only estimated to provide flood relief in flood events more frequent than the 10 year ARI event.

Two basins (one near the intersection of Racecourse Road and Cartledge Avenue, the other within grounds of the Whyalla Golf & Bowling Club) are used for stormwater harvesting. The Cartledge Avenue basin is used to store stormwater diverted from the Racecourse Road drain. This stormwater is later used by Council to water street trees. The golf club basin is used to passively collect runoff from north sloping city catchments. The captured water is used to supplement the golf club's use of recycled water. Neither basin provides much flood relief due to their size and location within the respective catchments.

A 4 km levee exists around the north western perimeter of the urban area of Whyalla Stuart and Whyalla Jenkins. The northern levee acts to exclude water from the catchments north-west of the city. The levee works well to prevent flooding of residential area in events up to and including the 50 year ARI event. However, due to a few low spots caused by vehicles traversing the levee, the levee is overtopped in six locations during the 100 year ARI event. The largest low spot is overtopped even in the 10 year ARI event, however, the area downstream of the breach has yet to be developed and therefore no residential properties are currently impacted. Around the north-eastern perimeter of the city the Iron Knob Road and Iron Knob – Whyalla railway act as barriers to runoff from the Mount Laura catchment. Small culverts beneath the road and railway convey water under the respective embankments. Due to the size of these culverts runoff is detained behind the embankments. As such the road and rail embankments act as pseudo-detention basins for the catchments of Mount Laura that drain south towards the city. Drainage infrastructure within the City catchment is shown in Figure 2.8.

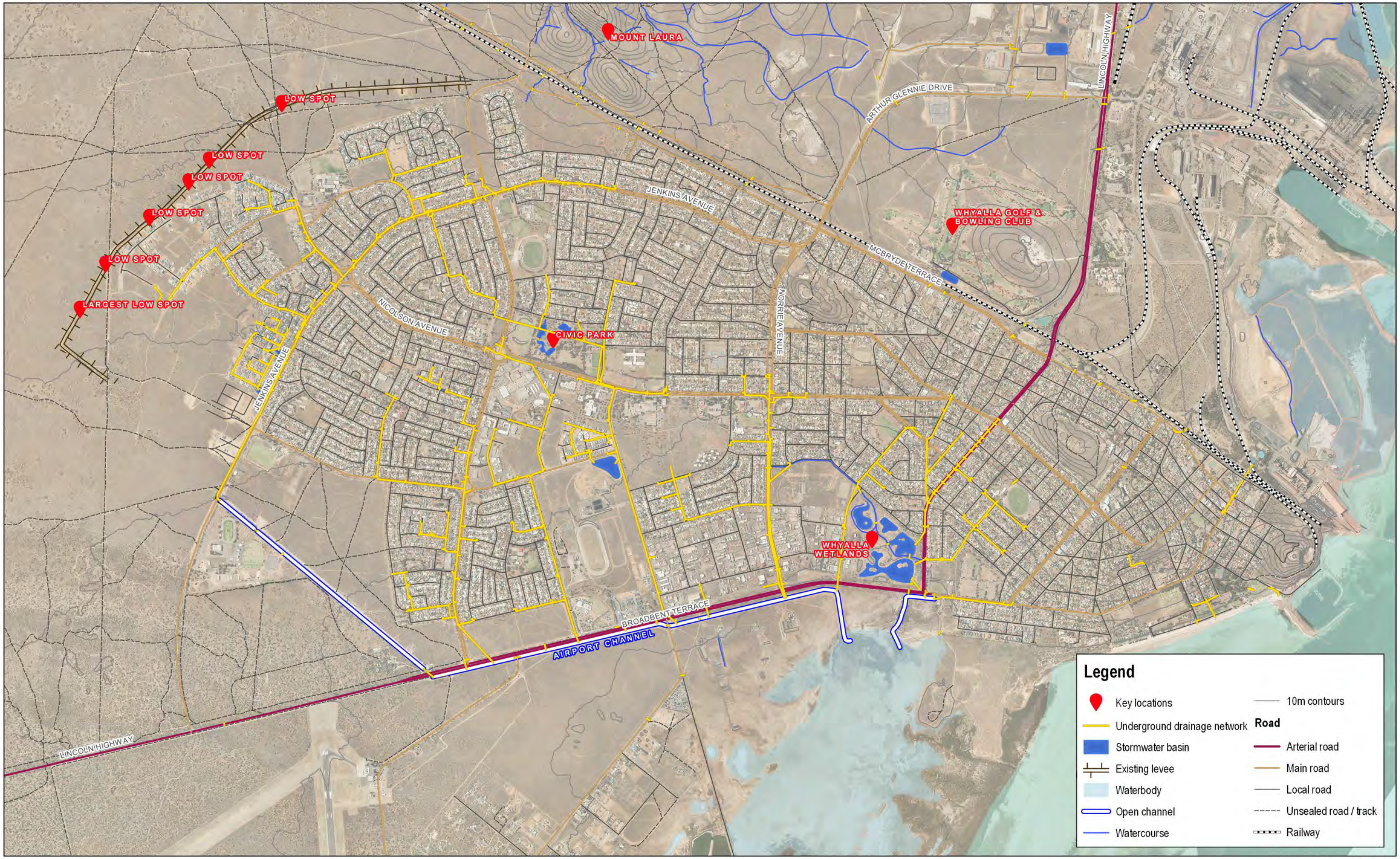
### 2.5.2 Industrial area

The industrial estate north of Whyalla CBD is serviced by large roadside channels and culverts with an estimated 20-year ARI capacity.

A single basin within the estate captures water for reuse by industry. The basin has a limited capacity for flood control due to a small storage volume; the basin overtops in the 10 year ARI event. Upstream contour drains direct runoff from the Mount Laura foothills to increase yield from small rainfall events.

A set of levees on the north and western sides of the estate appear in the DEM and would seemingly direct runoff from the large Mount Laura catchments around the allotments of the estate. However, it is clear from newer aerial imagery that some of these levees may no longer exist (other infrastructure was built in the same footprint) and it is unclear if the levees have been reinstated on a new alignment.

Runoff from the estate, if not captured by basins, is directed east beneath the Lincoln Highway via culverts. These culverts are estimated to have a 10 year ARI standard. Existing drainage infrastructure for the industrial area is shown in Figure 2.9.

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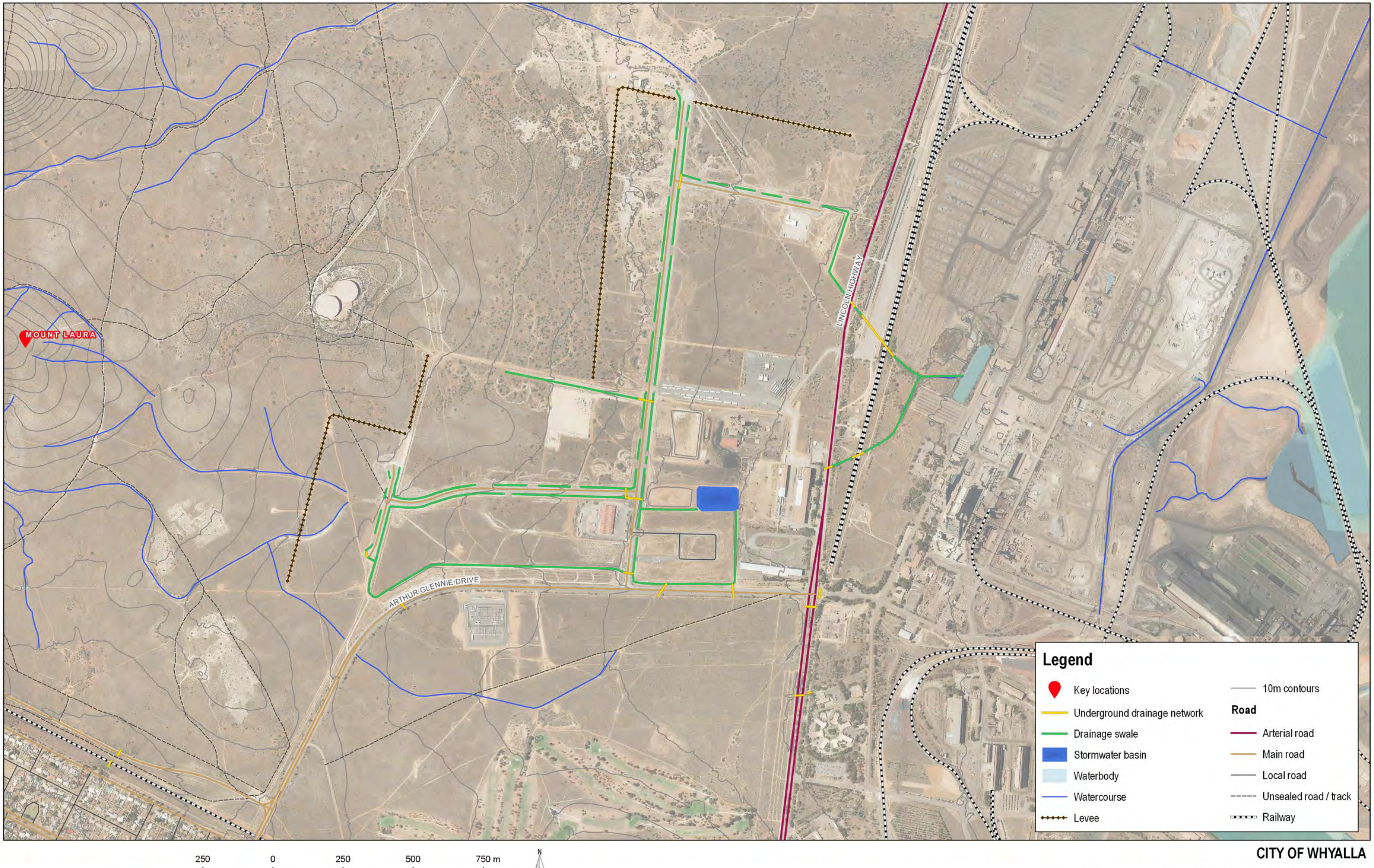
Filename: 20160064GQ040A
Revision: Rev B
Date: 2019-02-06
Drawn: DB

Data Acknowledgement:
Aerial photography supplied by Council, 2013
Base data from DataSA

CITY OF WHYALLA

**WHYALLA STORMWATER MANAGEMENT PLAN**
**CITY CATCHMENT DRAINAGE INFRASTRUCTURE**

Figure 2.8

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CITY OF WHYALLA

**WHYALLA STORMWATER MANAGEMENT PLAN**
**INDUSTRIAL CATCHMENT DRAINAGE INFRASTRUCTURE**

Figure 2.9

### 2.5.3 Rural living area (airport)

Drainage infrastructure within the airport catchment is limited, including only a few isolated and relatively small culverts beneath roads.

## 2.6 Climate

The climate of the Whyalla region is dominated by the Sub-tropical High-Pressure System. This pattern is varied in summer by monsoonal lows, which can bring heavy rain. These summer, tropical lows are responsible for the heaviest rainfall events in the region. In winter, frontal depressions from the Southern Ocean bring showers (DEHAA 1998).

Located within the arid zone of South Australia, Whyalla receives an average of just 267 mm rainfall per year. Mean monthly rainfall for Whyalla is shown in Figure 2.10. There are on average of 42 rain days (>1 mm) per year. The remaining days are, on average, clear and sunny, contributing to high evaporation rates. Figure 2.10 also displays mean daily evaporation for each month. Rainfall is in deficit for every month of the year. The mean annual evaporation is in the order of 2500 mm/year.

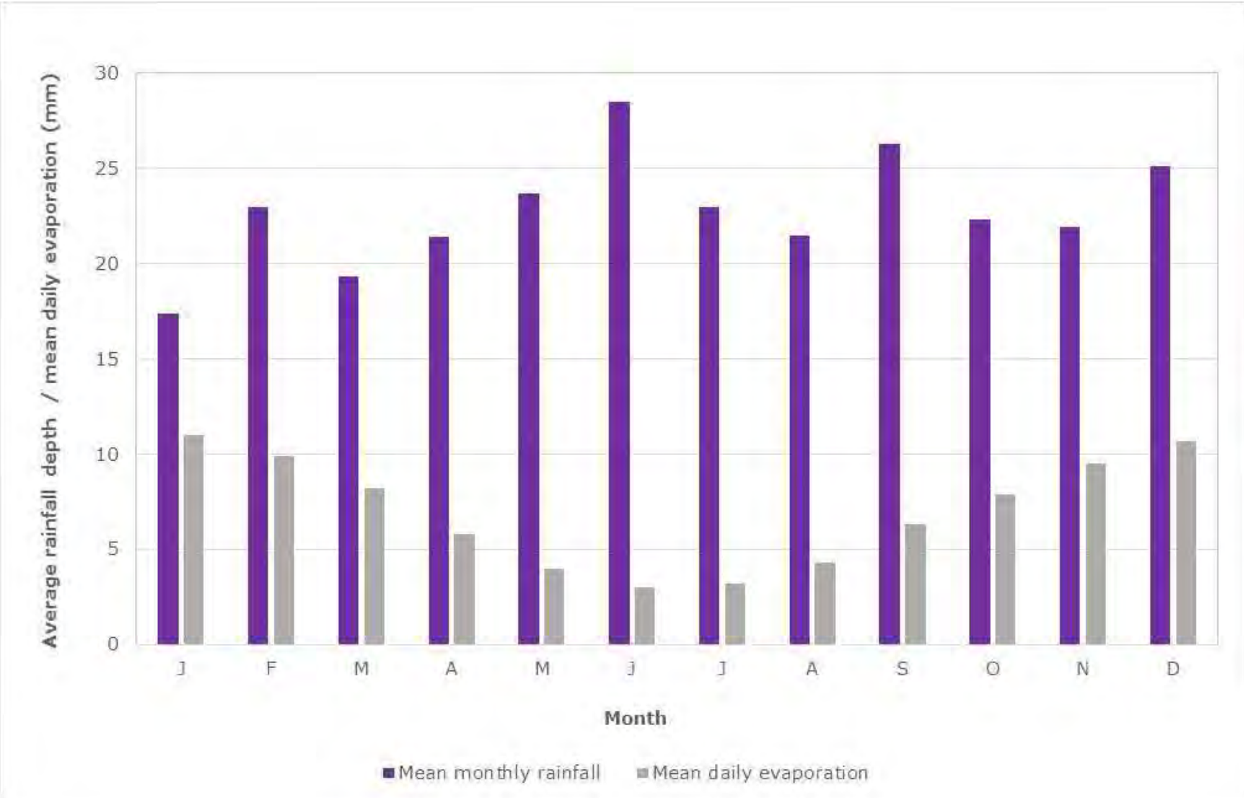



Figure 2.10 Mean monthly rainfall and mean daily evaporation for Whyalla (site number: 018120)

### 2.6.1 Climate change

The latest available science indicates that the climate is changing. CSIRO and the Bureau of Meteorology preface the latest regional climate change summaries with the following statement:

*"Australia's changing climate represents a significant challenge to individuals, communities, governments, businesses 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."*

Australian Rainfall and Runoff (ARR, 2016) states "*human induced climate change has the potential to alter the prevalence and severity of rainfall extremes, storm surge and floods*".

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 Whyalla

Climate Change in Australia (CSIRO and BoM) provides regional summaries of projected climate change for Australia. Whyalla is within the Southern and South-Western Flatlands East (SSWFE) cluster. The key climate change projections relevant to the design of stormwater systems for the SSWFE cluster 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.
- Increased intensity of extreme rainfall events is projected, with high confidence.
- Mean sea level will continue to rise and height of extreme sea-level events will also increase (very high confidence).

With respect to the management of stormwater in Whyalla, the projected changes in climate represent the following risks:

- 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.

The projected changes in maximum rainfall intensities (ARR 2016) and sea level rise (CCIA 2017) for Whyalla are summarised in Table 2.1. RCP 4.5 represents a low emissions future and RCP 8.5 represents a high emissions scenario.

Previous experience has indicated that the relationship between the increase in rainfall intensity and the increase in peak flows is not linear, with increases in peak flows generally greater than the increase in rainfall intensity.

| Year | RCP 4.5 | | RCP 8.5 | |
|---|---|---|---|---|
| | Rainfall intensity | Sea level [1] | Rainfall intensity | Sea level [1] |
| 2030 | 3.9% | 0.12 (0.07 to 0.16) | 4.3% | 0.12 (0.08 to 0.17) |
| 2060 | 6.6% | Not reported | 10.0% | Not reported |
| 2090 | 8.1% | 0.45 (0.28 to 0.63) | 17.0% | 0.59 (0.39 to 0.82) |

1 Sea level rise is reported as median (10th to 90th percentile)

### 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.

## 2.7 Known issues

Information has been provided by Council to highlight where existing stormwater flooding and drainage issues have occurred in the past. The following sources of information are referenced and discussed further below:

- Anecdotal information provided in AWE (2009)
- Council GIS database of flood complaints (provided 2016)
- Other information provided by Council throughout the study.

### Information referenced in AWE (2009)

AWE's 2009 Flood Risk Assessment report contains a brief description of 'Stormwater Drainage Deficiencies' based on available anecdotal information. The report highlights 16 areas within the Whyalla urban area and its immediate surrounds where "…drainage is inadequate and has failed to prevent flooding in the past" (AWE, 2009). The areas are highlighted on Figure 2.11.

AWE's report summarised the primary flooding areas as:

- Along Nicolson Avenue and its intersection with McDouall Stuart Avenue and Norrie Avenue, reportedly due to large flows originating from catchments to the north
- North of the Lincoln Highway near the Fauna and Reptile Park
- South of the Lincoln Highway, in and around the airport
- Lincoln Highway, west of the airport, with flows originating from the large rural (external) catchments.

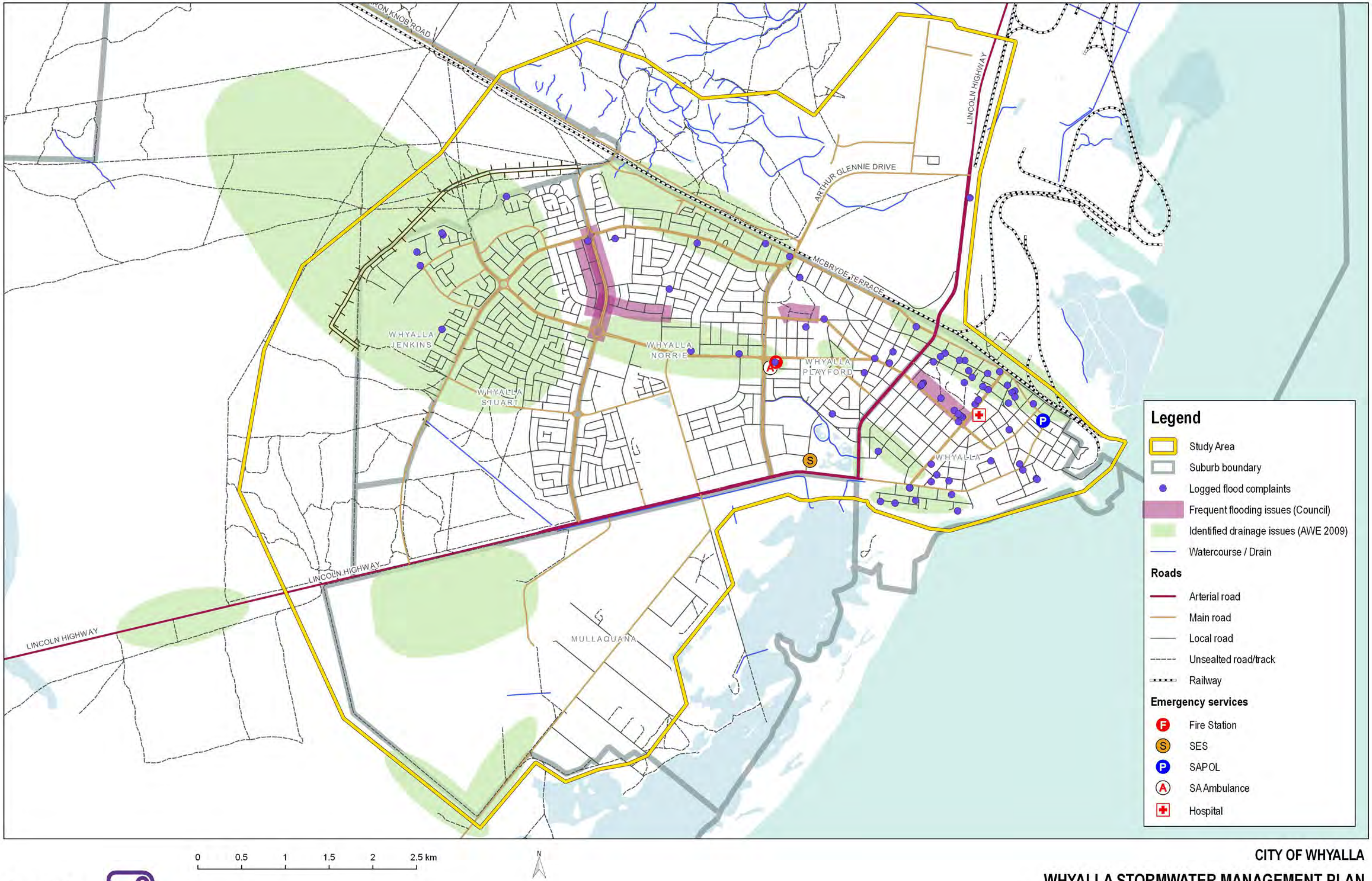
Whilst not specifically discussed, the areas also included two areas adjacent McBryde Terrace / Iron Knob Road newer development areas to the north-east of Jenkins Avenue (including Ocean Eyre development) and smaller pockets around Essington Lewis Avenue.

### Council GIS database

At the commencement of the study, Council provided a GIS database of flooding reports. The location of these complaints is shown on Figure 2.11.

A large number of the recorded flood complaints are clustered in the eastern part of the city where stormwater reportedly runs off the steeper terrain and floods rear of allotment laneways and properties. Flooding in these areas is exacerbated by the limited stormwater drainage infrastructure.

According to the comments in the database, a number of the recorded complaints also relate to debris and washouts due to heavy rainfall, rather than property flooding.

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Data Acknowledgement:
Aerial photography supplied by Council, 2013
Base data from DataSA
Flood data provided by Council and extracted from AWE (2009)

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CITY OF WHYALLA

**WHYALLA STORMWATER MANAGEMENT PLAN**
**RECORDED FLOODING ISSUES AND COMPLAINTS**

Figure 2.11

### Other Council information

In addition to the GIS database of flood reports provided by Council, a number of other 'flooding hotspots' were identified by Council throughout the study period. These are also highlighted on Figure 2.11. In summary these areas are:

- McDouall Stuart Avenue and Brook Street
- McLennan Avenue (see Figure 2.12)
- Rear laneways bordering steeper terrain in the eastern area of the city (properties fronting Elliot Street and Gowrie Avenue).

Figure 2.12 Flooding in McLennan Avenue in September 2016 (Whyalla News 30 September 2016)

## 2.8 Historical flood events

The Flood Risk Assessment undertaken in 2009 (AWE 2009) provided a summary of historical flood events within Whyalla, based upon information contained within the Bureau of Meteorology publication Floods in South Australia 1836 – 2005 (McCarthy, Rogers and Casperson ed. 2006). Based on the information presented, it was found that 23 individual flood events occurred within the region between 1836-2005.

Analysis of rainfall data by AWE (2009) at the Whyalla Norrie rainfall station (in operation 1906-2001) estimated a total of 23 events with a recurrence interval greater than or equal to the 5-year storm. Eleven of these events corresponded to reported floods in McCarthy, Rogers and Casperson ed. (2006). The two largest rainfall events were recorded included 1946, which was estimated to be greater than 100-year ARI and February 1979, estimated at greater than 50-year ARI. The March 1921 event corresponded to a 20-year ARI storm and two 10-year ARI storms caused flooding in January and February 1974. The remaining six storms were estimated at greater than 5-year ARI. Based on the rainfall information available, the further 12 flood events reported in McCarthy, Rogers and Casperson ed. (2006) were either less than 5-year ARI or localised storms not recorded at the rainfall gauge.

This information suggests that the stormwater drainage within the Whyalla area is certainly limited in some areas, with over half of the recorded flood events to 2005 attributable to storms of magnitude less than the design 5 year ARI event (based on daily duration) (AWE 2009).

An internet search for reported flooding within Whyalla since 2005 was conducted, with reported occurrences compared to daily rainfall records for the Whyalla Aero rainfall station (BOM #18120). Around seven reported flooding events were found to feature in news items or blog sites in 2010, 2011, 2012, 2014, 2015 and 2016 (two storms). This indicates that stormwater flooding of some significance occurs in most years, almost exclusively in late spring and summer.

In addition to reported flooding, inspection of daily rainfall records at the Whyalla Aero (018120) and Mullaquana (018058) sites indicated a further six occurrences of daily rainfall totals in the order of 50 mm or greater.

A summary of historical flood events referenced in news articles found online is provided in Table 2.1.

Table 2.1 Summary of historical flood events and rainfall events of significance

| Date | Recorded rainfall | News source |
|---|---|---|
| 3-4 September 2010(?) | 25+17.6 mm | http://blueskyscotland.blogspot.com/2010/10/whyallasouth-australia.html |
| 17-18 December 2011 | 49 mm | http://tempo11.blogspot.com/2011/12/great-storm-of-2011.html<br>https://www.youtube.com/watch?v=pWwHox_cYfA |
| 1 December 2012 | 12 mm | https://www.adelaidenow.com.au/news/south-australia/thousands-left-without-power-across-with-whyalla-hardest-hit-by-wild-storms/news-story/da0fd430c62ab3cfd5337b689db10287 |
| 14 February 2014 | (7.6+97.6 mm)* | https://www.whyallanewsonline.com.au/story/2089157/rain-washes-away-south-australias-hot-spell/ |
| 4-5 November 2015 | 53+30 mm | https://www.youtube.com/watch?v=ANW8Mr70esE |
| 29/30 September 2016 | 19.4 mm | https://www.whyallanewsonline.com.au/story/4199189/storm-strikes-whyalla-photos/ |
| 28-29 December 2016 | 23+12 mm | https://www.adelaidenow.com.au/news/south-australia/south-australias-summer-storm-continues-damaging-crops-flooding-towns-cutting-power-to-homes/news-story/9f3abc98c3544d75d0826ec91aa2807f |
| No recorded news item found: | | |
| 19-20 January 2007 | 36+55.8 mm | |
| 20 March 2007 | 50 mm | |
| 7-8 December 2010 | 11.4+50 mm | |
| 5 February 2011 | 55.2 mm | |
| 9-10 January 2015 | 48+12.2 mm | |
| 18-19 June 2016 | (99+21.4 mm)* | |

* rainfall recorded at Mullaquana site only. Data indicates fault at Whyalla Aero site

# 3 SMP objectives

## 3.1 Strategic plans, policies and documents

Objectives guiding the development of this SMP have been developed 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 guidelines
- State WSUD Guidelines
- Eyre Peninsula Natural Resources Management Region Strategic Plan
- Council Development Plan
- Council Strategic Plan
- Council Asset Management Plan

The sections of these plans of specific relevance to this SMP are discussed below.

### 3.1.1 State WSUD Guidelines

The State Government document "Water sensitive urban design – creating more liveable and water sensitive cities in South Australia" 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.

Objectives 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 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<br>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:<br>• Total suspended solids by 80%<br>• Total phosphorus by 60%<br>• Total nitrogen by 45% |

| Performance principle | Performance principle intent | State-wide performance target |
|---|---|---|
| | | • Litter/gross pollutants by 90% |
| Runoff quantity<br>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.<br>• Help to manage flood risk, by limiting the rate of runoff to downstream areas to appropriate levels. | For flood management:<br>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:<br>• the capacity of the existing drainage system is not exceeded<br>• 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<br>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 contribute to the wellbeing of South Australians. | 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. |

### 3.1.2 Eyre Peninsula Natural Resources Management Region Strategic Plan

The Strategic Plan for the Eyre Peninsula Natural Resources Management Region sets the ten-year direction for natural resources management (NRM) for the Region.

At an overarching level, the strategic plan aims to progress the objectives of the NRM Act including supporting ecologically sustainable development of the Region. A sub-regional approach was applied to understand the subtleties of the region, with Whyalla located in the Spencer sub-region.

The plan sets out the following goals:

1. Sustainable management and use of land, sea and water
2. Healthy and resilient land, sea and water ecosystems
3. Active participation in natural resource management.

Of specific relevance to the Whyalla SMP is sub-goal 2D: *Healthy and resilient land, sea and water ecosystems by supporting management of land, sea and water to maintain or improve condition*.

Within the Spencer sub-region, coastal and marine degradation was identified as a key challenge, with a corresponding opportunity identified as:

"*D7 Partner with Local Government to undertake urban stormwater planning and implementation focussing on water sensitive urban design that reduces water quality impacts*."

### 3.1.3 Whyalla City Council Strategic Plan 2017-2022

The Whyalla Strategic Plan 2017-2022 identifies the goals, visions, values and outcomes sought for the city over a five-year period. A number of objectives are identified according to four key themes; our people, our places, our economy and our image. Of relevance to this stormwater management plan's development are the objectives and strategies summarised in Table 3.2.

Table 3.2 Summary of objectives and strategies relevant to this SMP

| Theme | What success will look like | Objectives | Strategies | Relevance to SMP |
|---|---|---|---|---|
| Our Places | • Our parks, gardens and open spaces are well used and reflect the needs of our community<br>• Community assets are being renewed and replaced to maintain service levels<br>• Sustainability and environmental factors are reflected in our programs and decision-making processes. | Objective 2.2<br>*To protect our natural environment, minimise our ecological footprint and the impact of environmental issues on the city.* | 2.2.2<br>Promote environmental sustainability and aim to:<br>• Reduce carbon emissions as an organisation and across the city<br>• Reduce waste levels into landfill<br>• Increase the use of recycled water including storm water harvesting. | The SMP will seek to identify opportunities for stormwater harvesting and reuse, consistent with this strategic objective. |
| | | Objective 2.3<br>*To ensure that Whyalla is prepared for the physical changes that climate change may bring.* | 2.3.2<br>Effectively communicate and encourage action that reduces the rate and extent of the impacts of climate change, to support the council's climate change adaptation plan. | The SMP will identify the risk of climate change to the level of service provided by existing stormwater drainage infrastructure and provide recommendations for future management of stormwater reflective of future climatic conditions |

| Theme | What success will look like | Objectives | Strategies | Relevance to SMP |
|---|---|---|---|---|
| Our Image | • Community confidence<br>• National media coverage<br>• Increased visitor numbers. | Objective 4.2<br>*To create an attractive city for the community, visitors and potential investors.* | 4.2. 6<br>Develop landscape design plan for Civic Park/Schulz Reserve, Nicolson Avenue frontage and McDouall Stuart Avenue intersection. | Plans to create a landscape masterplan for key reserve areas, including Civic Park and Schulz Reserve, creates an opportunity to embed stormwater management infrastructure into these masterplans. |

### 3.1.4 Whyalla Council Development Plan

The Whyalla Development Plan (Consolidated 14 June 2017) contains several provisions to manage stormwater within new developments. Sections of relevance to this SMP are highlighted below.

#### General Section *Hazards*

##### Principles of Development Control – Flooding

6. Where located within the floodplain of a 1-in-100 year Average Recurrence Interval (ARI) flood event as shown on Overlay Maps – Development Constraints (except where satisfactorily protected by other approved flood mitigation works):
   - (a) the finished floor levels for dwellings, buildings for the keeping of animals, industrial and commercial premises, community facilities buildings, and the like, septic tank vent pipes and gully traps should be finished a minimum of 300 millimetres above the height of a 1-in-100 year ARI flood event
   - (b) the finished floor level for outbuildings should be a minimum 150 millimetres above the height a 1-in-100 year ARI flood event
   - (f) development should not occur where access by emergency vehicles or essential utility services vehicles would be prevented by a 1-in-100 year ARI flood event
   - (g) habitable development, or premises where workers are regularly present, should have a safe and effective evacuation route to an area located outside of the floodplain
7. Except where satisfactorily protected by approved flood mitigation works, a building proposed on an allotment that is partly or wholly within the floodplain shown on Overlay Maps – Development Constraints, should occur on that portion of the allotment with the lowest flood risk.

#### General Section *Natural Resources*

##### Principles of Development Control – Water Sensitive Design

7. Development should be sited and designed to:
   - (a) capture and re-use stormwater, where practical
   - (b) minimise surface water runoff
   - (c) prevent soil erosion and water pollution
   - (d) protect and enhance natural water flows

(e) protect water quality by providing adequate separation distances from watercourses and other water bodies

(f) not contribute to an increase in salinity levels

(g) avoid the water logging of soil or the release of toxic elements

(h) maintain natural hydrological systems and not adversely affect:

(i) the quantity and quality of groundwater

(ii) the depth and directional flow of groundwater

(iii) the quality and function of natural springs.

8 Water discharged from a development site should:

(a) be of a physical, chemical and biological condition equivalent to or better than its pre-developed state

(b) not exceed the rate of discharge from the site as it existed in pre-development conditions.

9 Development should include stormwater management systems to protect it from damage during a minimum of a 1-in-100 year average return interval flood.

10 Development should have adequate provision to control any stormwater over-flow runoff from the site and should be sited and designed to improve the quality of stormwater and minimise pollutant transfer to receiving waters.

11 Development should include stormwater management systems to mitigate peak flows and manage the rate and duration of stormwater discharges from the site to ensure the carrying capacities of downstream systems are not overloaded.

12 Development should include stormwater management systems to minimise the discharge of sediment, suspended solids, organic matter, nutrients, bacteria, litter and other contaminants to the stormwater system.

13 Stormwater management systems should preserve natural drainage systems, including the associated environmental flows.

14 Stormwater management systems should:

(a) maximise the potential for stormwater harvesting and re-use, either on-site or as close as practicable to the source

(b) utilise, but not be limited to, one or more of the following harvesting methods:

(i) the collection of roof water in tanks

(ii) the discharge to open space, landscaping or garden areas, including strips adjacent to car parks

(iii) the incorporation of detention and retention facilities

(iv) aquifer recharge.

15 Where it is not practicable to detain or dispose of stormwater on site, only clean stormwater runoff should enter the public stormwater drainage system.

16 Artificial wetland systems, including detention and retention basins, should be sited and designed to:

(a) ensure public health and safety is protected

(b) minimise potential public health risks arising from the breeding of mosquitoes.

### 3.1.5 Whyalla Asset Management Strategy 2018-2027

The Whyalla Asset Management Strategy notes that:

"*We do not have enough funding to provide all services at the desired service levels or provide new services. Works that cannot be provided under present funding levels are*:

- *Extension of stormwater network for mitigation purposes"*

It further notes that "*A Stormwater Management Plan is being developed to seek additional funding for the development of additional stormwater infrastructure through the State Government's Stormwater Management Authority."*

It is expected that the information contained within this plan will form an important input to future management of stormwater assets within the City.

## 3.2 Stormwater management goals

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 where relevant
- Extent of beneficial use of stormwater
- 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.

In alignment with these requirements, the following objectives have been identified and addressed in this SMP document.

#### Objective 1: *Provide an acceptable level of protection from flooding to the community and both private and public assets*

Stormwater drainage and flood protection infrastructure within the City generally comprises:

- Traditional stormwater pit and underground stormwater pipe system within the built-up areas of the city.
- Open channel drains, including the airport channel and swales within the industrial area.
- Overland flows and shallow sheet flows within undeveloped areas and built up areas predominantly within the eastern portion of the city. In these areas there is little formal drainage infrastructure and the depth and direction of flows is governed by landform and built features such as roads and kerbs.

- Flood protection levee around north-western city limits.

Above ground stormwater detention storages are limited.

The goals set for flood protection, outlined below, have been developed cognisant of the highly developed state of the city area, and limitations this poses on achieving the 'ideal' standard of protection in all areas. Similarly, the presence of shallow rock also limits what can be feasibly constructed in some areas.

Goals:

1. Improve the levels of service of the existing stormwater drainage infrastructure, where practicable, to reduce the risk of flooding.

   Within existing developed areas:

   a Where practical and economically viable, protect existing development from inundation in a 1% AEP event. A lower standard of protection may be adopted where physical and economic constraints limit the ability to achieve 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. Conversely, where no overflow route is possible, a higher design standard may be adopted.

   Within areas of new development:

   a Protect new development from above floor inundation from all events up to and including the 1% AEP event.

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

2. Protect the city against flood risk from external catchments up to and including the 1% AEP event.

### Objective 2: *Improve water quality to meet the requirements for protection of the receiving environment*

All stormwater generated within the study area discharges into the Upper Spencer Gulf Marine Park, which is located within the Northern Spencer Gulf. The area contains large areas of seagrass meadows, mangrove forests, mudflats and salt marshes that support a wide range of animals and plants. The Marine Park includes a number of sanctuary zones that provide habitat for species of international importance. Whilst stormwater does not discharge directly into these sanctuaries, the Eyre Peninsula Natural Resources Management Region Strategic Plan identifies the need to "Partner with Local Government to undertake urban stormwater planning and implementation focussing on water sensitive urban design that reduces water quality impacts."

Goals for stormwater quality improvement have been developed cognisant of the objectives of the Council Development Plan and Eyre Peninsula NRM Region Strategic Plan, and are outlined below.

Goals:

1. Improve the quality of stormwater runoff discharging into the Spencer Gulf to achieve the following targets:

   Suspended solids 80%

   Total Phosphorus 60%

   Total Nitrogen 45%

Gross Pollutants 90%

2. Identify opportunities to achieve additional water quality improvement within proposed flood management infrastructure.

### Objective 3: *Maximise the economic use of stormwater runoff for beneficial purposes*

Council have an existing recycled water scheme, supplied by SA Water's reclaimed water scheme. The Council distribution network supplies water to a number of reserves, schools, medians and roundabouts around the city for irrigation purposes. Whilst this scheme represents a reliable non-potable supply source, it is limited in quantity. Additionally, a limited amount of stormwater is collected in a Council basin which is used for local street tree watering, via a Council water truck. Council have expressed an interest in exploring opportunities for additional reuse of stormwater to augment the scheme already in place. This is an objective within Council's Strategic Plan.

Goals for stormwater reuse are outlined below.

Goals:

1. Maximise harvesting and reuse of stormwater runoff within the city, where economically feasible.

2. Seek opportunities to augment the existing reclaimed water reuse scheme with harvested stormwater.

### Objective 4: *Manage stormwater assets in a sustainable manner and provide adequate maintenance such that they can operate as originally intended.*

Stormwater drainage is a significant financial asset for Council. Council's Asset Management Plan states that "Most of the Council's Assets were constructed by the previous Commission, by developers or from government grants, often provided and accepted without consideration of ongoing operations, maintenance and replacement needs. Many of these assets are approaching the later years of their life and require replacement. Services from the assets are decreasing and maintenance costs are increasing. Our present funding levels are insufficient to continue to provide existing services at current levels in the medium term."

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. Rigorous asset management will allow for future planning to determine the timeline for replacement of assets.

Whilst Council are seeking to embrace water sensitive urban design, an increased implementation of water sensitive urban design necessitates a higher degree of maintenance, compared to traditional pits and pipes, to ensure that it is able to operate as originally intended.

Based on the above, the following general objectives have been set:

Goals:

- Consider maintenance requirements in the development of new or upgraded stormwater infrastructure. Seek low maintenance solutions.
- Maintain up to date information on the age and condition of existing drainage infrastructure by undertaking CCTV inspections of drains
- Plan for strategic replacement of infrastructure nearing the end of its life.
- Develop solutions with consideration of funding opportunities, recognising Council's limited ability to fund significant new works.

### Objective 5: *Achieve desirable planning outcomes associated with new development, open space, recreation and amenity*

Council's current Development Plan includes a number of development controls in relation to stormwater management. This includes development within flood prone areas, as identified on the Overlay Maps – Development Constraints, floor level controls, protection against major stormwater events, water quality management and peak flow management.

A number of the development controls are not quantitative and would benefit from being more specific to drive more consistent stormwater management if and when development expands within the City.

Goals:

1. Specify controls for development within flood prone areas for inclusion in Council development plan. Controls may include:
   - Floor level heights
   - Limit of development controls
2. Identify target stormwater drainage standards for future development for inclusion in the Council development plan.
3. Drive WSUD within new development to achieve target water quality improvement, as outlined within the state WSUD guidelines.

The outcomes of this SMP will enable the Council development plan to be updated with more specific and up to date information, including the flood overlays.

### Objective 6: *Manage stormwater runoff in a manner that protects and enhances biodiversity and the natural environment*

Council's Strategic Plan aims to create "…parks, gardens and open spaces [that] are well used and reflect the needs of our community".

More specifically, Council's desire to masterplan the landscaping of some key reserve areas, including Civic Park and Schulz Reserve, as outlined in the strategic plan provides an opportunity to build water sensitive urban design elements, including catchment flood mitigation, into the masterplan concept.

Creative, well planned and well executed WSUD has the potential to enhance public amenity, whilst providing a range of community benefits.

The following goals for enhanced biodiversity and the natural environment have been set.

Goals:

1. Incorporate water sensitive urban design elements into stormwater infrastructure upgrades, where possible.
2. Where new stormwater management facilities are constructed within new developments or existing open space, maximise the community use and benefit derived from the facility and ensure that opportunities for biodiversity, amenity and environmental enhancement are realised.
3. When planning upgrades to existing public reserve areas, consider opportunities for improving stormwater management and incorporation of water sensitive urban design elements.
4. When considering upgrade to existing or new drainage channels, aim to minimise removal of trees and remnant vegetation, and encourage revegetation with appropriate species.

# 4 Flooding

## 4.1 Background/introduction to modelling

One of the primary objectives of the Stormwater Management Plan (SMP) is the identification of existing flooding problems. To achieve this objective, extensive hydrologic and hydraulic modelling of the study area and surrounding catchments was undertaken.

The primary purpose of the modelling was to define the extent and magnitude of flooding during events of differing average recurrence interval (ARI) and to identify areas of significant inundation relevant to the preparation of the SMP. The risk to public safety, otherwise known as the 'flood hazard' was also categorised for two of the rarer flood events. 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.

The modelling undertaken for the SMP involved the following:

- Hydrological modelling of local and regional catchments.
- Obtaining details of the hydraulic structures, including underground drainage systems and flood detention basins.
- Preparing a 1D model of the drainage network to assess underground drain capacity.
- Preparing a combined linked 1D−2D hydrodynamic flood model to assess the extent of surface flooding within the study area for the predicted levels of development.
- Analysing the resultant flooding for the following storm events:
  - 5 year ARI storm event
  - 20 year ARI storm event
  - 100 year ARI storm event
  - 500 year ARI storm event
  - Probable Maximum Precipitation (PMP) storm event
- Altering the 2D flood models to include proposed mitigation measures.

As described in Section 2.1 the study area was separated into three distinct zones for the purposes of modelling the impacts of flooding. Each zone (City, Industrial, or Airport) has been modelled separately, and consequently the approach to modelling for each is slightly different. A full description of the modelling is provided in the Hydrologic and Hydraulic Modelling report (Reference 20160064R003A), however, a short description is provided here.

The determination of flood extents is a two-step process. Firstly, an estimation of catchment runoff is prepared based on catchment properties (e.g. land cover and soil type) and rainfall statistics (e.g. how frequently does intense heavy rain occur?); this is known as the hydrologic modelling. The outputs from the hydrologic modelling are then used as inputs to the hydraulic modelling to determine the resultant flood extents.

Three types of hydrologic modelling were employed for this study. For the City area, it is important to model the effectiveness of the local drainage system as this can have a big impact on which areas are affected by flooding. Therefore, a detailed division of the city into sub-catchments contributing to each drainage system was required. This process was completed using data provided by Council and involved specifying sub-catchment boundaries, land cover and response times. In discussion with Council, a development scenario was determined that represents the anticipated level of development (or land cover) in the catchment over the foreseeable future. The sub-catchment properties determine how each sub-catchment responds to rainfall and generates runoff. The runoff from the hydrologic model was subsequently fed into the hydraulic model. Because the City is relatively small, the hydraulic model covers the entire city and allows for all the interactions of runoff and drainage systems to be captured.

For the Salt Creek catchment, it was impractical to model the entire catchment in 2D (due to the computational effort involved). Therefore, a different approach was required to manage the sheer size of the catchment. For this catchment a hydrologic model was used on a much larger scale to estimate not only the runoff from sub-catchments but also the accumulation of runoff as the floodwater moves down the catchment towards the study area. At a point just upstream of the study area, the accumulated runoff is transferred to the 2D hydraulic model which then determines the flood extent. This approach drastically reduces the computational effort required to determine the flood extent that results from the Salt Creek catchment.

For the industrial area a third approach to modelling was adopted due to the unique topography of the catchments involved. Unlike either the City or Salt Creek catchments, the Industrial area does not have well defined drainage flow paths, which makes it difficult to apply either of the techniques already discussed. Consequently, the hydraulic model was used to simulate rain falling directly onto the catchment. This allows the rainfall to accumulate naturally across the entire catchment and avoids the need to pre-define sub-catchment boundaries prior to hydraulic modelling.

## 4.2 Limitations of the modelling

While every care has been taken in preparation of the models and the choice of the adopted parameters, all hydrological and hydraulic modelling has an inherent level of uncertainty. This is due to a number of factors including the following:

- The accuracy and resolution of the DEM used and the interpretation of this information by the hydraulic model.
- Dynamic changes to topography due to erosion or deposition of soil during a flood event; which can lead to changes in the distribution of flow. These processes have not been included in this model.
- Uncertainty in the rainfall pattern and catchment conditions prior to a flood. Actual flood events are dependent on the antecedent moisture conditions prior to rainfall, initial detention storage levels at the beginning of rainfall runoff and the intensity and uniformity of the rainfall event itself. The floods modelled by this study are based on design storm bursts which attempt to reproduce the expected average temporal pattern of a storm burst within specified rainfall zones (see AR&R for greater explanation). As such, individual rainfall events may exhibit a differing temporal pattern than those modelled.
- Estimation of input parameters to the model (such as runoff coefficients, times of concentrations, Manning's roughness, entry and exit losses). In particular, there is considerable uncertainty surrounding the hydrologic parameters due to a general lack of guidance for arid areas across Australia.
- Quality and extent of underground drainage data from existing model. While some obvious omissions and errors have been corrected, the modelling of the underground drainage is only as good as the data provided.

## 4.3 Assessment of stormwater drainage system standard

### 4.3.1 Modelling approach

A one-dimensional (1D) hydraulic model of the existing underground drainage systems was created in the software DRAINS to investigate the capacity, or the 'drainage standard', of each conduit. The model assumed that inlets to the drainage system do not limit inflow. This assumption ensures that the capacity of the conduits is not overestimated. The hydraulic model was used to assess each drain segment on the basis that all runoff from upstream areas would be conveyed through the system without restriction. This approach ensures that the capacity of the drainage system is not overestimated in the lower parts of the catchment due to upstream restrictions that would otherwise limit flow.

The hydraulic model was run to simulate the 1, 2, 5 and 10 year ARI storm events to assess the standard of each drain. The model was run to provide estimates of the design flow for each pipe for each event. The design flow was compared against the existing pipe capacity to determine the point at which the design flow would exceed the pipe capacity and thus determine the standard of each pipe.

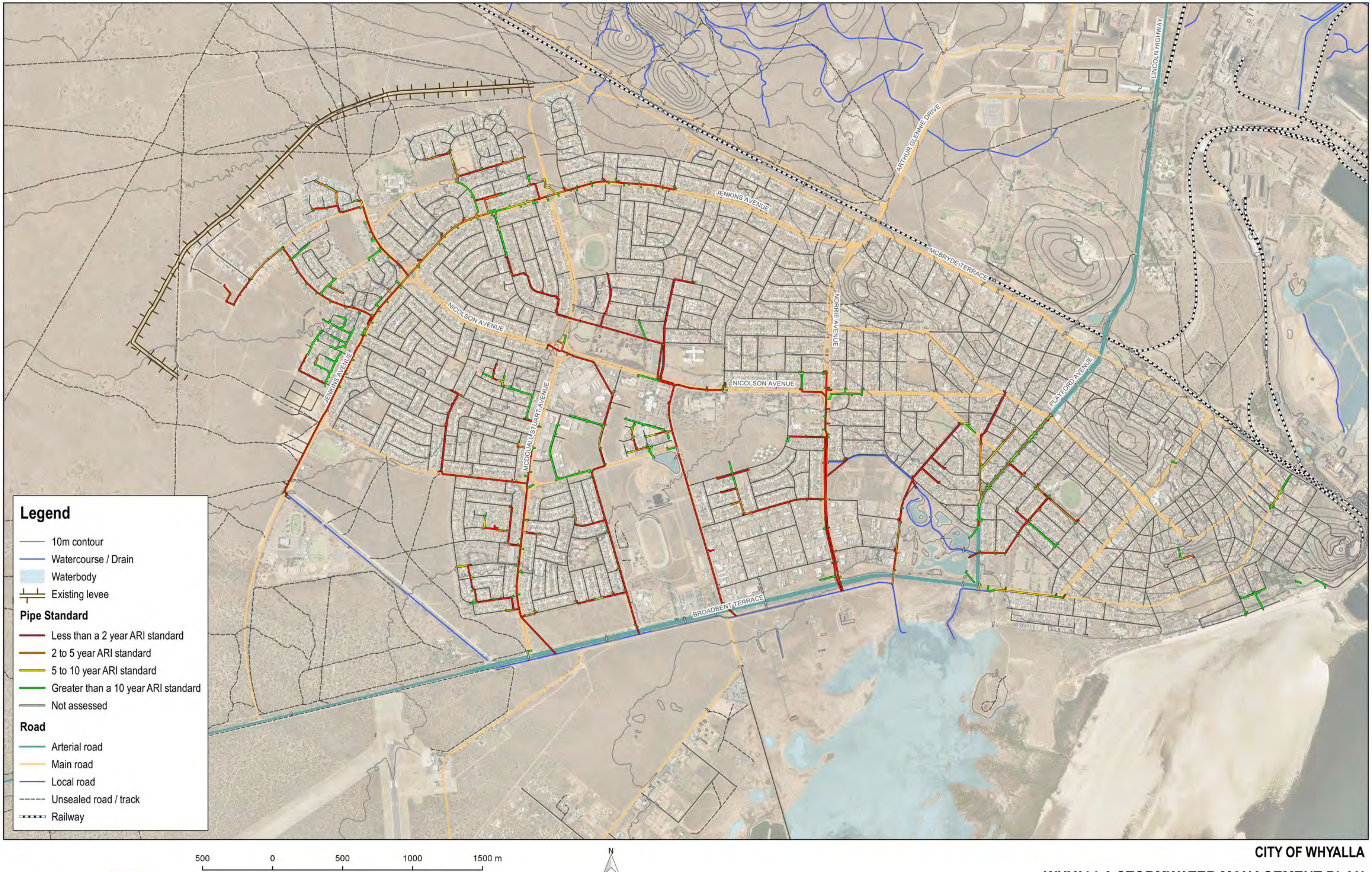
## Results

Figure 4.1 shows the colour coded results of the capacity assessment across the study area. Drain systems highlighted in red indicate drains that may require upgrades to reach the desired standard of protection.

Whilst newer areas of development typically have a drain standard greater than 5 year ARI, the majority of the trunk drainage in Whyalla has less than a 2 year ARI standard with the exception being the Playford Avenue drain which has between a 2 and 5 year ARI standard.

Of the drainage systems assessed, 31% (by length) have capacity to convey the estimated flow for an event greater than or equal to the 5 year ARI, whilst 43% is greater than or equal to a 2 year ARI standard.

The DRAINS model was also used to identify where the drainage system could benefit from extension of the underground drainage network upstream to capture more surface flows from a sub-catchment and reduce flow widths within the road. An analysis of the 5 year ARI flows was undertaken to highlight where flows approaching pits exceed the inlet capacity of the pit. This analysis is shown on Figure 4.2. The most critical sub-catchment flows, generating more than 1 $m^3/s$ in a 5 year ARI event, were identified as areas that would benefit the most from extending the pit and pipe system further. The amount of additional surface flow that can be captured by extending the underground drainage network is likely to be limited by the capacity of the existing drainage system.

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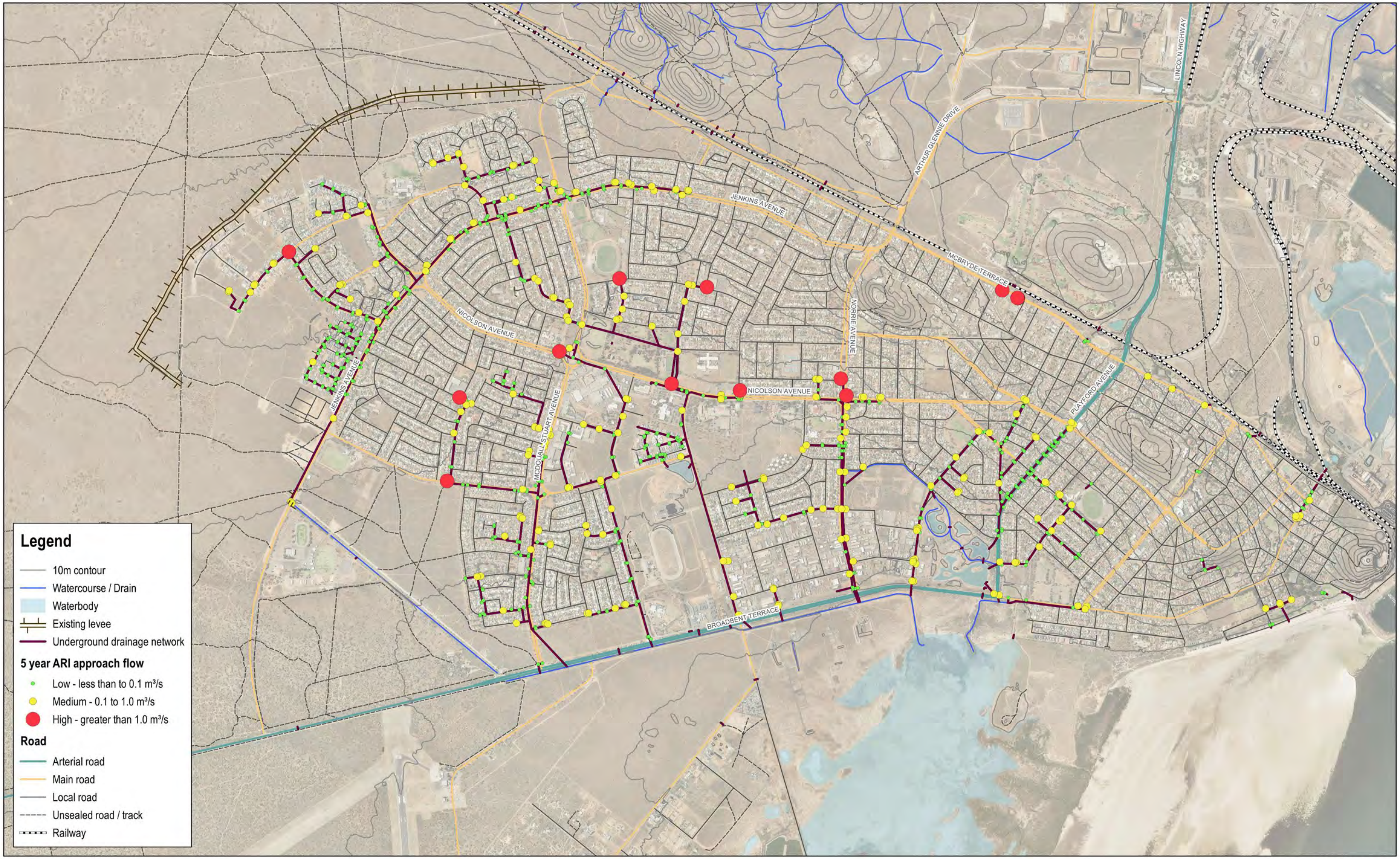
CITY OF WHYALLA

**WHYALLA STORMWATER MANAGEMENT PLAN**
**EXISTING DRAINAGE STANDARD**

Figure 4.1




500 0 500 1000 1500 m

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**WHYALLA STORMWATER MANAGEMENT PLAN**
**5 YEAR ARI - INLET APPROACH FLOWS**

Figure 4.2

## 4.4 Key flood prone areas

This section describes the nature and cause of the most prominent flooding issues identified by the flood modelling. It does not discuss all areas of flooding illustrated by the flood modelling, instead focussing on the most problematic locations. The predominant flood behaviour is described, and the main causal mechanisms are defined if possible. For easy reference, an extract of the 100 year ARI flooding is included with the description of each area. Figure 2.3 is reproduced here to illustrate the general location of each area being discussed.

A full set of flood inundation maps can be found in Appendix A.

### 4.4.1 Valley 1

The area referred to as 'Valley 1' is a very broad and shallow valley, which runs south east through Whyalla Norrie extending from Knight Street at its upper end, to Jacobs Street at its lowest point. The valley passes through McLennan Avenue, Nicolson Avenue and Russell Street. The valley is serviced primarily by the Racecourse Road drainage system. Figure 4.3 shows the location of Valley 1 and the extent of flooding in the 100 year ARI event.

In the 10 year ARI event, most surface flooding is contained to the road network. Notable flooding occurs in properties along Knight Street, Head Street, Brook Street, Flavel Street, Remilton Street, McLennan Avenue and Nicolson Avenue. Generally, the road network can convey the majority of surface floodwater in the 10 year ARI event with few properties being affected in the areas mentioned. During the 20, 50 and 100 year ARI events the road network is unable to convey enough floodwater to avoid extensive flooding of properties.

Flooding is primarily caused by a lack of capacity in the underground drainage system. This leads to floodwater pooling in low spots within the road corridor. Eventually, when the available storage in the road corridor is exceeded floodwater inundates many properties.

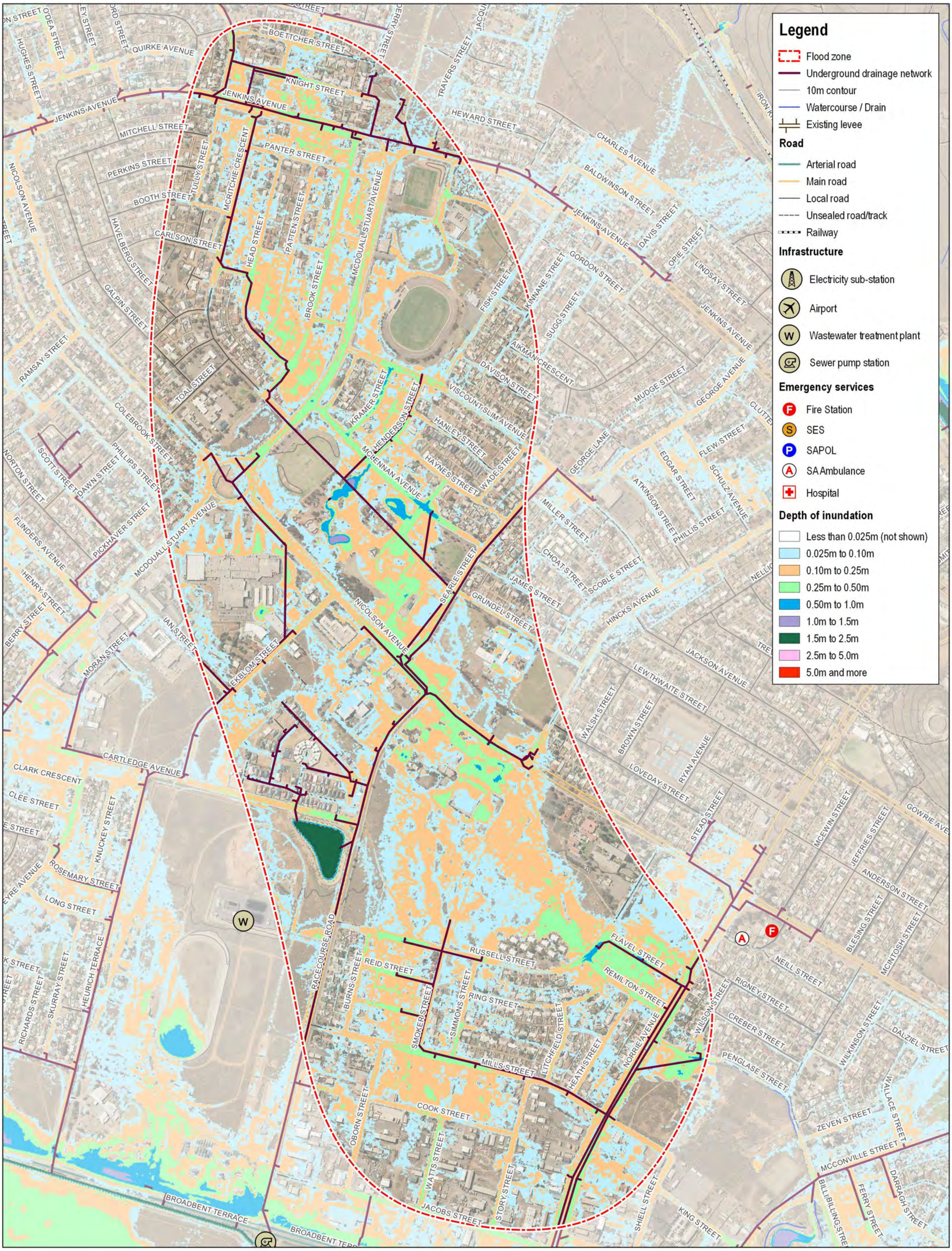
### 4.4.2 Valley 2

The area referred to as 'Valley 2' experiences similar flood conditions as Valley 1 and the causes of flooding are identical. The primary difference between the two locations is the that size of the contributing catchment is much smaller. Valley 2 is approximately located between Flinders Avenue and Heurich Terrace. Figure 4.4 shows the location of Valley 2 and the extent of flooding during the 100 year ARI event.

The flood mapping shows that the majority of floodwater is contained to the road network during the 10 year ARI event. During larger events, the flooding of properties is significant with the average depth of inundation in the 100 year ARI event being 150 mm. The main locations that experience flooding of properties are:

- between Noble Street and Hutchens Street
- between Berry Street and McDouall Stuart Avenue
- between Rosemary Street and Long Street
- between Cartledge Avenue and Clee Street.

In the 100 year ARI event, there is very deep flooding along McDouall Stuart Avenue, up to 400 mm between Murray Street and Flinders Avenue.

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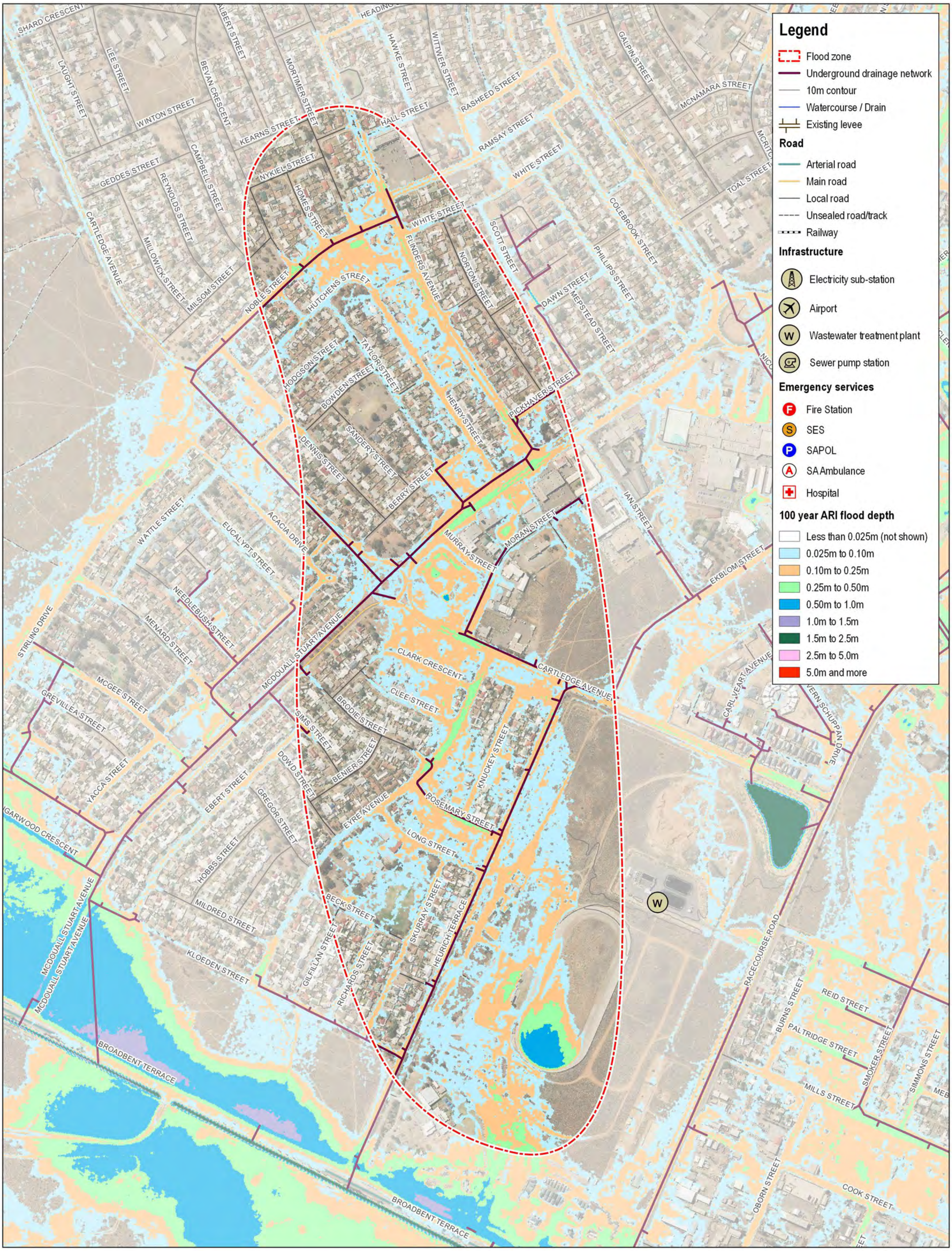
## WHYALLA STORMWATER MANAGEMENT PLAN
## 100 YEAR ARI FLOODING WITHIN 'VALLEY 1' AREA

Figure 4.3

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## WHYALLA STORMWATER MANAGEMENT PLAN
## 100 YEAR ARI FLOODING WITHIN 'VALLEY 2' AREA

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Figure 4.4

#### 4.4.3 Ocean Eyre development and Broadbent Terrace

Due to the raised nature of Broadbent Terrace compared to the adjacent roads, floodwater is prevented from flowing towards the sea. Consequently, there is significant flooding of properties on the northern side of Broadbent Terrace. In the 10 year ARI event the flooding is generally contained to the road corridors, however, in the 20, 50 and 100 year ARI events flooding is extensive and significant. Flood depths adjacent Broadbent Terrace in the 100 year ARI event are up to 1.0 m deep (refer Figure 4.5). Access to the city via McDouall Stuart Avenue, Heurich Terrace, Racecourse Road, Norrie Avenue, Keith Street and Playford Avenue is impacted by floodwater over these roads in all events greater than 10 year ARI.

The main source of flooding along Broadbent Terrace is floodwater that originates from the large catchments north-west of the city. Runoff from these catchments are initially redirected westward by the northern levee, however, the northern levee currently does not extend around the entirety of the Ocean Eyre development area. Consequently, the floodwater that arrives from the external catchments to the north-west is directed through the southern, undeveloped portion of the Ocean Eyre site. This floodwater continues through the Jubilee Park sports centre and surrounding open areas; eventually contributing to the flooding behind Broadbent Terrace. The Airport channel is unable to convey the very large volume of runoff. Exacerbating the channel flooding is the low capacity of various culverts along its length which are too small compared to the capacity of the channel. This lack of capacity leads to floodwater spilling from the channel and pooling behind Broadbent Terrace.

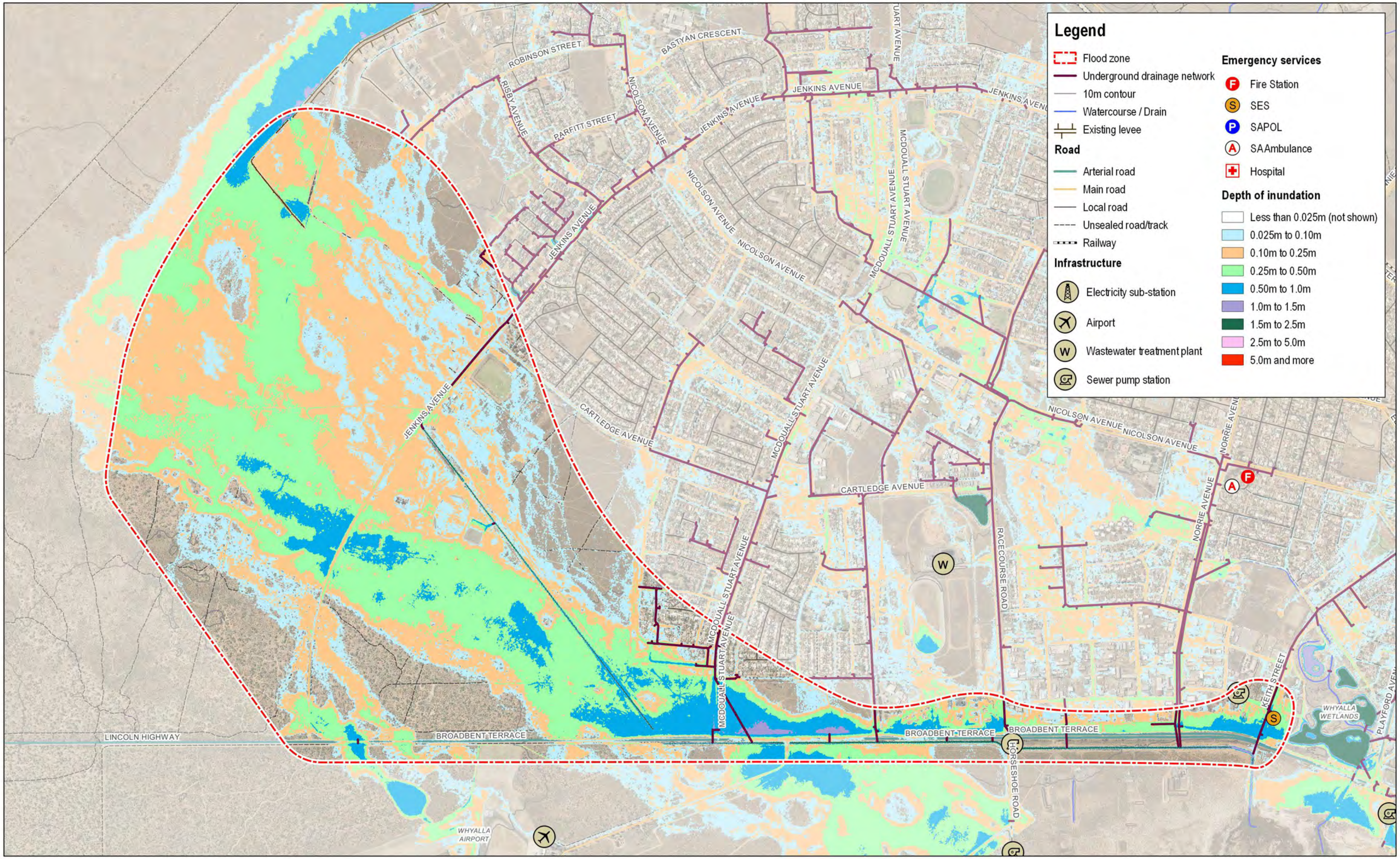
A secondary source of flooding for Broadbent Terrace is floodwater that originates from within the city's urban areas. Due to the limited capacity of upstream drains, and the lack of significant drains beneath Broadbent Terrace, the water from the urban areas is unable to drain into the airport channel and ponds on the northern side of the road.

Flooding is not limited to Broadbent Terrace. The southern portion of the Ocean Eyre site and the open area bounded by Jenkins Avenue, Broadbent Terrace and the airport channel are subject to widespread shallow flooding due to the flat undulating terrain and lack of a defined water course.

While dwarfed by the runoff from external catchments, a significant amount of runoff is generated internally by the Ocean Eyre development. Although not easily discerned from the flood maps, runoff generated internally by the Ocean Eyre development contributes to flooding along Jenkins Avenue.

#### 4.4.4 McConville Street and surrounding areas

McConville Street, Ferry Street, Darragh Street and Billing Street (to the west of Playford Avenue) are parallel to each other and are perpendicular to the natural direction of flow. Due to a lack of drainage capacity and the presence of trapped low-spots, properties along both streets are inundated in events as small as the 10 year ARI event. The average depth of flooding in the affected properties is 150−200 mm during the 100 year ARI event (refer Figure 4.6). Up to 40 properties are affected by flooding in the 100 year ARI event. Floodwater collects in the low spot whenever the capacity of the drain in Rudall Avenue is exceeded. Additional floodwater arrives from Nicolson Avenue near the intersection with Bradford Street.

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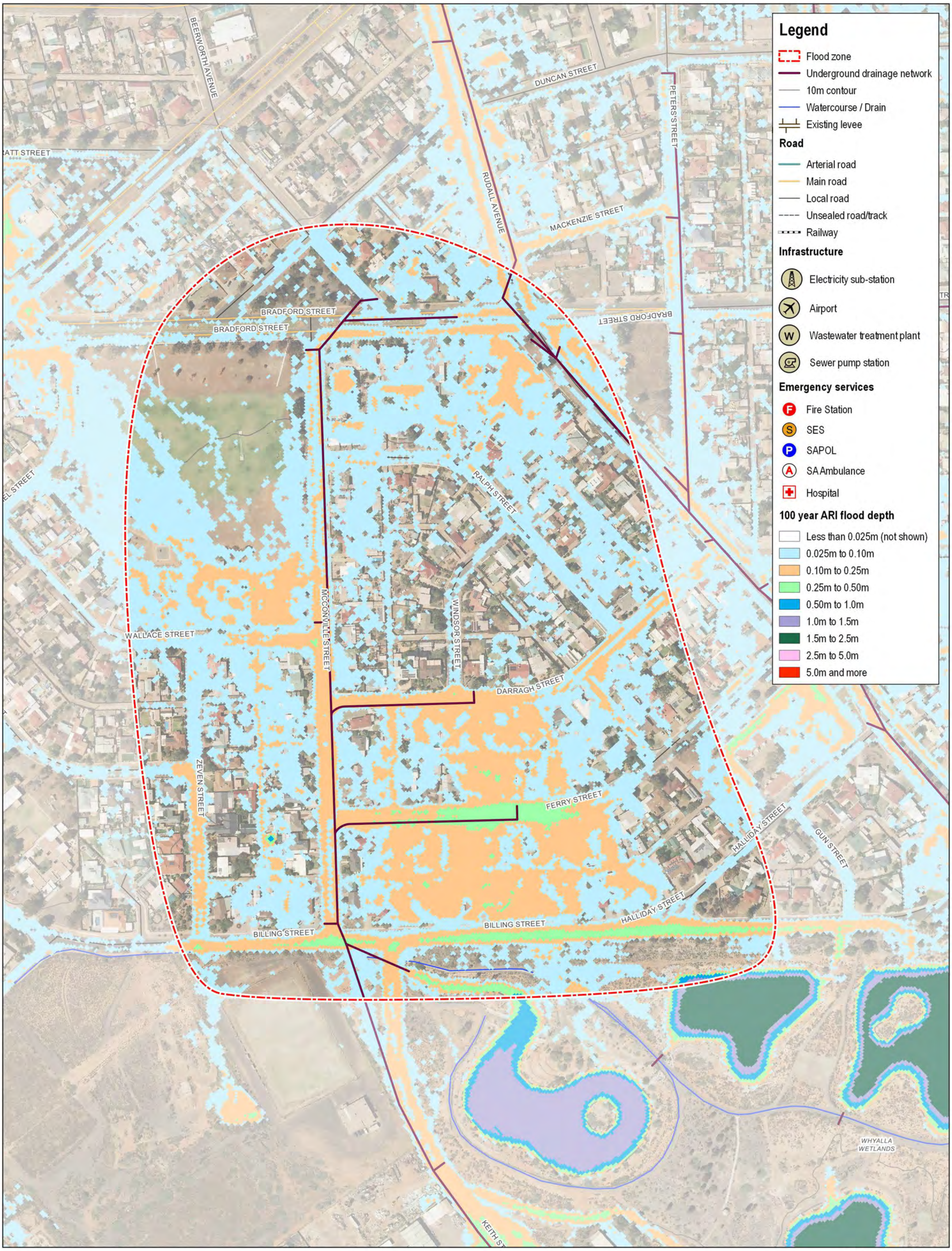
**WHYALLA STORMWATER MANAGEMENT PLAN**
**100 YEAR ARI FLOODING WITHIN OCEAN EYRE DEVELOPMENT AND BROADBENT TERRACE AREA**

Figure 4.5

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CITY OF WHYALLA

**WHYALLA STORMWATER MANAGEMENT PLAN**
**100 YEAR ARI FLOODING WITHIN MCCONVILLE STREET AND SURROUNDING AREAS**

Figure 4.6

### 4.4.5 Farrell Street area

This area of the city experiences relatively shallow surface flooding due to the lack of underground drainage in the area and steep topography. During the 100 year ARI event flooding is generally 100 to 150 mm deep through properties and along streets (refer Figure 4.7). Floodwater is contained along the northern side of this area by the steelworks railway. At the two low-spots along the railway, culverts convey floodwater under the railway. The low-spot at the intersection of Darling Terrace and McBryde Terrace is well-known for flooding. During the 100 year ARI event, floodwater reaches a depth of up to 1 m. In the 10 year ARI event, flooding reaches a depth of up to 800 mm. The primary cause of this flooding is the size of the culvert barrels (three DN375 RCPs) under the railway which are insufficient to pass significant flows without flooding of the intersection.

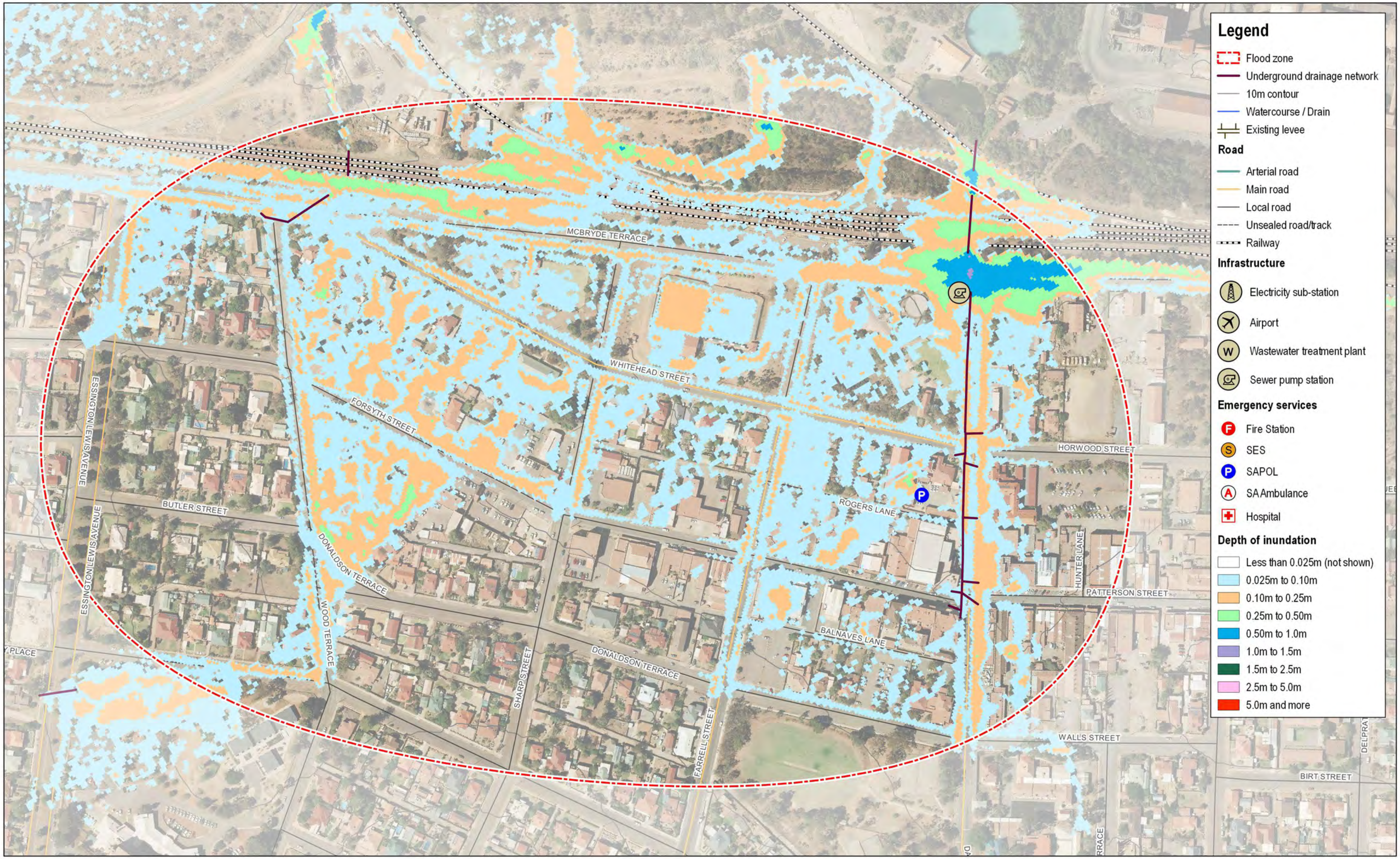
Flooding in this area is also characterised by relatively high flow velocities along roads; often reaching as high as 2.0 m/s in the 10 year ARI event. Such high velocities can present a hazard to pedestrians during flood events, particularly children and the elderly. During the 100 year ARI event the flood hazard is problematic along Wood Terrace, Farrell Street and Darling Terrace.

### 4.4.6 Newton Street area

The Newton Street area is roughly bounded by Broadbent Terrace, Dunstone Street and the coastal sand dunes (refer Figure 4.8). Flooding in this area is characterised by surface flows from Broadbent Terrace through properties to the south. In the 100 year ARI event flow through properties is generally between 100 and 160 mm. However, this area is dominated by housing with finished floor levels that are estimated to be only 100 mm above natural surface levels. Therefore, flood depths greater than 100 mm in this area potentially represent flooding of dwellings. It is estimated that up to 36 dwellings are affected by inundation greater than 100 mm.

### 4.4.7 Industrial area

The industrial area is located north of the city and is approximately bounded by Arthur Glennie Drive and the Lincoln Highway. Flooding in this area is characterised by shallow surface flow from the Mount Laura area which then becomes trapped behind the Lincoln Highway (refer Figure 4.9). Floodwater trapped behind the Lincoln Highway is the predominant cause of flooding within the industrial area. Sheet flow that arrives from the west is conveyed through the roadside swale drains and culverts in events up to a 20 year ARI event. In rarer events overflows from the swales are largely contained to the road network. Flooding behind Lincoln Highway is caused by the limited capacity of the culverts conveying floodwater to the west.

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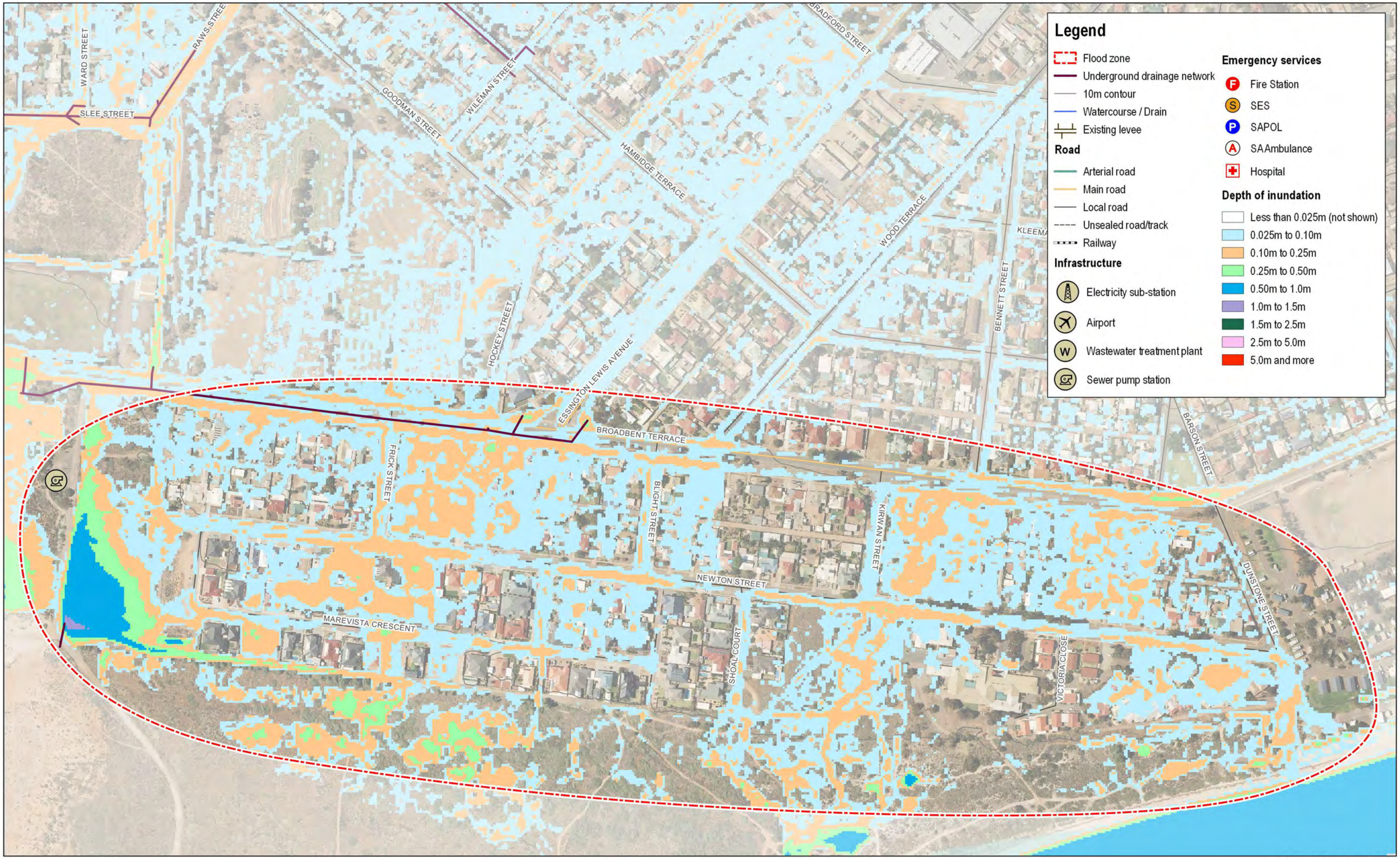
**WHYALLA STORMWATER MANAGEMENT PLAN**
**100 YEAR ARI FLOODING WITHIN FARRELL STREET AREA**

Figure 4.7

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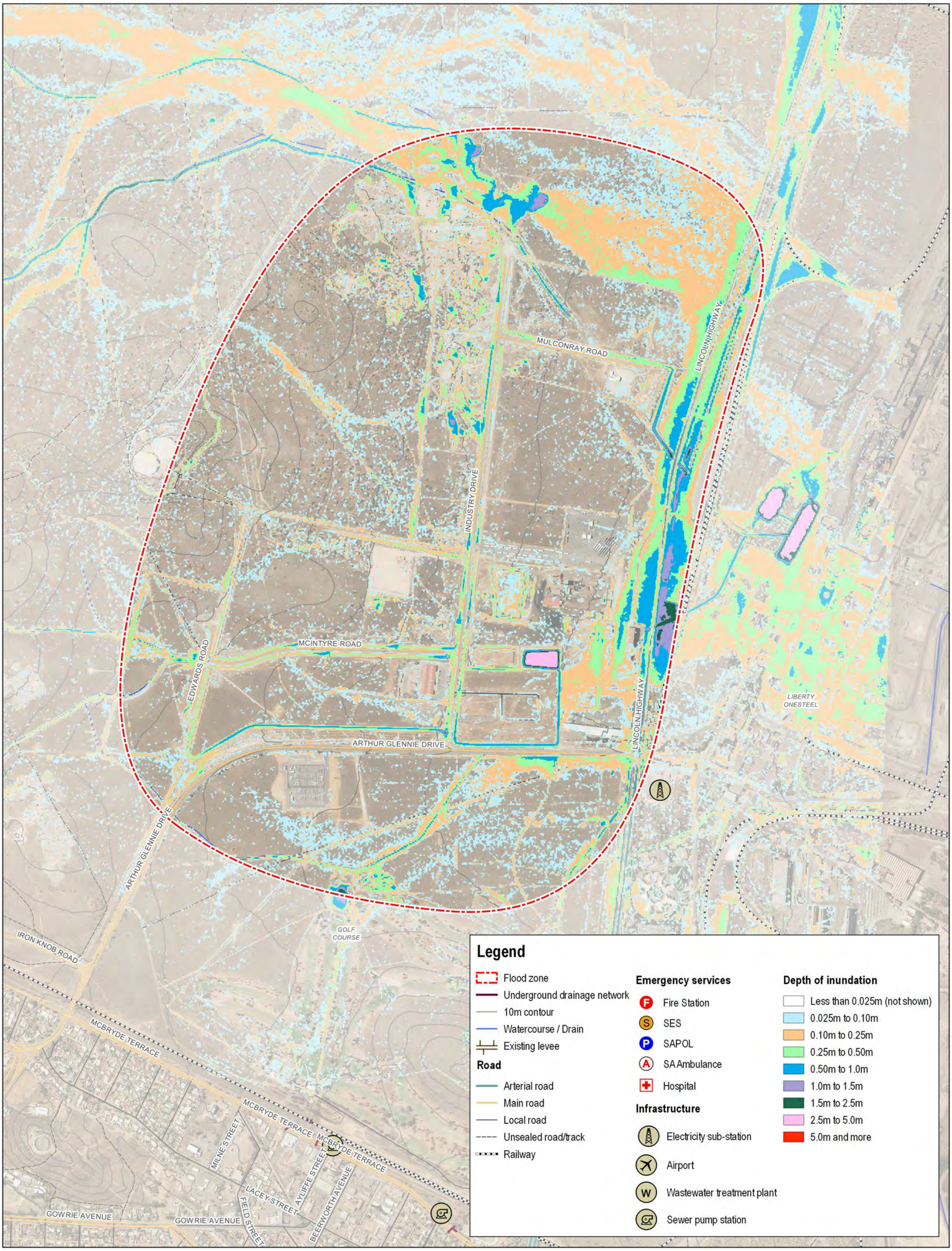
**WHYALLA STORMWATER MANAGEMENT PLAN**
**100 YEAR ARI FLOODING WITHIN NEWTON STREET AREA**

Figure 4.8

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CITY OF WHYALLA

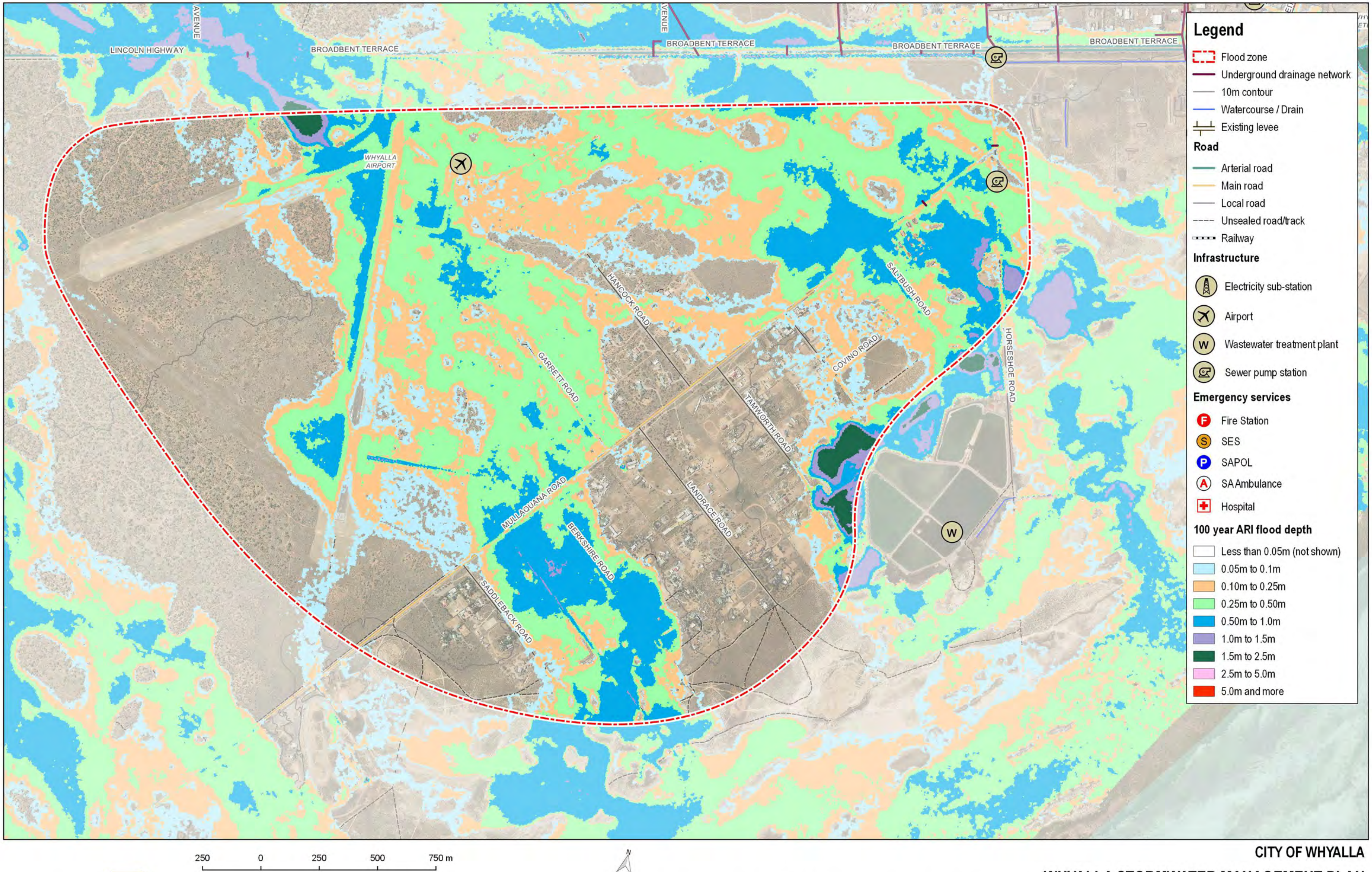
WHYALLA STORMWATER MANAGEMENT PLAN
100 YEAR ARI FLOODING WITHIN INDUSTRIAL AREA

Figure 4.9

### 4.4.8 Airport and Mullaquana rural living area

The Mullaquana rural living area is located to the south of the city urban areas; to its west is the Whyalla Airport. Both the Whyalla Airport and Mullaquana area are situated in the middle of one of the main flow paths originating from the Salt Creek catchment. The estimated flooding through Mullaquana and the Airport is extensive due to the relatively flat terrain which results in a broad and meandering floodplain (refer Figure 4.10). About one third of the Mullaquana rural living properties are situated on a small rise in the terrain which is above the 100 year ARI flood level. Roughly 86 properties are affected by flooding deeper than 100 mm in the 100 year ARI event. The main north-south runway of the Airport (Runway 17 35) is inundated to a depth of 150 mm in the 100 year ARI event; the Airport terminal is inundated to a similar depth.

During the 100 year ARI event floodwater from Salt Creek approaches the Airport and Mullaquana from the north west along a floodplain about 1.5 km wide. After crossing Broadbent Terrace the floodwater spreads out along a front about 2.5 km wide as it flows towards the coast before separating into two isolated flow paths. The northern-most flow path extends between Horseshoe Road and Covino Road. The southern-most flow path extends between Berkshire Road and Saddleback Road. Flood depths are up to 1.0 m in some locations during the 100 year ARI event. Due to the depth of the floodwater, much of both flow paths are regarded as hazardous even to able bodied adults.

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CITY OF WHYALLA

WHYALLA STORMWATER MANAGEMENT PLAN

100 YEAR ARI FLOODING WITHIN AIRPORT AND MULLAQUANA RURAL LIVING DEVELOPMENT AREA

Figure 4.10

## 4.5 Flood hazard

In terms of floodplain management, hazards are the source of potential harm or a situation with the potential to result in loss. Personal danger and physical property damage caused by floods varies in both time and place across the floodplain. In some areas floodwaters can flow deeply and slowly, while in other areas they may be more shallow and swift – either situation may unbalance people and vehicles and sweep them away. Structures can be undermined or have their structural integrity damaged by floodwater and debris, and contents are vulnerable to contact with floodwater.

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

Flood hazard maps were produced using the combined flood hazard threshold curves developed by Smith et al (2014), as shown in Figure 4.11. 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 vulnerability thresholds and limits for the classifications are provided in Table 4.1.

Table 4.1 Hazard vulnerability thresholds and classification limits (reproduced from AIDR Guideline 7.3, 2017)

| Hazard vulnerability classification | Description | Classification limit (D × v) $m^2/s$ | Limiting still water depth (D) m | Limiting velocity (v) m/s |
|---|---|---|---|---|
| H1 | Generally safe for vehicles, people and buildings | ≤ 0.3 | 0.3 | 2.0 |
| H2 | Unsafe for small vehicles | ≤ 0.6 | 0.5 | 2.0 |
| H3 | Unsafe for vehicles, children and the elderly | ≤ 0.6 | 1.2 | 2.0 |
| H4 | Unsafe for vehicles and people | ≤ 1.0 | 2.0 | 2.0 |
| H5 | Unsafe for vehicles and people. All building types vulnerable to structural damage. Some less robust building types vulnerable to failure. | ≤ 4.0 | 4.0 | 4.0 |
| H6 | Unsafe for vehicles and people. All building types considered vulnerable to failure. | > 4.0 | – | – |

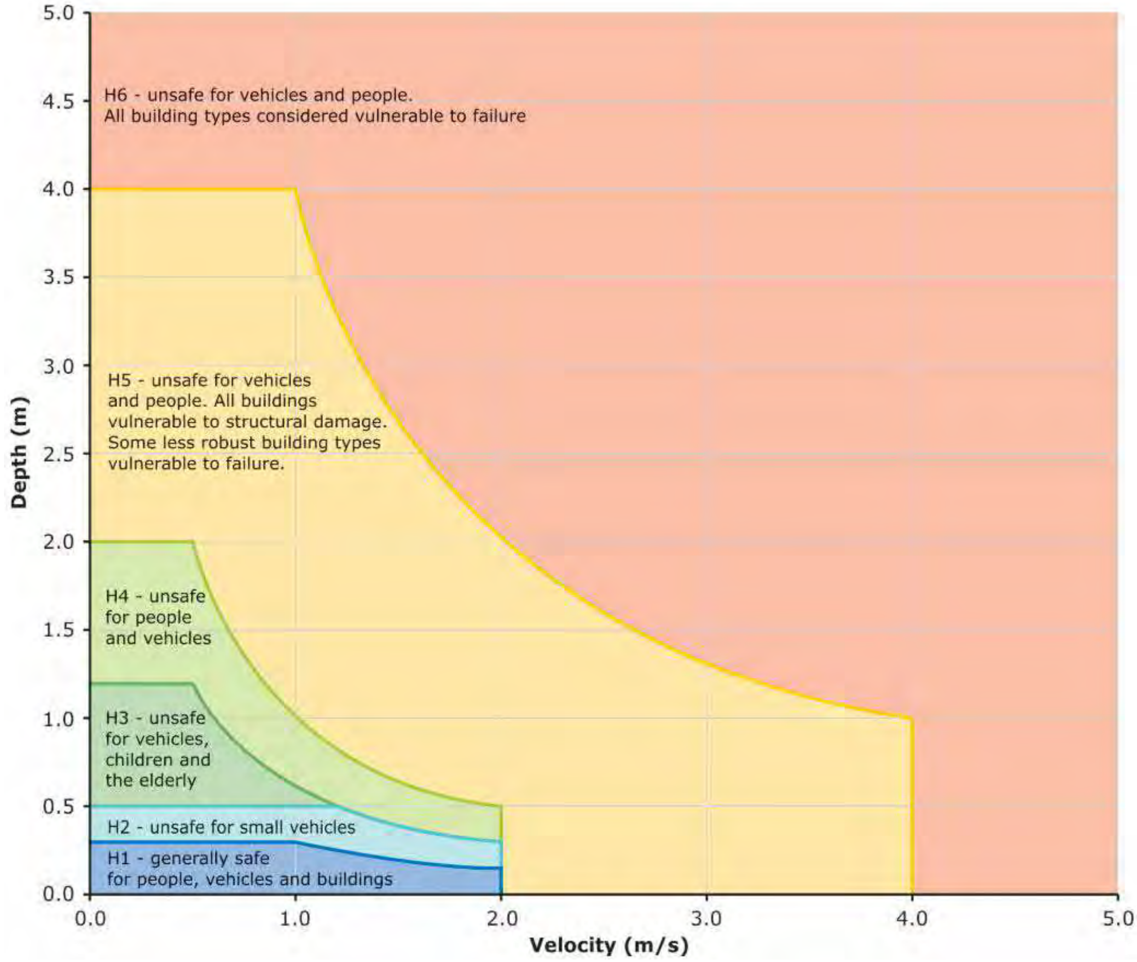



Figure 4.11 Combined flood hazard curves (Smith et al. 2014)

The flood hazard maps were produced for the 100 and 500 year ARI events. These maps are presented in Appendix A of this report.

Figure 4.12 shows that the majority of flooding caused by local, urban catchments within the city is of low hazard (H1) since a large portion of inundation on the floodplain consists of shallow sheet flow that can be waded.

Existing buildings within the city are not expected to be vulnerable to structural damage in events up to a 500 year ARI, as flood hazard classifications remain below H5 at all existing building locations. Flooding through allotments rarely reaches depths or velocities that would be unsafe for people or vehicles in a 100 year ARI event as the hazard classifications remain at H1. There is only a small area (less than 1 hectare) of residential allotments, on the southern side of Flavel Street, that are inundated to levels that are unsafe for small vehicles (H2) in a 100 year ARI event. The potential hazard is greater at this location due to floodwaters exceeding a depth of 300 mm, due to spills from the sag location on Russell Street. It is however possible for flooding at these properties to be waded or traversed via larger vehicles such that residents would be capable of evacuating their property in a 100 year ARI event.

The number of allotments with a hazard classification greater than H1 is significantly increased in a 500 year ARI event. The majority of the increased hazard results from water ponding up to large depths on the northern side of Broadbent Terrace.

While there is minimal hazard at the existing residential allotments, there is a significant portion of the areas zoned for future residential development that is inundated to levels that are of risk to people and vehicles. These hazards are the result of flooding from flows generated by the Salt Creek catchment heading around the levee and moving in a south-westerly direction through open land. The high hazard is caused by a combination of large flow depths (up to 600 mm) and relatively high velocities (approximately 1 m/s).

The majority of this open land is zoned for future residential development, including the Ocean Eyre development. There is roughly 16 hectares within future residential zones that has a hazard classification of H3, in a 100 year ARI event. This increases to 36 hectares in a 500 year ARI event. Of this, there is approximately 2 hectares within land on the north-east side of the intersection with McDouall Stuart Avenue and Broadbent Terrace that would have the potential to cause structural damage to buildings (category H5).

As these floodwaters move in a south-westerly direction through areas zoned for future residential development, they spill over Jenkins Avenue. This results in large flows with high velocities (greater than 2 m/s) freely spilling over the crown of the road. These high velocities cause there to be a 350 m section along Jenkins Avenue that is of H5 hazard category in a 100 year ARI event. This section of the road is therefore considered unsafe for all people and vehicles and would not provide a safe evacuation route in a 100 year ARI event.

There are also some localised areas along roads within the city where the hazards are above an H2 category. These hazards are generally the result of deep floodwaters at sag locations. Having a hazard greater than an H2 classification along local roads can restrict vehicular movement and make it difficult for residents to evacuate. The main locations along roads where the hazard is classified as H3 or greater in the 100 year ARI event include:

- a 115 m section along Jenkins Avenue, directly south of the intersection with Risby Avenue
- across the sag location (roughly 100 m) at the intersection with McLennan Avenue and Sydney Street
- for 300 m along Sugarwood Crescent
- blocking access to the Sundowner Cabin and Tourist Park
- at the intersection with Broadbent Terrace and Norrie Avenue
- a 170 m section along Keith Street, at the southern end of the road
- at the south-east corner of Neagle Terrace
- at the intersection with McBryde Terrace and Darling Terrace
- a 150 m section along the Iron Knob Road, located 490 m west of the intersection with Arthur Glennie Drive.

It is important that a safe evacuation route can be achieved in a 100 year ARI event by avoiding these locations or through mitigation measures.

Figure 4.13 shows that, when the entire Salt Creek catchment is flooding, there is a significant amount of flooding that is of high hazard, ranging from H2 to H5.

The majority of flooding caused by the Salt Creek catchment occurs within undeveloped land, therefore having minimal impact on the community. There is however a large area (26 hectares) of high hazard, above an H2 classification, in the rural living area of Mullaquana, in a 100 year ARI event. This is due to the large depths of flooding through this area, ranging from 0.5 to 1 m deep.

A large portion of the local roads in Mullaquana are inundated to levels that result in risks to people and vehicles. The main roads that are inundated to depths that result in an H3 or greater hazard in a 100 year ARI event include Berkshire Road, Landrace Road and Saltbush Road. There are also high hazards (H3 and above) along the main roads servicing the rural residential area, making it difficult for residents to evacuate in a 100 year ARI event. This predominantly includes Mullaquana Road and Eight Mile Creek Road.

## Disclaimer

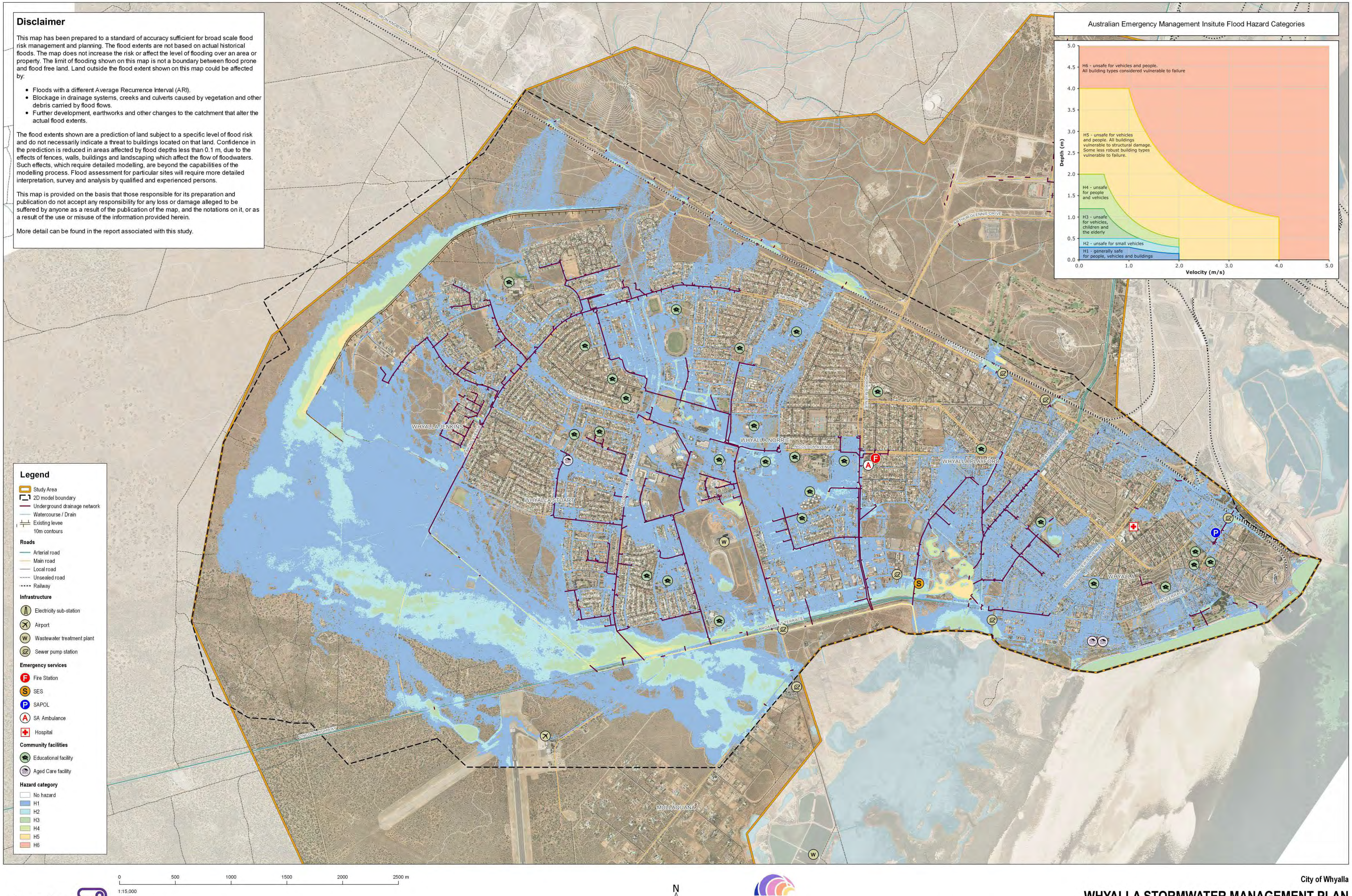
This map has been prepared to a standard of accuracy sufficient for broad scale flood risk management and planning. The flood extents are not based on actual historical floods. The map does not increase the risk or affect the level of flooding over an area or property. The limit of flooding shown on this map is not a boundary between flood prone and flood free land. Land outside the flood extent shown on this map could be affected by:

- Floods with a different Average Recurrence Interval (ARI).
- Blockage in drainage systems, creeks and culverts caused by vegetation and other debris carried by flood flows.
- Further development, earthworks and other changes to the catchment that alter the actual flood extents.

The flood extents shown are a prediction of land subject to a specific level of flood risk and do not necessarily indicate a threat to buildings located on that land. Confidence in the prediction is reduced in areas affected by flood depths less than 0.1 m, due to the effects of fences, walls, buildings and landscaping which affect the flow of floodwaters. Such effects, which require detailed modelling, are beyond the capabilities of the modelling process. Flood assessment for particular sites will require more detailed interpretation, survey and analysis by qualified and experienced persons.

This map is provided on the basis that those responsible for its preparation and publication do not accept any responsibility for any loss or damage alleged to be suffered by anyone as a result of the publication of the map, and the notations on it, or as a result of the use or misuse of the information provided herein.

More detail can be found in the report associated with this study.

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Data Acknowledgement:
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Base data from DataSA

City of Whyalla

**WHYALLA STORMWATER MANAGEMENT PLAN**

**CITY Catchment- 100 year ARI flood hazard existing development scenario**

Figure 4.12

## Disclaimer

This map has been prepared to a standard of accuracy sufficient for broad scale flood risk management and planning. The flood extents are not based on actual historical floods. The map does not increase the risk or affect the level of flooding over an area or property. The limit of flooding shown on this map is not a boundary between flood prone and flood free land. Land outside the flood extent shown on this map could be affected by:

- Floods with a different Average Recurrence Interval (ARI).
- Blockage in drainage systems, creeks and culverts caused by vegetation and other debris carried by flood flows.
- Further development, earthworks and other changes to the catchment that alter the actual flood extents.

The flood extents shown are a prediction of land subject to a specific level of flood risk and do not necessarily indicate a threat to buildings located on that land. Confidence in the prediction is reduced in areas affected by flood depths less than 0.1 m, due to the effects of fences, walls, buildings and landscaping which affect the flow of floodwaters. Such effects, which require detailed modelling, are beyond the capabilities of the modelling process. Flood assessment for particular sites will require more detailed interpretation, survey and analysis by qualified and experienced persons.

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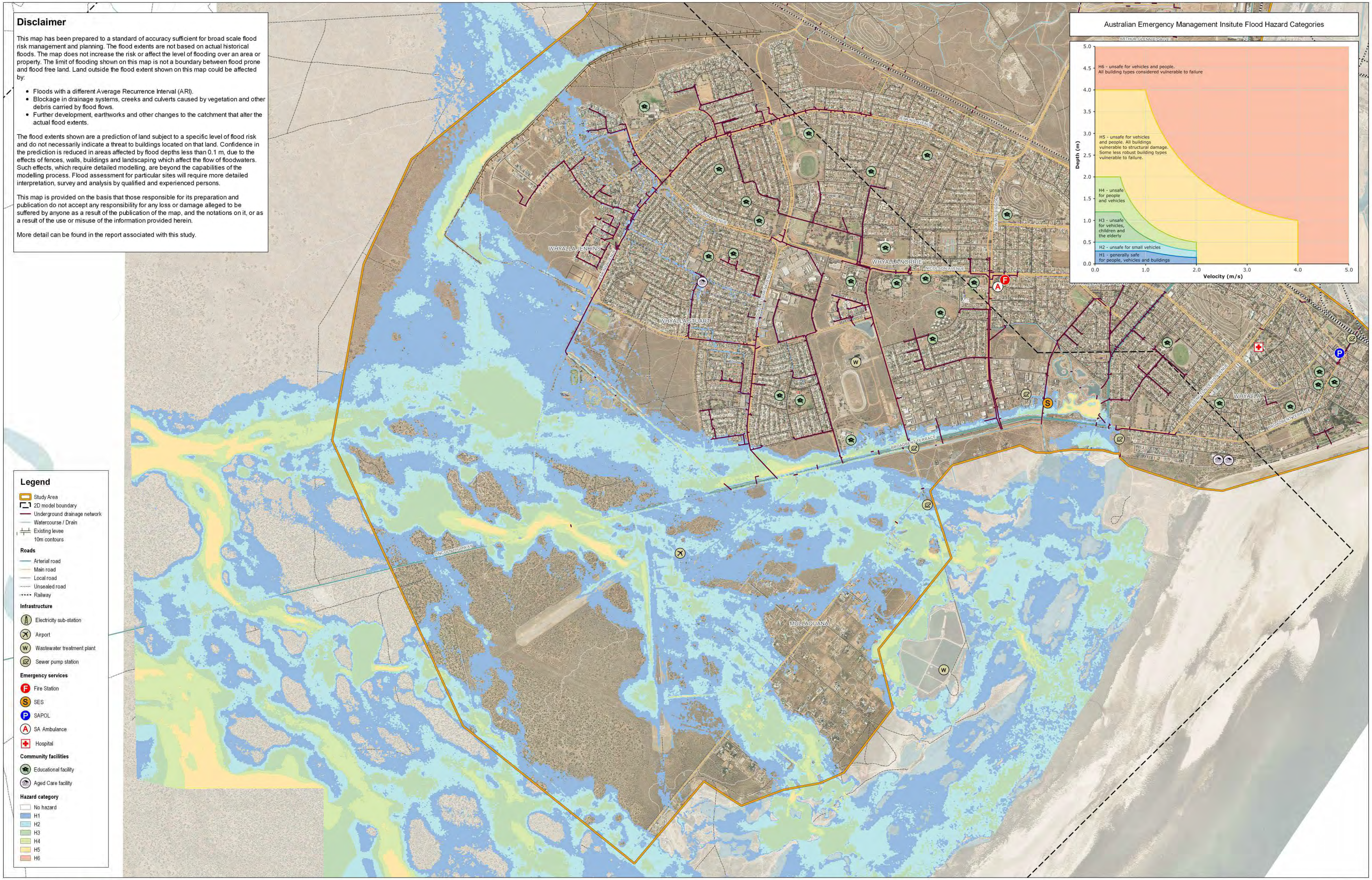


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WHYALLA

City of Whyalla

**WHYALLA STORMWATER MANAGEMENT PLAN**

**AIRPORT Catchment - 100 year ARI flood hazard existing development scenario**

Figure 4.13

## Disclaimer

This map has been prepared to a standard of accuracy sufficient for broad scale flood risk management and planning. The flood extents are not based on actual historical floods. The map does not increase the risk or affect the level of flooding over an area or property. The limit of flooding shown on this map is not a boundary between flood prone and flood free land. Land outside the flood extent shown on this map could be affected by:

- Floods with a different Average Recurrence Interval (ARI).
- Blockage in drainage systems, creeks and culverts caused by vegetation and other debris carried by flood flows.
- Further development, earthworks and other changes to the catchment that alter the actual flood extents.

The flood extents shown are a prediction of land subject to a specific level of flood risk and do not necessarily indicate a threat to buildings located on that land. Confidence in the prediction is reduced in areas affected by flood depths less than 0.1 m, due to the effects of fences, walls, buildings and landscaping which affect the flow of floodwaters. Such effects, which require detailed modelling, are beyond the capabilities of the modelling process. Flood assessment for particular sites will require more detailed interpretation, survey and analysis by qualified and experienced persons.

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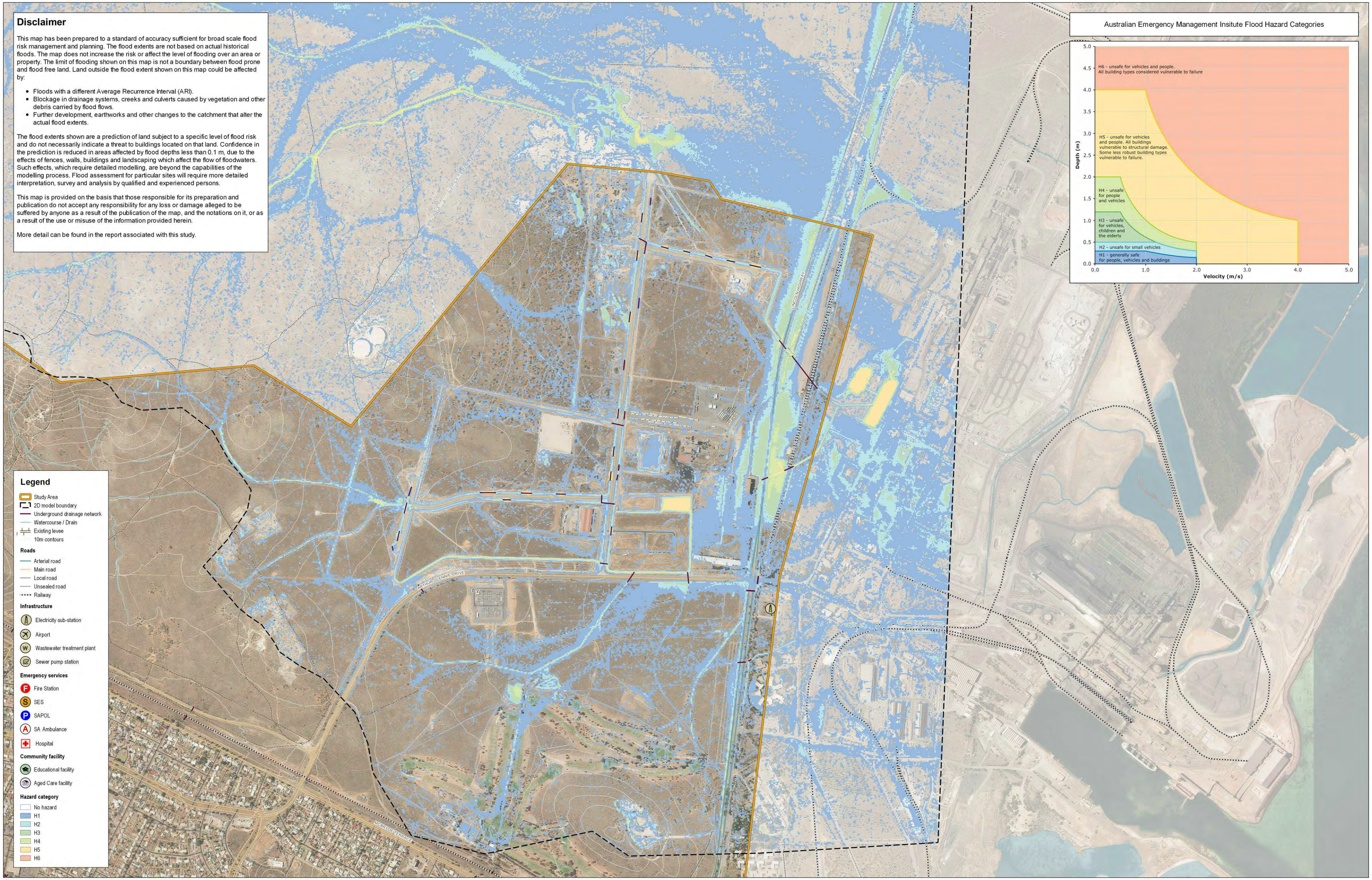


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| Revision: | Rev. C |
| Date: | 2019-06-04 |
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**WHYALLA STORMWATER MANAGEMENT PLAN**

**INDUSTRIAL Catchment - 100 year ARI flood hazard existing development scenario**

Figure 4.14

Flows from the Salt Creek catchment cause hazard levels of H3 and above at a number of locations (2400 m in total, in a 100 year ARI event) along Lincoln Highway as flows freely spill over the road, at high velocities. It is likely that this road would need to be closed during a major event. This also occurs for a length of 540 m along Iron Knob Road, and it provides restrictions on vehicle movement in a 100 year ARI event. Residents would have to travel in a northerly direction, away from the flooding, to avoid locations where flooding is not safe for vehicles.

There is also significant ponding (up to depths of 1 m) on the upstream side of the airport runway, which results in high hazards. However, flooding along the runway remains at shallow depths and low velocities, thereby reducing risks to a hazard category below H3 in all events up to and including a 500 year ARI event.

Figure 4.14 shows that the industrial zone, north of the Iron Knob Road, is located within areas of low hazard (H1). There are some locations that are assigned a hazard classification of H3 and greater – mainly along Lincoln Highway – as the result of large flow depths. However, these locations are contained within roadside swales, basins and open channels, away from industrial buildings and the Lincoln Highway in a 500 year ARI event.

## 4.6 Flood damages

The damages resulting from flooding were estimated using the Rapid Appraisal Method (RAM), developed by the Victorian Department of Natural Resources and Environment (DNRE, 2000). The RAM provides a rapid approach for economic evaluation of the floodplain management measures in a benefit-cost framework.

The calculation process uses the modelled flood maps to estimate the damages at individual allotments. The damages are calculated as a function of the amount of flooding at an allotment, the damage potential of that allotment and the associated damage rate or equation.

It relies on information within the digital cadastral database, including allotment boundaries, the type of land use and property valuations. The cadastral database was processed prior to performing the calculations in order to get all of the required information in the correct format.

### 4.6.1 Data preparation

The damage potential of an allotment will vary between the different types of land use. The allotments were therefore categorised as either:

- low: where the majority of the allotment is pervious (grassed) area, and there is minimal infrastructure; for example, reserves, parks and sports grounds.
- medium: allotments comprising important infrastructure as well as significant (around 50%) pervious area; for example, schools and colleges.
- high: where the majority of the allotment comprises important infrastructure; for example, industrial and commercial buildings.
- existing residential: developed or established residential allotments.
- future residential: large areas zoned for future residential development.

The general basis for assigning the damage potential categories is summarised in Table 4.2.

Aerial imagery was used to assign damage potential categories to allotments without land use information, as well as for validation of the allocation process.

The final damage potential distribution is shown on Figure 4.15.

Table 4.2 Basis for assigning damage potential categories to allotments

| Land use type | Damage potential category |
|---|---|
| Public reserves | Low |
| Recreation areas | Low |
| Agricultural | Low |
| Education institutions | Medium |
| Public utilities | Medium |
| Industrial | High |
| Retail | High |
| Residential (existing) | Existing residential |
| Residential (future) | Future residential |

### Property valuations

The property valuation is used to calculate the damages for residential allotments only. As there was no valuation data available, the approximate average valuation for properties within the City of Whyalla ($220,000) was adopted.

### Excluded allotments

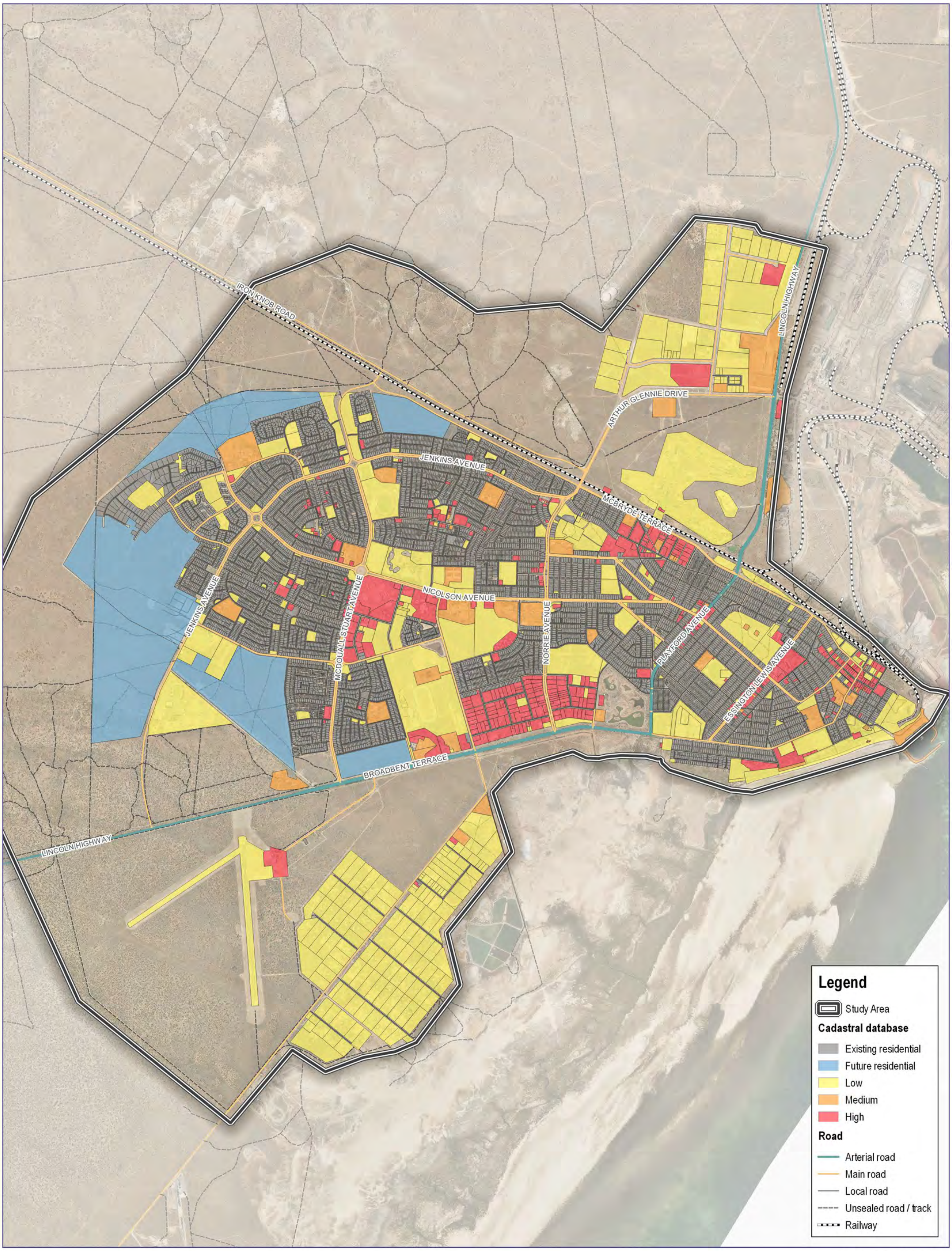
A number of allotments were excluded from the calculation process for the following reasons:

- multi-storey properties: only ground level properties of a multi-storey complex were included. Properties above ground level were excluded, as flood levels would need to be at least 2 m deep to affect these
- small areas: a number of small parcels (less than 50 $m^2$) were excluded as they generally consisted of individual car parks and strata titles. If left in the dataset, they would have contributed a large residential damage when, in reality, minimal property damage would occur.
- unaffected areas: there were a number of large, open area parcels with flooding that had very minimal infrastructure. This includes allotments that contain natural watercourses, drainage easements, or large vacant/rural areas. If these parcels were retained they would generate large flood damage costs when, in reality, very little damage would occur.
- bodies of water: any areas where it is acceptable to have large depths of water, such as wetlands, detention basins and open channels, were excluded.
- roads: damages to roads were not included as part of this assessment.

## 4.6.2 Damage calculation process

The RAM distinguishes between three types of damages:

- Direct (tangible) damages result from the physical impact of the flood, such as damages to structures and contents of buildings.
- Indirect (tangible) damages include losses from disruption to normal economic and social activities that arise as a consequence of the physical impact of the flood; for example, costs associated with emergency response, clean-up, community support, as well as disruption to transport, employment and commerce.
- Intangibles, or 'non-market' impacts, include losses which cannot be quantified in monetary terms; for example, loss in biodiversity, or increased stress levels or physical/mental illness of residents following a major flood event affecting their homes.

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CITY OF WHYALLA

**WHYALLA STORMWATER MANAGEMENT PLAN**
**DAMAGE POTENTIAL CATEGORIES**

Figure 4.15

Intangible damages cannot be calculated with any degree of accuracy, and it is probably impossible to do so given the potential for future or ongoing physical or mental illness responses to a specific event. For this reason, only the tangible (direct and indirect) damages were calculated as part of this assessment. Notwithstanding this, intangible damages are commonly believed to be in the order of 50 to 100% of the tangible damage bill for a community that is not flood aware or has not experienced a major flood event.

### Direct damages

The direct potential damage for the existing residential allotments were calculated using Equation 4.1.

Equation 4.1

$$\$D = \$30{,}000 + \$30{,}000\left(d\,\frac{CV}{CV_{ave}}\right)$$

where,

$$\begin{aligned}&\$D = damage\ in\ dollars\\ &d = depth\ of\ flooding\ above\ finished\ floor\ level\\ &\quad at\ the\ centroid\ of\ the\ allotment\\ &CV = property\ valuation\\ &CV_{ave} = average\ residential\ property\ valuation\end{aligned}$$

The floor level of residential allotments was indicatively determined from an inspection undertaken by Council. The inspection distinguished between areas with floor levels nominally 200 mm above surrounding surface levels, and those only 100 mm (nominally) above surrounding surface levels.

Individual allotment boundaries in areas zoned for future residential development were not included in the cadastral database. Therefore, the damages were calculated using a variable rate as opposed to a flat rate. The rate assumes that, in the ultimate state of development, these zones will consist of 15 residential allotments per hectare, on average, and the total area will comprise 70% residential allotments and 30% roads and open space. On this basis, the damages for future residential allotments were calculated using Equation 4.2.

Equation 4.2

$$\$D = [\$35 + \$35(d_{ave})]A$$

where,

$$\begin{aligned}&\$D = damage\ in\ dollars\\ &d_{ave} = average\ depth\ of\ flooding\ above\ finished\ floor\ level\\ &\quad across\ the\ area\ zoned\ for\ residential\ development\\ &A = area\ of\ flooding\ above\ finished\ floor\ level\end{aligned}$$

It was assumed that development controls imposed by Council would cause all future residential properties in the Ocean Eyre development area to be protected from local flooding originating in the City catchment in all events up to and including a 100 year ARI event. Therefore, these properties do not incur damages in these events.

The Ocean Eyre development area is also impacted by flooding from the Salt Creek catchment, however, the magnitude of flooding is significantly greater for the same ARI. Therefore, the Salt Creek catchment flood extents were compared to the 100 year ARI flood extents of the City catchment. It was found that the 50 year ARI Salt Creek flood extents were similar to the 100 year ARI City catchment flood extents. Consequently, it was assumed that the Ocean Eyre development area would not incur damages from flooding originating in the Salt Creek catchment in all events up to and including a 50 year ARI event.

The damages for all non-residential allotments (i.e. low, medium and high damage potential categories) were calculated using flat rates and variable rates for small (less than or equal to 1000 $m^2$) and large (greater than 1000 $m^2$) allotments, respectively. The adopted damage rates are summarised in Table 4.3.

Table 4.3 Mean potential damages for non-residential allotments

| Damage potential category | < 1000 $m^2$ Mean potential damages per allotment | > 1000 $m^2$ Mean potential damages per $m^2$ |
|---|---|---|
| Low | $4,000 | $5 |
| Medium | $30,000 | $25 |
| High | $48,000 | $60 |

For small allotments, the flat rate was only applied if flooding at the centroid of the allotment was above the floor level (100/200 mm). For large allotments, the variable rate was applied to the area of flooding above 100 mm deep.

Damages within the Whyalla Airport are based on damage to the terminal building alone. Other direct damages due to damage to any specialist runway lighting or pavements has not been included in this assessment. Similarly, indirect damages associated with disruption to services as a result of flooding and closure of the airport have not been considered.

#### Indirect damages

The indirect damages were calculated as a percentage of the direct damages. The adopted percentages are summarised in Table 4.4.

Table 4.4 Indirect proportion of direct damages

| Damage potential category | Indirect damage |
|---|---|
| Existing residential | 15% |
| Future residential | 15% |
| Low | 15% |
| Medium | 60% |
| High | 60% |

As discussed above, indirect damages associated with disruption to airport services due to flooding or the risks associated with closure of the airport in terms of emergency/medical response have not been quantified. The benefit associated with protecting the airport from flood damage is likely to have far more benefit than purely in monetary terms.

#### Conversion to actual damages

The tangible damages are not considered equivalent to realised damages due to mitigating factors, such as the community's preparedness to flooding. Therefore, a potential to actual conversion value of 0.9 was adopted for the Industrial and City catchments due to the quick response time of contributing catchments, and 0.8 for the Airport catchment due to the delayed response time of the large Salt Creek catchment. These are based on values provided in Table 3.5 of the RAM report (DNRE, 2000).

### 4.6.3 Actual damages

The damages were assessed using the zones shown on Figure 4.16.


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CITY OF WHYALLA

WHYALLA STORMWATER MANAGEMENT PLAN
DAMAGE ASSESSMENT ZONES

Figure 4.12

Table 4.5 Total actual damages ($million)

| ARI | AEP (%) | Airport | City | Industrial |
|---|---|---|---|---|
| 10 year | 9.5% | $ 10.46 | $ 4.67 | $ 2.38 |
| 20 year | 5.0% | $ 14.06 | $ 13.31 | $ 3.50 |
| 50 year | 2.0% | $ 17.37 | $ 26.09 | $ 4.42 |
| 100 year | 1.0% | $ 75.39 | $ 39.26 | $ 5.36 |
| 500 year | 0.2% | $ 93.32 | $ 167.63 | $ 7.60 |
| PMF | 0.00001% (City)<br>0.0001% (Airport) | $ 263.46 | $ 656.49 | $ 18.97 |

The total actual damages (direct and indirect) in $millions for each of the modelled events and various models are summarised in Table 4.5.

In events less than or equal to a 100 year ARI there is minimal damage to residential allotments. The residential damages amount to 10% of the total damages in a 100 year ARI event for the City model. The majority of damages arise from flooding to reserves, schools, industrial and commercial allotments in Whyalla Norrie (part of Zone 3) – particularly the allotments along Nicolson Avenue and Lincoln Highway.

In the 500 year ARI and PMF events there is a significant amount of damage to residential allotments. In particular, allotments in the western suburbs (Whyalla Jenkins, Whyalla Stuart and Whyalla Norrie) are affected by flows from the Salt Creek catchment overtopping the existing levee and moving in a south-easterly direction through the city. During the PMF event, more than 75% of the damages are caused by flooding of residential allotments for the City model (45% existing residential and 30% future residential).

The percentage breakdown of damages from the City model in the 100 year ARI event is shown in Figure 4.17.

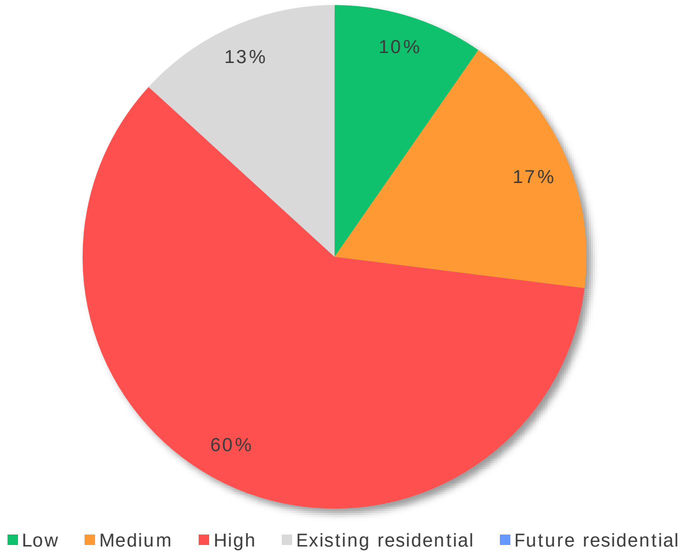



Figure 4.17 Breakdown of damages by damage categories for the City model (100 year ARI)

The rate at which damages for the Airport model increase between the 50 and 500 year ARI is significantly less than that for the City model. This occurs because the extents of inundation in the Airport model do not increase significantly between the different events. Although the depth of inundation increases significantly, the natural topography causes floodwater to be contained to similar extents. The RAM is more sensitive to the extent of inundation, as opposed to depth of inundation.

### 4.6.4 Annual average damages

The annual average damage (AAD) provides an estimate of the mean annual expenditure for resolving flood related damages over a long period of time. It balances small, frequent damages against rare, but significant damages and provides a convenient way to assess the effectiveness of different floodplain management measures by using the reduction in AAD as the benefit of a management option. It is a probability-weighted mean of the actual flood damages and is equivalent to the area beneath the damage-probability curve. The damage-probability curve for each of the models is shown in Figure 4.18.

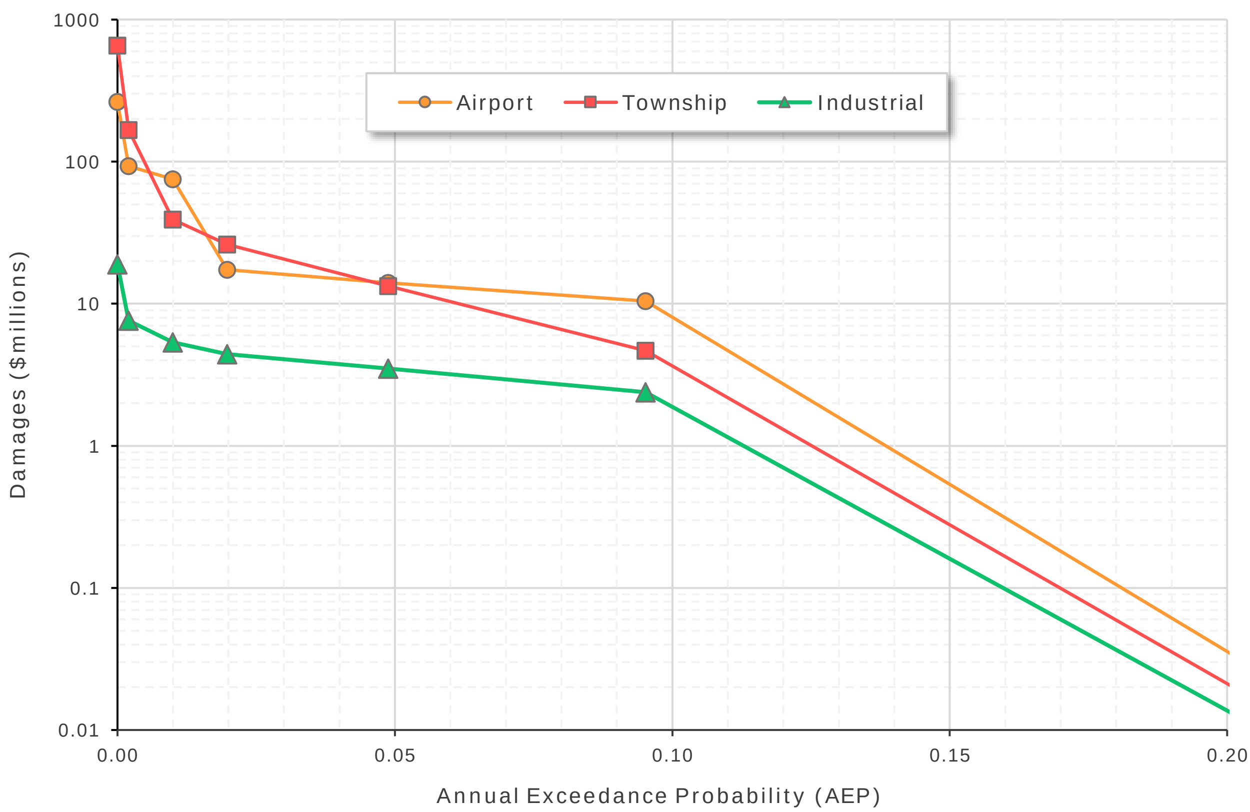



Figure 4.18 Damage probability curve

It was assumed that the stormwater drainage system is capable of containing flows generated by events up to and including a 2 year ARI (39.35% AEP). Consequently, it is assumed that there are no damages resulting from events with an ARI less than or equal to 2 years. The AAD for the various models are summarised in Table 4.6.

Table 4.6 Annual average damages

| Zone | Airport | City | Industrial | Total |
|---|---|---|---|---|
| 1 | $ 0 | $ 199,000 | $ 0 | $ 199,000 |
| 2 | $ 169,000 | $ 192,000 | $ 0 | $ 361,000 |
| 3 | $ 1,068,000 | $ 2,170,000 | $ 0 | $ 3,238,000 |
| 4 | $ 1,370,000 | $ 1,034,000 | $ 0 | $ 2,404,000 |
| 5 | $ 1,461,000 | $ 44,000 | $ 0 | $ 1,505,000 |
| 6 | $ 0 | $ 13,000 | $ 733,000 | $ 746,000 |
| Total | $ 4,068,000 | $ 3,652,000 | $ 733,000 | $ 8,453,000 |

# 5 Flood management strategies

## 5.1 Introduction

The management strategies presented here are targeted towards managing flooding within the key flood prone areas described in the preceding chapter. The strategies listed do not exhaustively address all problems across the study area, rather the strategies are targeted to reduce the largest flooding issues affecting the majority of the community. Both structural (e.g. construction works or drain upgrades) and non-structural strategies (e.g. development controls) are discussed.

A set of flood maps showing post-mitigation inundation and hazard is available in Appendix A. The post-mitigation maps show the effects of implementing structural mitigation options. Figure 5.1 shows the location of the structural mitigation options investigated.

## 5.2 Structural flood mitigation strategies

### 5.2.1 Northern Levee repair and extension

The effectiveness of the current levee around the north-western side of the city is compromised by several breach points where the levee height has been reduced. These low-spots in the levee bank need repair to restore the full function of the existing levee. In addition to repairs to breach points, it is recommended that the protection provided by the existing levee be improved through increases to the length and height of the levee.

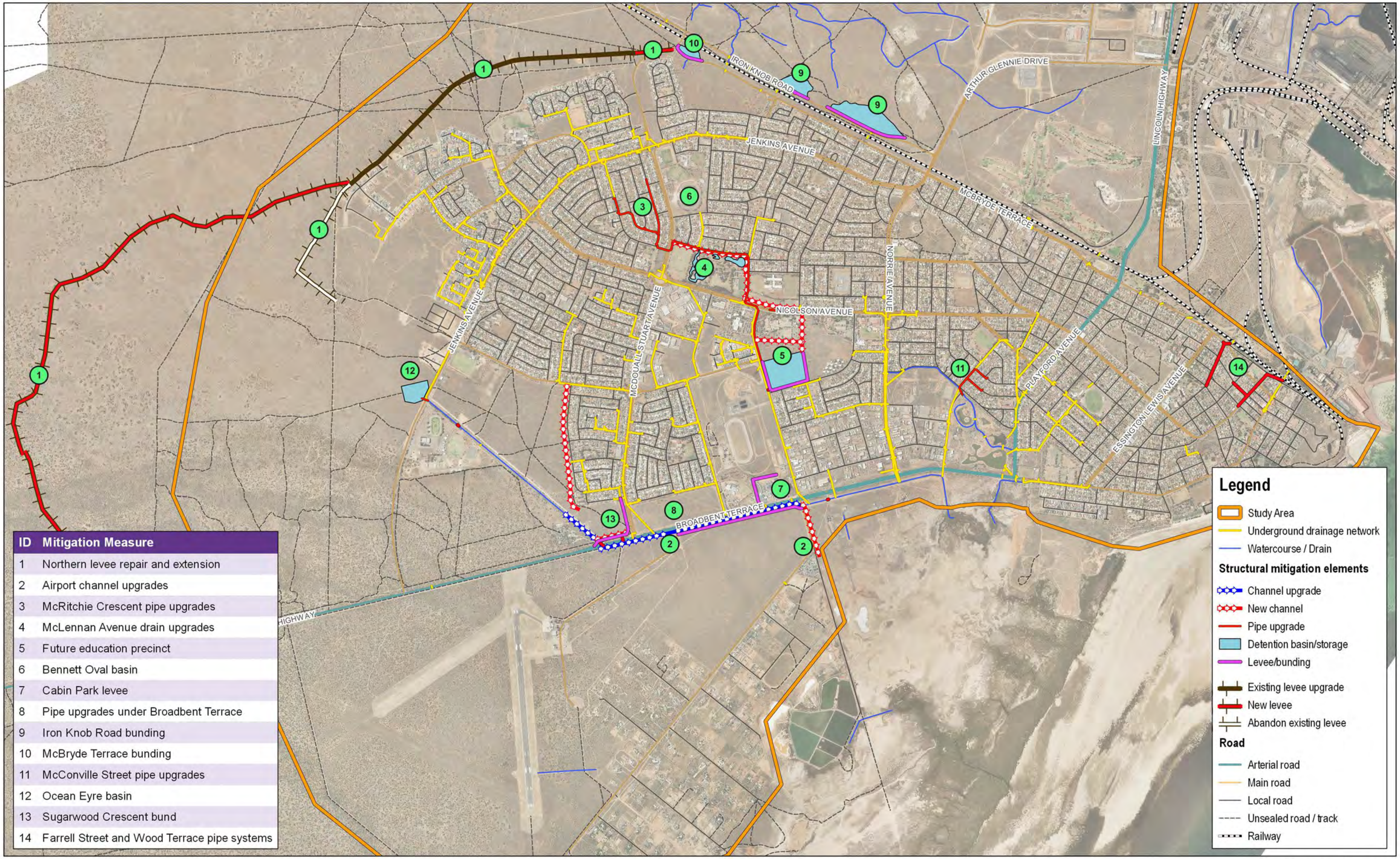
Upgrades to the levee along the north-western edge of the city aim to provide further protection against external flows from the Salt Creek catchment. Extension of the levee aims to redirect the external flows around the City of Whyalla to reduce the amount of flooding:

- in areas that are proposed for future residential development,
- adjacent to the airport channel including along Broadbent Terrace and the Lincoln Highway,
- at the airport and rural residential allotments within Mullaquana.

Figure 5.2 shows the proposed levee upgrades. The proposed solution involves construction of a 6.2 km extension of the levee from the southern end of the existing levee, towards the Lincoln Highway following the natural topography. It also includes a 320 m extension of the levee from the northern end of the existing levee that brings the levee up to the intersection of McDouall Stuart Avenue and McBryde Terrace. The height of the levee ranges between 0.5-2.0 m to hold all external flows from the Salt Creek catchment on the northern side of the levee in a 100 year ARI event. This will include a freeboard allowance, normally in the order of 0.2-0.5 m. Flows larger than the 100 year ARI event will overtop the levee bank.

In addition to the levee extension, upgrades to the existing levee need to be undertaken to prevent flows from overtopping or flowing through breaks within the existing levee.

The effectiveness of the levee upgrades is demonstrated in Figure 5.3. The levee is capable of containing all external flows from the Salt Creek catchment on the northern side of the levee, directing flows around the airport and discharging to the ocean in a 100 year ARI event. This significantly reduces the extents of inundation within the city and airport regions, thus opening up space free of inundation for future development. In particular, it significantly reduces flooding within the proposed extents of the Ocean Eyre development.




| ID | Mitigation Measure |
|---|---|
| 1 | Northern levee repair and extension |
| 2 | Airport channel upgrades |
| 3 | McRitchie Crescent pipe upgrades |
| 4 | McLennan Avenue drain upgrades |
| 5 | Future education precinct |
| 6 | Bennett Oval basin |
| 7 | Cabin Park levee |
| 8 | Pipe upgrades under Broadbent Terrace |
| 9 | Iron Knob Road bunding |
| 10 | McBryde Terrace bunding |
| 11 | McConville Street pipe upgrades |
| 12 | Ocean Eyre basin |
| 13 | Sugarwood Crescent bund |
| 14 | Farrell Street and Wood Terrace pipe systems |

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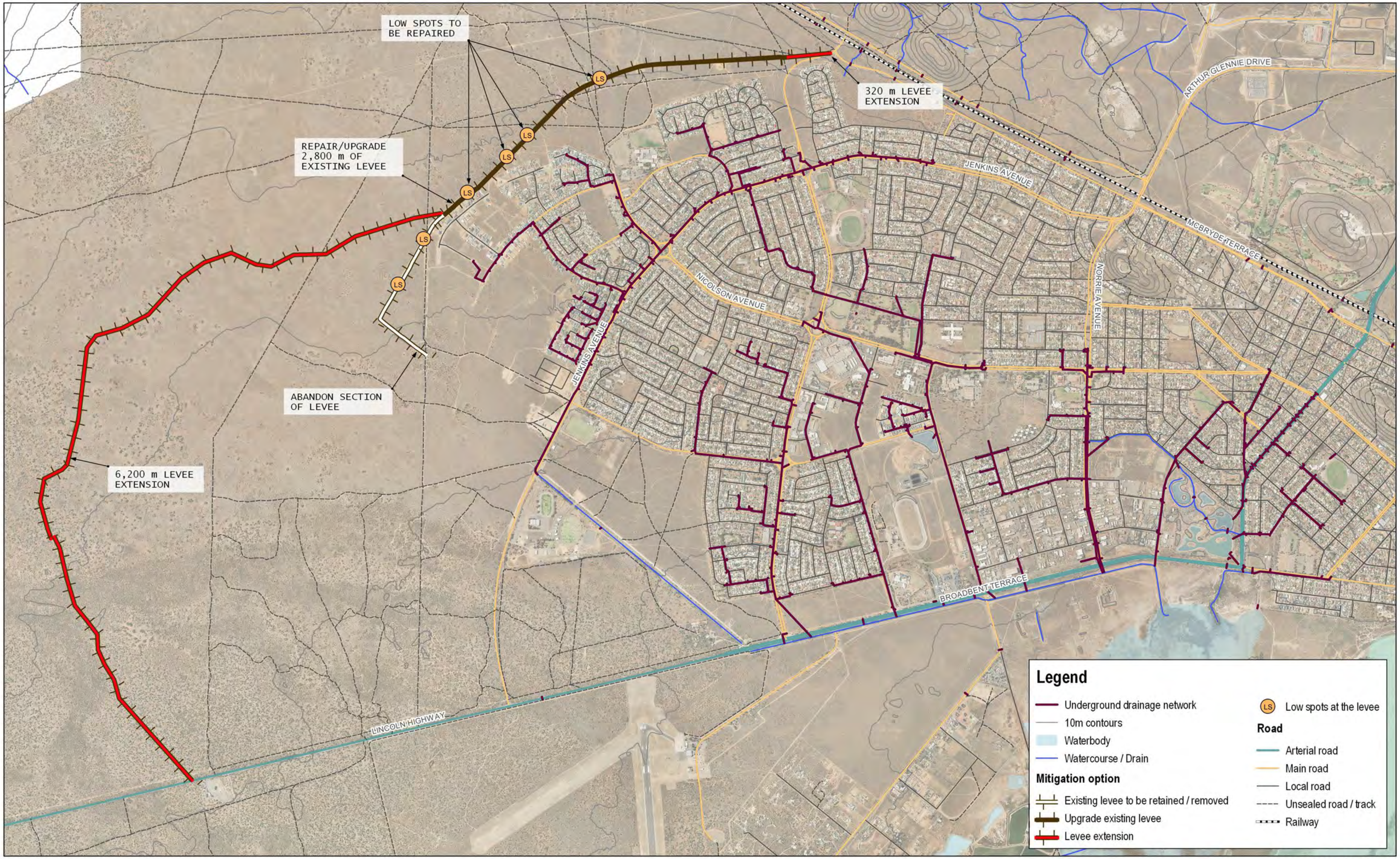
**WHYALLA STORMWATER MANAGEMENT PLAN**
**OVERVIEW OF STRUCTURAL MITIGATION MEASURES**

Figure 5.1

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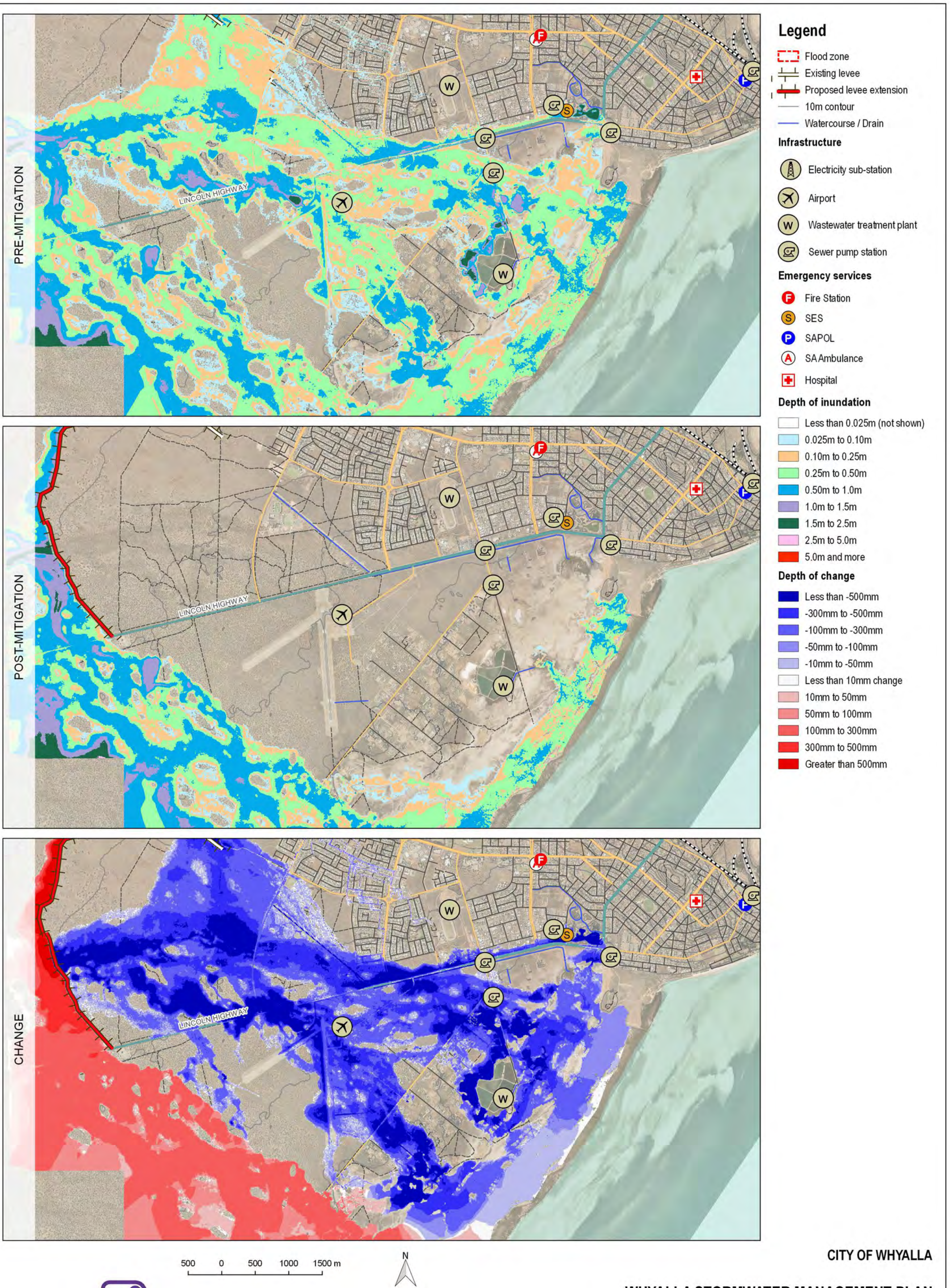
**WHYALLA STORMWATER MANAGEMENT PLAN**
**NORTHERN LEVEE REPAIR AND EXTENSION**

Figure 5.2

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WHYALLA STORMWATER MANAGEMENT PLAN
100 YEAR ARI CHANGE MAP WITHIN AIRPORT AND MULLAQUANA RURAL LIVING AREA

Figure 5.3

The levee extension creates a diversion of floodwaters which will cross the Lincoln Highway to the west of the study area. The highway is already subject to flooding in several locations, with modelling predicting floodwaters cross the road during the 10 year ARI event (refer Map 17). The levee will change the distribution of floodwaters, and some concentration of flow may occur immediately west of the proposed levee. East of this location (closer to the city) the road will largely remain flood free, assuming other proposed flood mitigation measures are put in place. During the detailed design phase consideration could be given to culverts under the road to potentially reduce the frequency of overtopping. The feasibility of culverts under the road will be dependent upon local site levels (the road appears to be 'at grade' rather than a raised formation which will make installation of culverts difficult) and the outcome of discussions with the Department of Planning, Transport and Infrastructure.

It is recommended that the levee upgrades be implemented in a staged manner:

- Extension of existing levee northwards to McDouall Stuart and infill of existing low points (to match existing)
- Concept design and optimisation study to determine the best combination of levee height and alignment for levee extension
- New levee extension – could also be staged in accordance with fill availability.

As with any project involving construction through currently undisturbed areas of native vegetation, further ecological investigations including flora and fauna studies and any other necessary studies to support the relevant statutory approvals process will need to be carried out.

### 5.2.2 Airport channel upgrades

Widening the airport channel will increase its capacity and in turn reduce the amount of dispersed flow across adjacent land by capturing and conveying more of this flow within the channel. When increasing the size of the channel it is important to also increase the capacity of the culverts and bridges at road crossings such that flow is not restricted, causing backwater effects.

The proposed solution also includes an outfall channel at Horseshoe Road, disconnecting the upstream portion of the channel from the downstream portion and directing flows within the upstream portion in a southerly direction towards the outfall at coastal zones. Disconnecting the diverted channel from the downstream portion of the airport channel will reduce the amount of flow within this section of the channel meaning that this portion of the channel requires minimal channel works, including clearing vegetative growth. The feasibility of constructing a new outfall channel will require further consideration and discussion with relevant agencies, land tenure and native title holders.

Details of the airport channel were modelled in HEC-RAS, using mitigated flow rates as a result of the levee upgrades, to determine channel upgrades required to contain the 100 year ARI flow. It was assumed that the culvert crossings would be upgraded to a size that would not affect the hydraulic grade line (HGL) within the channel.

The proposed solution has split the channel into four sections of upgrades (shown on Figure 5.4), as follows:

- channel upgrades for a length of 330 m upstream of Broadbent Terrace
- channel upgrades between Broadbent Terrace and the Whyalla Airport entrance road (600 m)
- channel upgrades between the Whyalla Airport entrance road and Horseshoe Road (1,050 m)
- new diversion channel along the eastern side of Horseshoe Road, to an agreed outfall location

Table 5.1 summarises the estimated channel upgrades needed to convey the 100 year ARI flows. The dimensions are based on a trapezoidal channel.

Table 5.1 Estimated dimensions of channel upgrades within the airport channel

| Section | Base width (m) | Depth (m) | Side slopes (V:H) | Top width (m) |
|---|---|---|---|---|
| 1 | 7.5 | 1.7 | 1:3 | 12.6 |
| 2 | 10.0 | 2.0 | 1:3 | 16.0 |
| 3 | 15.0 | 2.0 | 1:3 | 21.0 |
| 4 | 15.0 | 2.0 | 1:3 | 21.0 |

Based on the predicted flow rates in the 100 year ARI event, it is also necessary to upgrade the size of the three existing culverts to avoid water spilling from the channel. To minimise costs, it is proposed that the existing culverts be expanded with additional cells to reach the necessary capacity. Table 5.2 lists the changes proposed to expand the capacity of the culverts. An important consideration will be maintaining the accessibility of the three roads traversed by the culverts. The three roads are Broadbent Terrace, the airport entrance road, and Horseshoe Road (the main access to Mullaquana). Each road is a major thoroughfare that would need to be maintained during construction.

Table 5.2 Channel culvert dimensions before and after proposed upgrades

| Culvert | Cell width (m) | Cell Height (m) | Current cells | Additional cells | Total cells |
|---|---|---|---|---|---|
| 1 | 2.4 | 1.2 | 1 | 2 | 3 |
| 2 | 2.4 | 1.2 | 2 | 2 | 4 |
| 3 | 3.0 | 1.6 | 2 | 3 | 5 |

It is recommended that consideration of upgrades to the airport channel, including a new outfall drain, include further investigations, such as:

- Identification of the appropriate location for the new Horseshoe Road outfall.
- Assessing the impact of concentrated stormwater discharge on the samphire flat area at the southern end of Horseshoe Road, near the SA Water treatment plan discharge point.
- Identification of management measures required to mitigate any impacts at the new outfall location (such as weed management and water channelling).

### 5.2.3 McRitchie Crescent pipe upgrades

Located within Valley 1, the McRitchie Crescent drain system serves the upper sub-catchments of Valley 1, namely Head Street, Patten Street and Brook Terrace. The pipe system starts at the intersection with Jenkins Avenue and proceeds along McRitchie Crescent, Myall Street, Head Street and Brook Street before passing beneath Civic Park and connecting to the Racecourse Road drain. The estimated standard of the McRitchie Crescent drain is between a 5 and 10 year ARI between Jenkins Avenue and Booth Street. South of Booth Street the standard falls to a 1 year ARI or less.

Currently, existing properties along Brook Street experience flooding in modelled events with a 10 year ARI and above. It is understood that more frequent flooding also occurs in this area. To address this flooding, upgrades to the pipe system were trialled in order to obtain a 10 year ARI standard from Booth Street through to the proposed McLennan Avenue open channel system. New underground drainage was also investigated for Brook Street which currently has no underground drainage system. New inlet pits were positioned at the intersection of Brook Street and Head Street to ensure that there was no limitation on the rate stormwater was able to enter the new pipe system. The full layout of upgrades is shown in Figure 5.5.

Modelling showed that the upgrades in Figure 5.5 were effective at increasing protection of properties along Brook Street and Head Street to a 20 year ARI standard compared with the less than 10 year ARI standard that exists currently. This measure therefore directly contributes to meeting Objective 1 of the SMP (outlined in Section 3.2). Whilst protection to a 1% AEP standard is not considered feasible in this location, the strategy meets Goal 1(a) of the SMP: "*Where practical and economically viable, protect existing development from inundation in a 1% AEP event. A lower standard of protection may be adopted where physical and economic constraints limit the ability to achieve 1% AEP standard*".

Figure 5.6 shows the impact of the proposed upgrades on the 20 year ARI flood extents.

### 5.2.4 McLennan Avenue drain upgrades

Flooding of McLennan Avenue occurs during modelled events with a 10 year ARI and above and is well-known to Council as a location of frequent flooding. In the 10 year ARI event McLennan Avenue is inundated to depths between 150 to 400 mm. Small basins within Civic Park allow for some floodwater to leave the road corridor, but these basins do not contain the 10 year ARI event and eventually overtop. Floodwater that spills from the basins flows towards the southeast corner of Civic Park and eventually contributes to flooding along Nicolson Avenue. McLennan Avenue is served by underground drains that connect to the Racecourse Road drainage system. The Racecourse Road drain system is estimated to have less than a 1 year ARI standard despite the existing trunk drain being a DN1650 pipe. The low capacity of the downstream drainage system exacerbates the flooding problems along McLennan Avenue.

To achieve a 5 year ARI standard with underground pipes alone would require installation of approximately 2.4 km of DN2700 pipe parallel to the existing DN1650 pipe. Such an upgrade is unlikely to be of value due to the extreme cost of construction. An alternative to full system upgrades is the use of detention storage to reduce discharge to a rate that the existing system has capacity to convey. To that end Civic Park adjacent McLennan Avenue was initially identified as a potential location for detention storage. To not limit use of the park during every rainfall event a two-tier system of storage was investigated. A two-tier system attempts to contain stormwater from events up to a 20 year ARI to a defined portion of the park whilst larger floods would be allowed to inundate the other areas of the park if needed.

Various configurations of basins were trialled to determine the storage volume required to achieve a two-tier system. If existing drains are used to discharge water from the basin, the depth of the basin becomes constrained by the pipe inverts resulting in a maximum possible basin depth of 1.2 m. With this constraint on basin depth modelling found that a detention basin of approximately 57,000 $m^3$ volume was necessary to contain the 20 year ARI flood. This is equivalent to a footprint of approximately 57,000 $m^2$—approximately one third of the Civic Park site. After discussion with Council it was determined that a basin of this size would too severely restrict future use of the Civic Park site. Consequently, alternative mitigation measures were investigated to address flooding along McLennan Avenue.

An alternative mitigation measure preferred by Council was the construction of a new underground drainage along McLennan Avenue (sized to convey the 5 year ARI event flows) coupled with a grassed open channel along the northern and eastern boundary of the site to convey any remaining surface runoff during rarer flood events (up to the 100 year ARI event).

Due to the close proximity to McRitchie Crescent, the proposed McRitchie Crescent pipe was aligned to connect into the McLennan Avenue pipe. Runoff from events less than 5 year ARI will be conveyed by the underground pipe system, whilst larger flows from McRitchie Crescent will surcharge from the McLennan Avenue underground system and be conveyed by the grassed open channel.

To minimise the length of the proposed McLennan Avenue pipe system, it is proposed that this system discharge into the future education precinct detention basin on Russell Avenue (discussed in Section

5.2.5 below). The alignment chosen for the McLennan Avenue pipe system and grassed channel is shown in Figure 5.5. The alignment of the upgraded pipe system includes upgrades to existing systems in Searle Street.

To safeguard public safety, the open channel dimensions have been selected to be within safe limits, with 1V:5H batter slopes. The channel can be landscaped to suit the masterplan for the site—either grassed or planted with other suitable plants. The grassed open channel has a top width of approximately 20 m—roughly equivalent to a standard road corridor. The open channel was sized to convey surface floodwater in events up to 100 year ARI. The alignment of the grassed channel is shown in Figure 5.5. A new and large culvert system is required to convey the channel flows under Nicolson Avenue and into the grassed channels proposed for the Russell Street basin (discussed in Section 5.2.5 below).

It is recommended that the proposed McLennan Avenue pipe and channel system is considered further during the planned landscape master planning of Civic Park proposed within Council's strategic plan. The masterplan and proposed works will also provide the opportunity to integrate drainage and water quality elements into the park-scape as water features.

It is also recommended that additional modelling and a detailed optioneering process be undertaken to further assess the most effective solution from a flood mitigation and cost perspective.

### 5.2.5 Future education precinct

Works within the currently vacant land on the northern side of Russell Street, including open channel drains and a detention basin, are aimed at capturing, containing and conveying incoming flows from Nicolson Avenue and McLennan Avenue into a basin in the south-west corner of the site (near the intersection of Russell Street and Racecourse Road). This basin and channel system will control the extents of inundation within the site and alleviate flooding of downstream locations. By providing a formalised drainage path, flow will be concentrated to a narrow corridor, as opposed to the wide (up to 500 m) nature of existing sheet flow. By directing floodwater into the basin floodwater is prevented from continuing in a south-easterly direction towards Norrie Avenue.

It is understood that part of the adjacent site is earmarked for a new Whyalla 'Super School' which will ultimately replace the existing Edward John Eyre High School, Stuart High School and Whyalla High School. Provision for flood proofing the new school site is therefore considered important in the context of the planning process. Council have identified the opportunity to investigate the incorporation of flood mitigation and water sensitive urban design elements into a potential future 'education precinct'.

The proposed basin and channel arrangement is shown in Figure 5.5. It is important to note that Figure 5.5 illustrates the basin footprint for a 100 year ARI design standard. Should a lower level of protection be adopted, a smaller basin could be implemented. Conversely, landscaping and the incorporation of water quality treatment and reuse elements may increase the footprint of the basin. The balance between flood protection and land use within this site will require further investigation during the planning of works associated with the new school and any other associated development.

The proposed open channel drainage system would consist of a cut-off drain 380 m long running west-east and collecting flows moving in a southerly direction through the TAFE site, and a main drain (550 m) running north-south collecting flows from Nicolson Avenue. Table 5.3 summarises the estimated sizes of the drains required to convey the 100 year ARI flows to the basin. The dimensions are based on a trapezoidal channel shape.

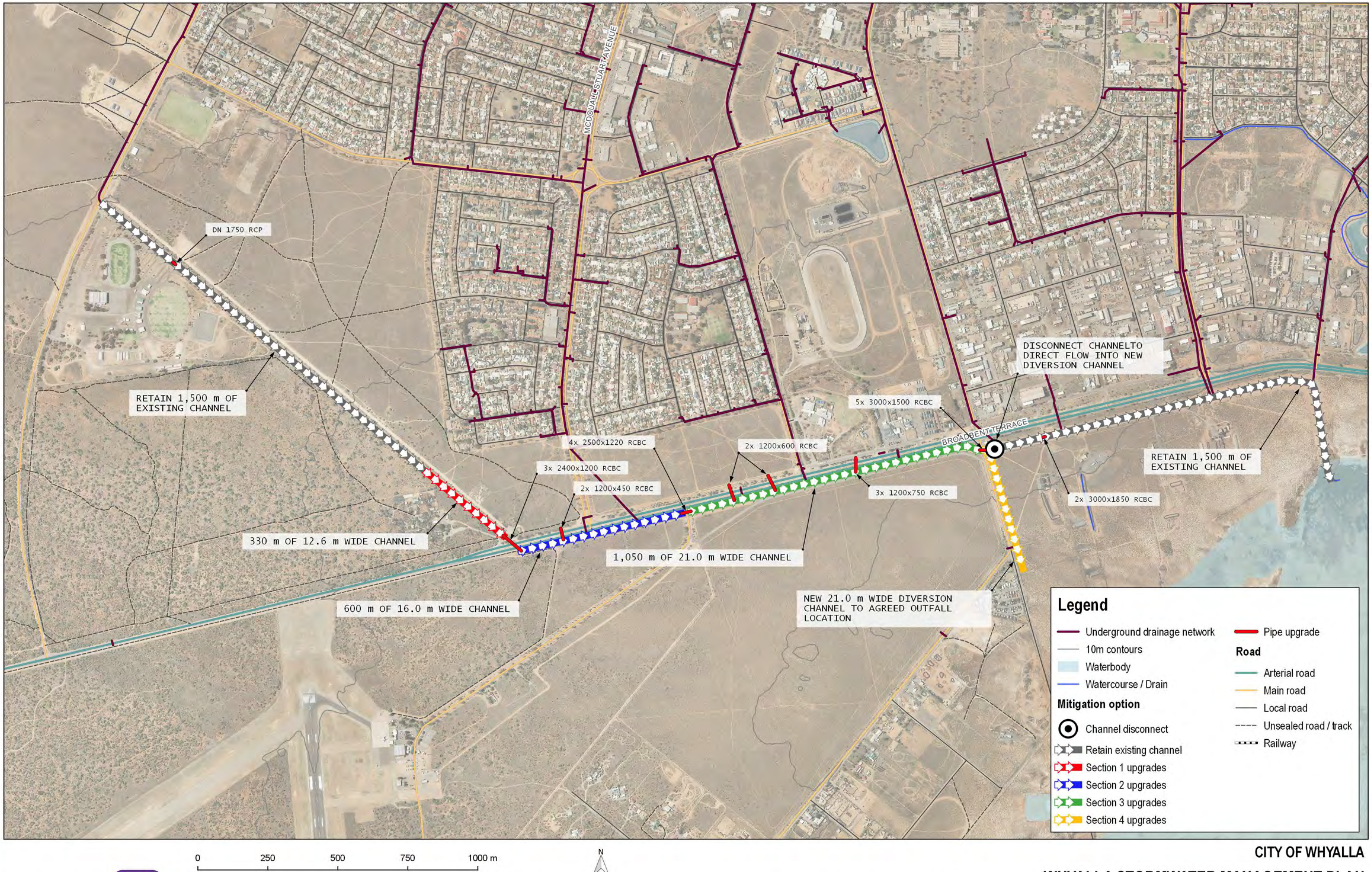
To further alleviate flooding along Racecourse Road and Nicolson Avenue, it is recommended that pipes within Nicolson Avenue east of Racecourse Road are regraded towards the proposed channels within the Russell Street reserve and increased in size. This would reduce the amount of floodwater being directed into the Racecourse Road drain and direct more floodwater into the basin. It will also reduce overflows through the University of South Australia campus.

Table 5.3 Estimated dimensions of open drains

| Drain | Base width (m) | Depth (m) | Side slopes (V:H) | Top width (m) |
|---|---|---|---|---|
| Cut-off | 4.0 | 1.3 | 1:3 | 11.8 |
| Main | 7.0 | 1.5 | 1:3 | 16.0 |

The basin will provide detention storage to attenuate flows and alleviate flooding at several downstream locations. The proposed solution requires bunding up to a level of 10.3 mAHD around the outside of the basin to increase storage capacity of the basin. The basin invert level has been modelled at 7.55 mAHD based on interpolation of pipe inverts in Racecourse Road. The basin outlet pipe (DN1200) is directed into the Racecourse Road drainage system as it has significantly greater capacity than the nearby Smoker Street drainage system.

It is estimated that a 210,000 $m^3$ basin is necessary to detain floodwaters in a 100 year ARI event. By detaining the floodwater in a 100 year ARI event, the basin significantly reduces the amount of flooding to downstream locations—in particular, surrounding Smoker Street and Flavel Street. The estimated footprint of this basin is 87,500 $m^2$ when full, however, the inundated footprint will be smaller during less severe floods. The size of the basin is also subject to the needs of the super school development and will depend on the adopted level of flood protection.

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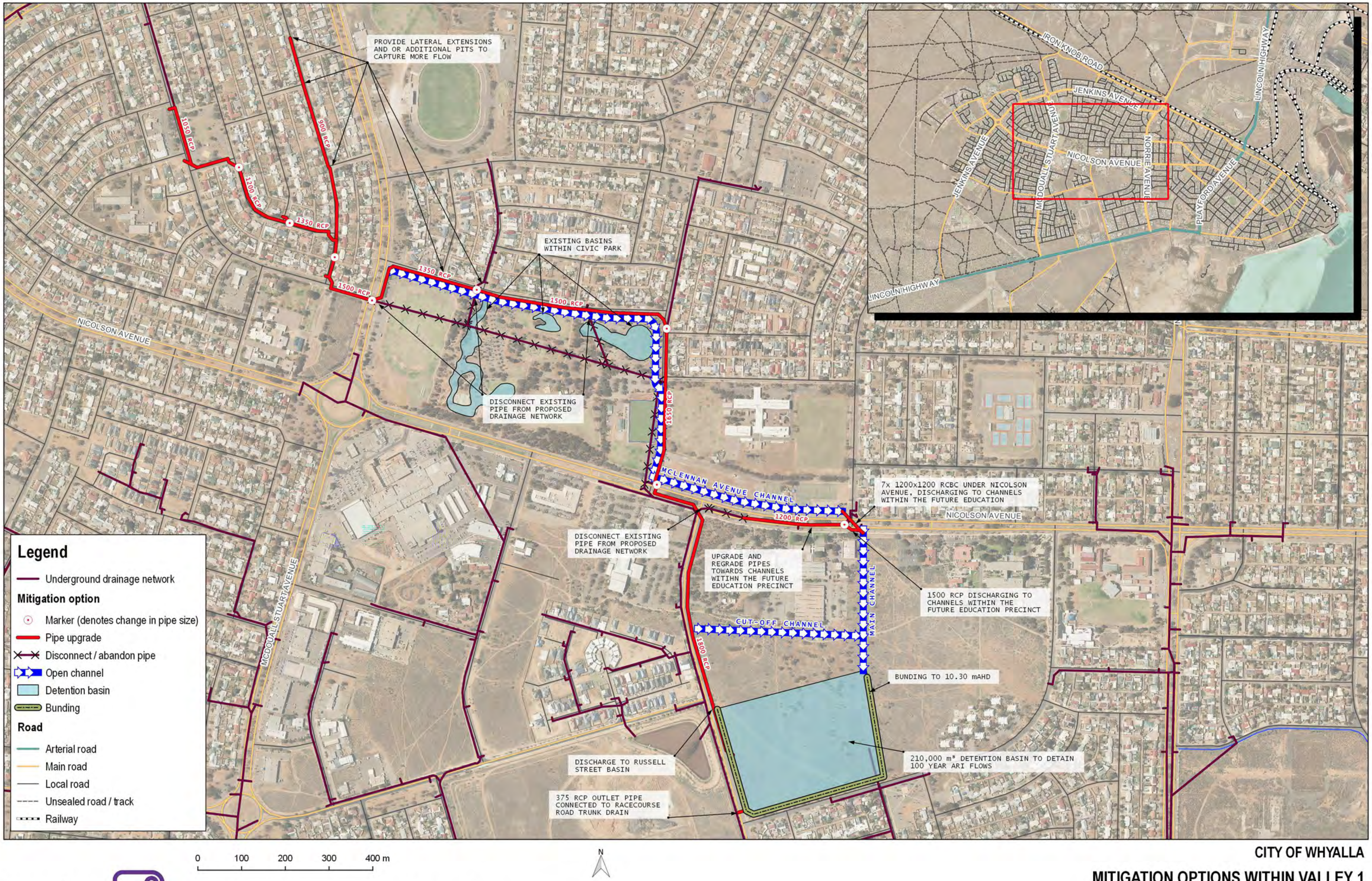
**WHYALLA STORMWATER MANAGEMENT PLAN**
**AIRPORT CHANNEL UPGRADES AND PIPE UPGRADES UNDER BROADBENT TERRACE**

Figure 5.4

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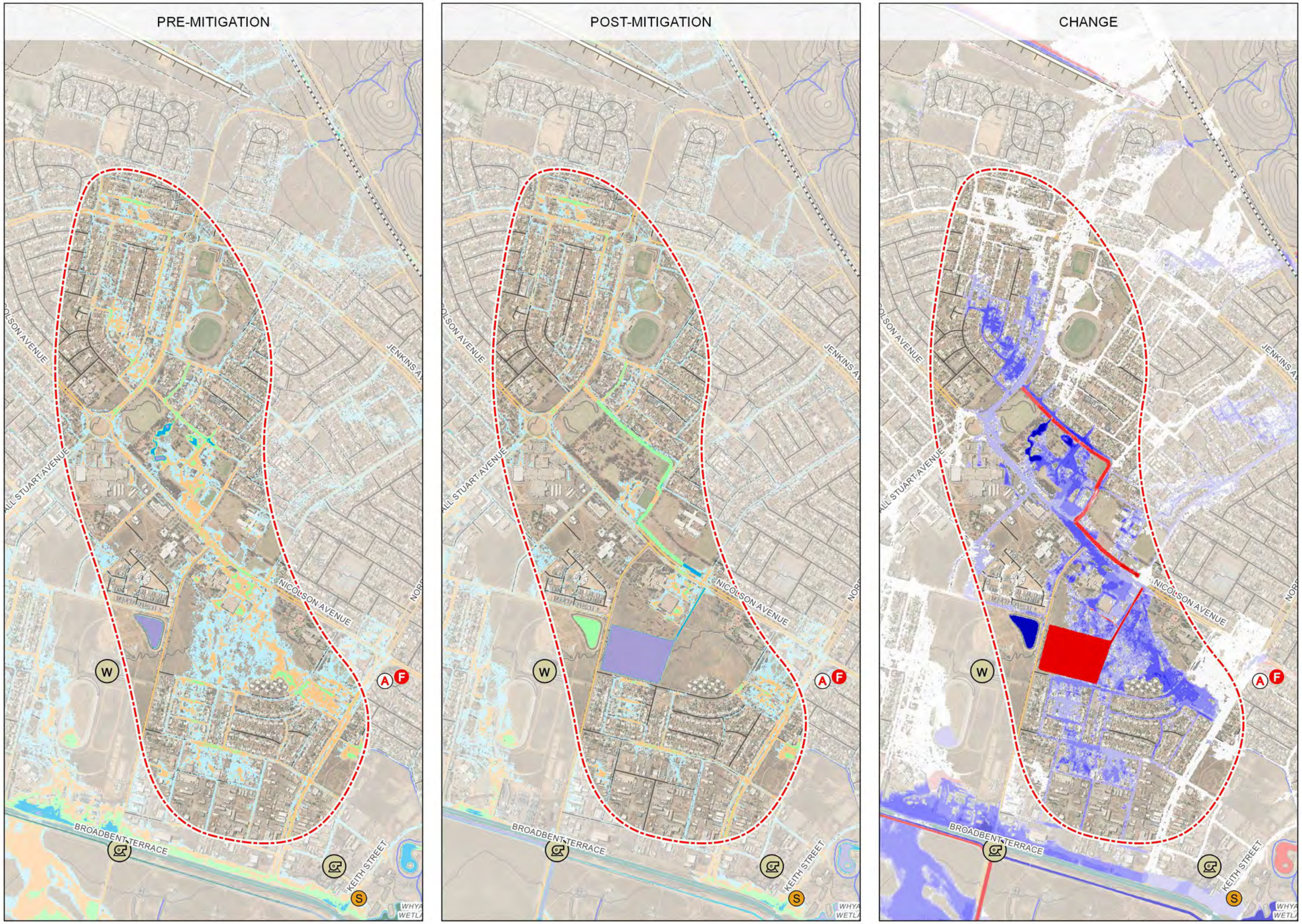
MITIGATION OPTIONS WITHIN VALLEY 1

Figure 5.5




**Legend**

- Flood zone
- Existing levee
- 10m contours
- Watercourse / Drain

**Infrastructure**

- Electricity sub-station
- Airport
- Wastewater treatment plant
- Sewer pump station

**Emergency services**

- Fire Station
- SES
- SAPOL
- SA Ambulance
- Hospital

**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

**Depth of change**

- Less than -500mm
- -300mm to -500mm
- -100mm to -300mm
- -50mm to -100mm
- -10mm to -50mm
- Less than 10mm change
- 10mm to 50mm
- 50mm to 100mm
- 100mm to 300mm
- 300mm to 500mm
- Greater than 500mm

500 0 500 1000 1500 m

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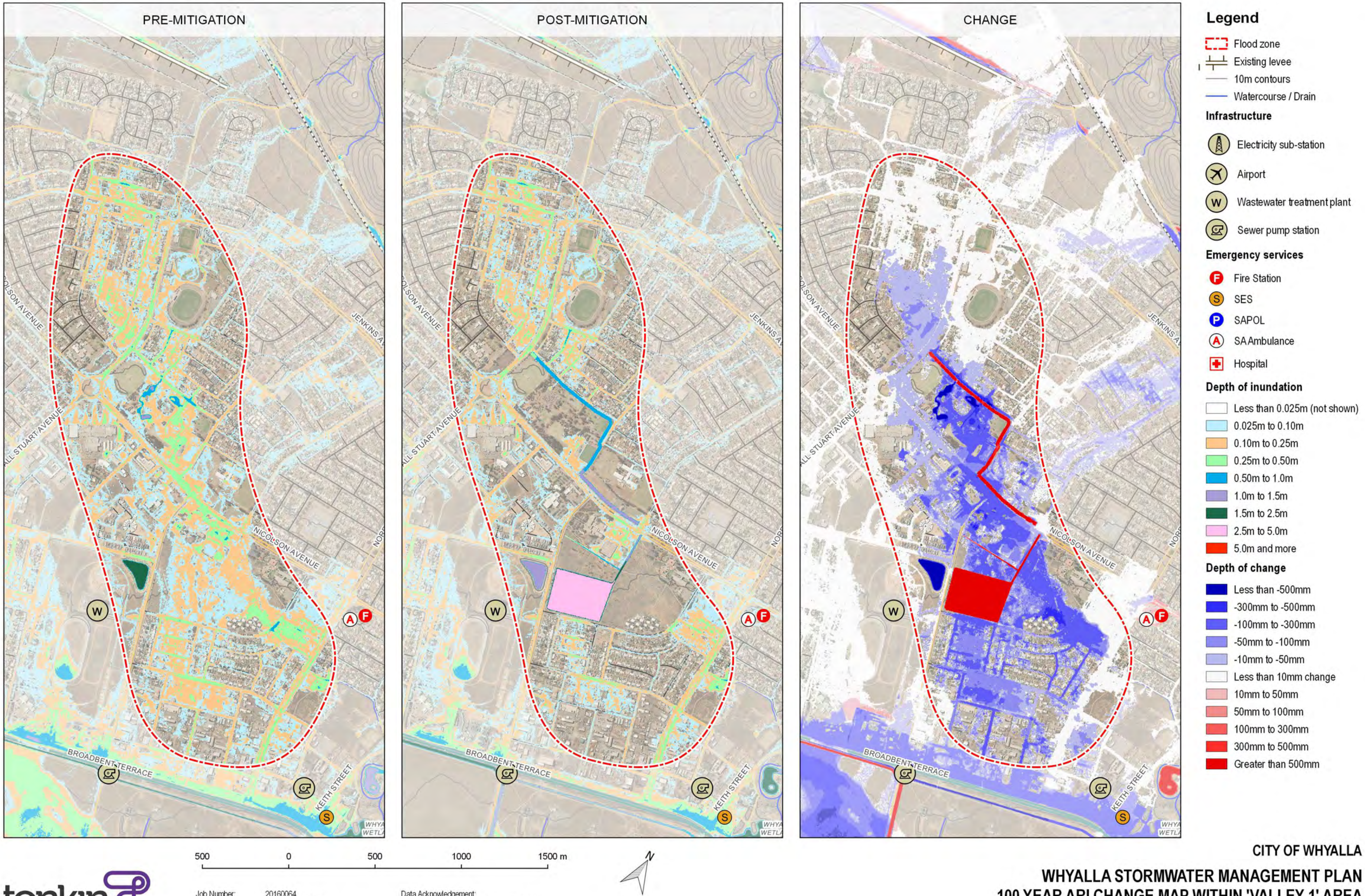
**WHYALLA STORMWATER MANAGEMENT PLAN**
**20 YEAR ARI CHANGE MAP WITHIN 'VALLEY 1' AREA**

Figure 5.6

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**CITY OF WHYALLA**

**WHYALLA STORMWATER MANAGEMENT PLAN**
**100 YEAR ARI CHANGE MAP WITHIN 'VALLEY 1' AREA**

**Figure 5.7**

## 5.2.6 Bennett Oval basin

A small basin in the southwest corner of the Bennett Oval reserve was trialled as a measure to reduce flooding within Brook Street. Due to elevation and space constraints it was found that a basin in this location was of limited effectiveness. Additionally, the Bennett Oval Master Plan (refer Figure 5.8) has proposed additional sport facilities across the site including netball courts at the location of the trialled basin. Given the above factors, the basin concept was not pursued further. Instead a new pipe system in Brook Street was investigated as part of the McRitchie Crescent drain upgrade (refer Section 5.2.3 above).


Figure 5.8 Bennett Oval Master Plan (supplied by Whyalla City Council)

## 5.2.7 Cabin Park levee

The Cabin and Tourist Park on Broadbent Terrace was identified as a site of interest for flood protection due to the likelihood of visitors to Whyalla being exposed to flooding. Caravan and cabin / mobile home parks are considered particularly vulnerable to flood events because they generally involve temporary occupants that are not familiar with the local risk posed by flooding.

The Cabin Park becomes flooded due to two different flood behaviours. The first is sheet flow from the racecourse land that originates from Valley 2 and Heurich Terrace. This floodwater enters the northern side of the cabin park at a depth between 100 and 200 mm deep. The second mechanism is via floodwater that flows along Broadbent Terrace originating further from the west. This water becomes trapped behind Broadbent Terrace and Racecourse Road; eventually pooling to a depth sufficient to flood the cabin park and surrounding properties. The second mechanism causes greater depths of flooding, up to 500 mm deep in the 100 year ARI event.

To protect against the shallow flooding emanating from the racecourse land, a levee bank around the northern and western perimeter of the cabin park was investigated. It was found that a levee approximately 0.6 m high would be sufficient to mitigate the flooding of the cabin park due to floodwater from the racecourse land in all events up to the 100 year ARI event. The location of this levee bank is shown in Figure 5.9.

To address the second mechanism of flooding, other strategies were investigated and are discussed separately: Ocean Eyre basin (Section 5.2.12), northern levee upgrade (Section 5.2.1), airport channel upgrades (Section 5.2.2) and drain upgrades along Broadbent Terrace (Section 5.2.8).

### 5.2.8 Pipe upgrades under Broadbent Terrace

To manage the residual flooding along Broadbent Terrace, additional culverts under Broadbent Terrace conveying floodwater into the Airport Channel were investigated. Table 5.4 shows the culverts implemented in the flood model. It should be noted that the ultimate dimensions and effectiveness of these culverts is dependent on the management strategies that are implemented upstream, namely the northern levee upgrades, Ocean Eyre basin and Sugarwood basin. As such these culverts will require further investigation to find the optimal management strategy in combination with other schemes.

Table 5.4 Culvert upgrades beneath Broadbent Terrace

| Culvert | Width (m) | Height (m) | Number of barrels |
|---|---|---|---|
| 1 | 1.2 | 0.45 | 2 |
| 2 | 1.2 | 0.60 | 2 |
| 3 | 1.2 | 0.60 | 2 |
| 4 | 1.2 | 0.75 | 3 |


0 25 50 75 100 m

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WHYALLA STORMWATER MANAGEMENT PLAN
CABIN PARK LEVEE

Figure 5.9

### 5.2.9 Iron Knob Road bunding

To address flooding caused by the Mt Laura rural catchments, bunding along Iron Knob Road is proposed to hold runoff on the northern side of the road. The bunding will act to detain flows and reduce the amount of flow that discharges under or over the road and flows towards the city. The discharge will be limited by the capacity of the outlet pipes. The proposed solution comprises two suitable locations for bunding as follows (refer Figure 5.10):

- Eastern bunding capturing flows from the 165 hectare rural catchment.
- Western bunding capturing flows from the 30 hectare rural catchment.

Provided that the eastern detention system has a DN375 outlet pipe, it is estimated that bunding up to an elevation of 37 mAHD (maximum height of 3.0 m) extending approximately 700 m along the northern side of the Iron Knob Road is sufficient for holding up to 85,000 $m^3$.

The proposed solution results in substantially reduced flooding along Hincks Avenue. With the proposed bunding, Hincks Avenue would have sufficient capacity to contain events up to a 100 year ARI. This is a considerable improvement to the existing 10 year ARI standard of the road. By alleviating flooding along Hincks Avenue, nuisance flooding through residential allotments on the northern side of Jenkins Avenue in events up to a 50 year ARI is eliminated. Flooding is significantly reduced through residential properties on the southern side of Jenkins Avenue as well.

Provided that the western detention system retains the existing DN375 pipe passing under Iron Knob Road, it is estimated that bunding up to a level of 40 mAHD (maximum height of 3.0 m) extending 330 m along the northern side of Iron Knob Road is sufficient to store 47,000 $m^3$.

The western bund results in a significant reduction in sheet flow moving in a south-westerly direction through the Charles Avenue reserve and towards properties on the southern side. It is capable of eliminating nuisance flooding through the properties on the southern side of the Charles Avenue reserve in a 10 year ARI event. It reduces the extents of flooding through these properties in the larger events.

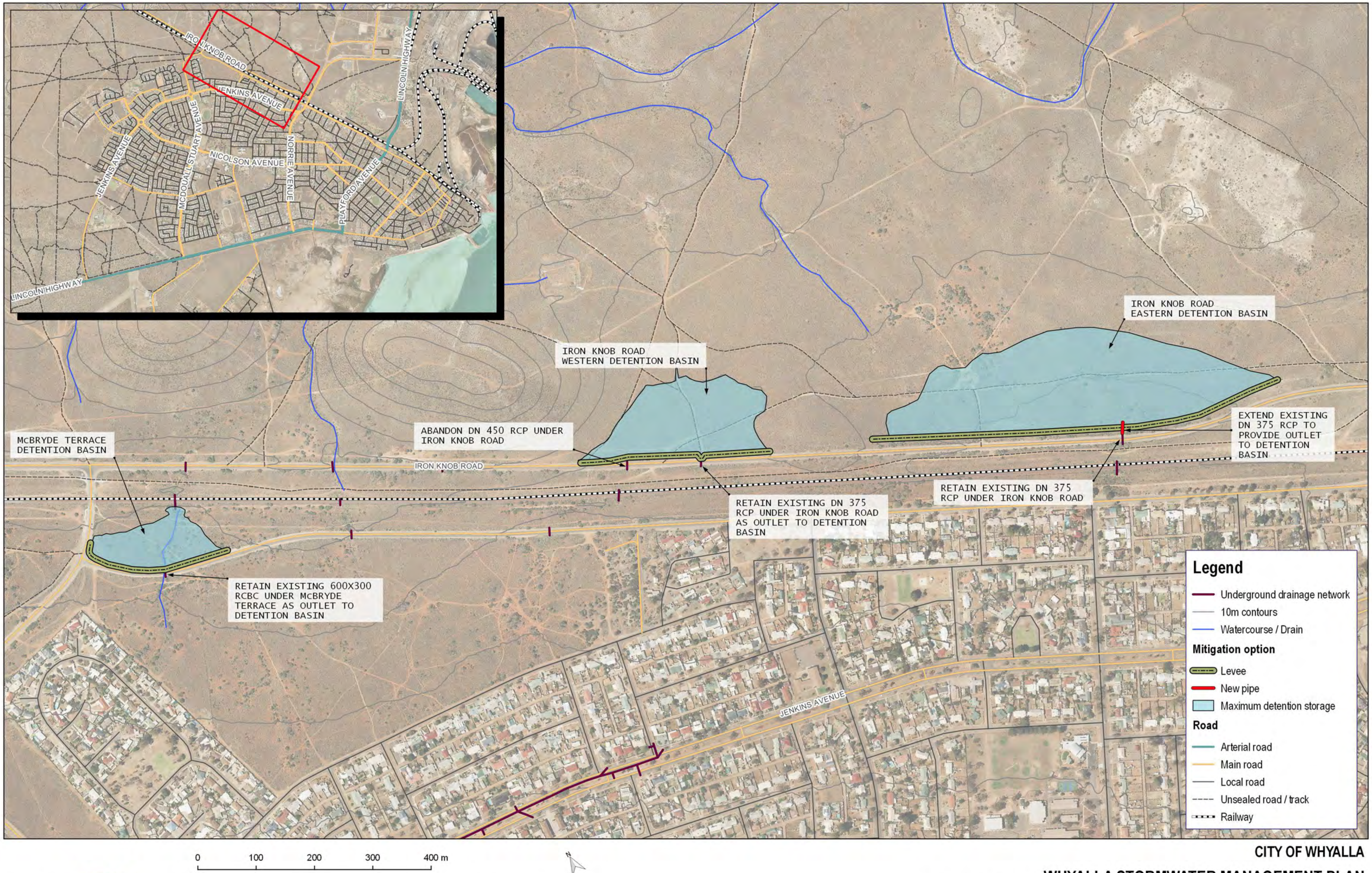
The final design of both solutions will need to consider an overflow weir to control discharge from the detention system in events larger than a 100 year ARI event.

### 5.2.10 McBryde Terrace bunding

To address flooding caused by the Mt Laura rural catchments, it is proposed to construct a bund along the northern side of McBryde Terrace to hold flows on the northern side of the road. This aims to limit the flow heading in a south-westerly direction towards residential properties along Jacquier Crescent. The existing culvert (600 mm wide by 300 mm high) passing under McBryde Terrace will be retained to act as an outlet to the detention system.

Figure 5.10 shows the extents of the proposed bunding and its maximum storage level. It is estimated that bunding up to a level of 39 mAHD will allow water to pond up to 3 m deep on the northern side of McBryde Terrace. It is estimated that 265 m of bunding is required to allow water to build up to this level, providing 22,500 $m^3$ of detention storage. The final design of the solution will need to consider an overflow weir to control discharge from the detention system in events larger than a 100 year ARI event.

The proposed detention system is capable of detaining flows in events up to and including a 100 year ARI event. It prevents flows from overtopping McBryde Terrace and sheeting towards the residential properties in a 100 year ARI event, thereby constraining flows to the natural flow path. A portion of this flow still enters properties along Jacquier Crescent in events larger than a 20 year ARI. There is potential to eliminate this problem by constructing a channel along the eastern side of the residential development to direct flows in a southerly direction towards Charles Avenue.

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**WHYALLA STORMWATER MANAGEMENT PLAN**
**IRON KNOB ROAD AND McBRYDE TERRACE DETENTION BASINS**

Figure 5.10

### 5.2.11 McConville Street pipe upgrades

Upgrades to the underground drainage network directly upstream of the Whyalla Wetlands aims to reduce the amount of flooding through properties downstream of the sag locations on Darragh Street and Ferry Street. The current underground drainage network does not have sufficient capacity to evacuate flows from the sag locations in frequent (less than 10 year ARI) events, causing flows to overtop the road and spill through adjacent properties.

It would be ideal to have a drainage easement that runs along the low point between sag locations, towards the Whyalla Wetlands, however, this would require acquisition of land that is currently occupied by residential dwellings.

It is difficult to achieve a 100 year ARI standard within this area, due to the flat grade of the pipes running in a westerly direction, away from the sag locations. Therefore, the solution involves upgrading pipes to prevent flooding through the downstream properties in a 20 year ARI event. Additional pits surrounding the sag locations are also required to capture the majority of flows heading towards the sag in a 20 year ARI event. In practice, system upgrades may consist of lateral extensions collecting flow at upstream locations, as opposed to increasing the number of pits at the sag location.

The trunk drain along McConville Street also requires upgrade to allow for additional flow coming from the sag locations. This will increase the amount of flow entering the Whyalla Wetlands. While this has the potential to have environmental impacts on the wetlands, the increase in discharge does not result in a noticeable change in water levels within the wetlands.

The proposed pipe upgrades are shown on Figure 5.11.

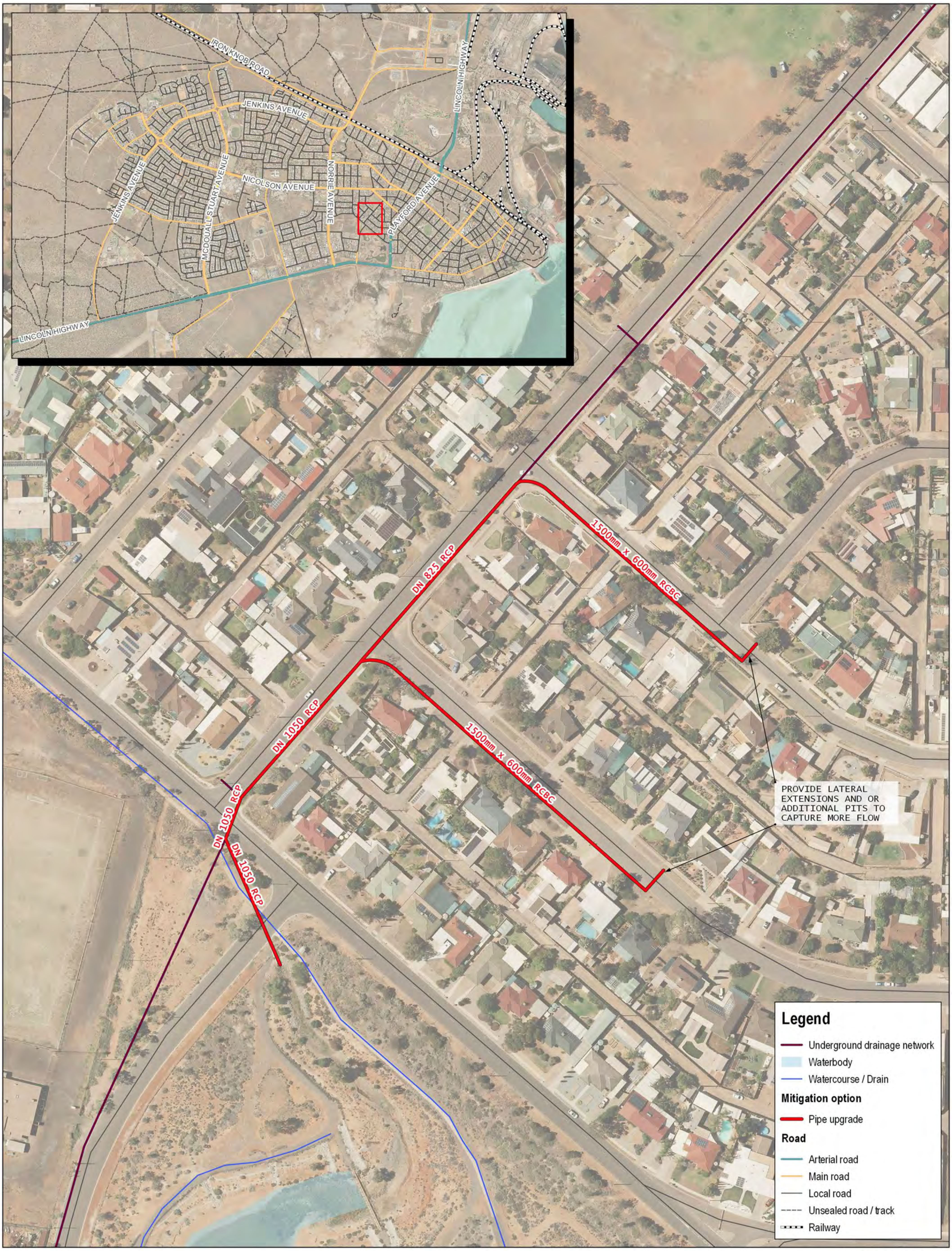
The proposed system upgrades result in substantially reduced flooding through properties downstream of the sag locations (refer Figure 5.12). Some minor (less than 100 mm deep) flooding still remains in the frequent events, but the extent of flooding is significantly improved.

### 5.2.12 Ocean Eyre basin

A basin on the northern side of Jenkins Avenue, within the area proposed for the future stages of the Ocean Eyre development, is aimed at limiting discharge to acceptable flow rates, to prevent additional flooding downstream as the development expands. Discharge from the developed site (171 ha) will be limited to flow rates from the site as if it were undeveloped.

It is estimated that a 93,000 $m^3$ basin is sufficient to detain flows in a 100 year ARI event, thereby limiting discharge from the basin to undeveloped flow rates. The extents of the basin are shown on Figure 5.13. In practice, this strategy may comprise a number of smaller detention basins throughout the development, that in combination limit discharge from the developed site to undeveloped flow rates. This approach also allows for development works to be staged but will increase Council maintenance as multiple basins will need to be maintained rather than a single basin.

By detaining flows from the Ocean Eyre site, the amount of stormwater spilling over Jenkins Avenue and through Jubilee Park is significantly reduced (refer Figure 5.14). Inundation of the open land adjacent to the airport channel is also significantly reduced. However, there still remains some sheet flow from residential development north of the Ocean Eyre site. These flows would need to be managed by provision of surface flow paths either along road ways or through reserves within any future development of the area.

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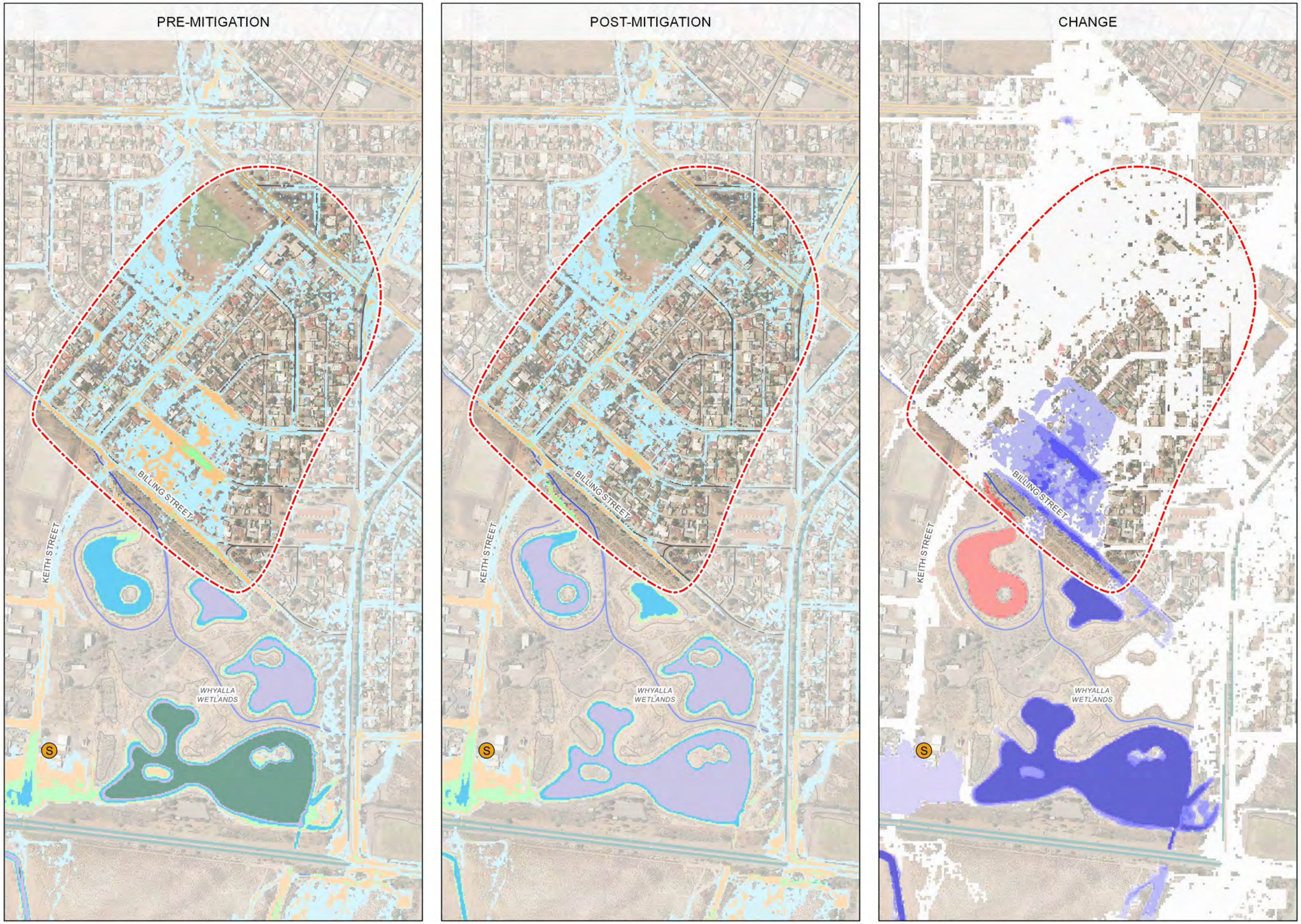
| Job Number: | 20160064 |
| Filename: | 20160064GQ008A |
| Revision: | Rev B |
| Date: | 2019-02-06 |
| Drawn: | DB |

Data Acknowledgement:
Aerial photography supplied by Council, 2013
Base data from DataSA

CITY OF WHYALLA

**WHYALLA STORMWATER MANAGEMENT PLAN**
**McCONVILLE STREET PIPE UPGRADES**

Figure 5.11




**Legend**

- Flood zone
- 10m contours
- Watercourse / Drain

**Infrastructure**

- Electricity sub-station
- Airport
- Wastewater treatment plant
- Sewer pump station

**Emergency services**

- Fire Station
- SES
- SAPOL
- SA Ambulance
- Hospital

**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

**Depth of change**

100 0 100 200 300 m

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Job Number: 20160064
Filename: 20160064GQ042A
Revision: Rev B
Date: 2019-02-06
Drawn: DB

Data Acknowledgement:
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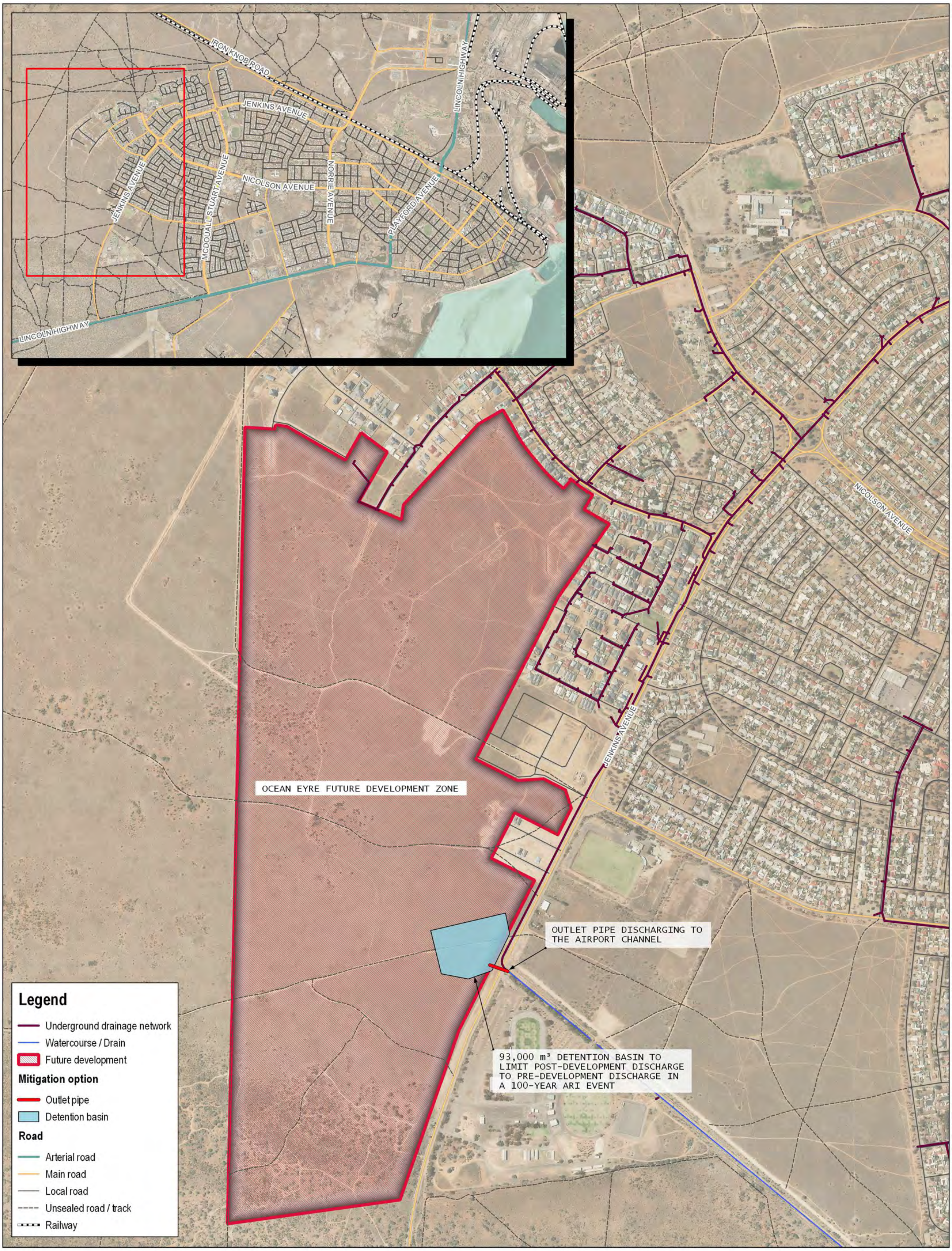
**CITY OF WHYALLA**

**WHYALLA STORMWATER MANAGEMENT PLAN**
**20 YEAR ARI CHANGE MAP WITHIN McCONVILLE STREET AREA**

**Figure 5.12**

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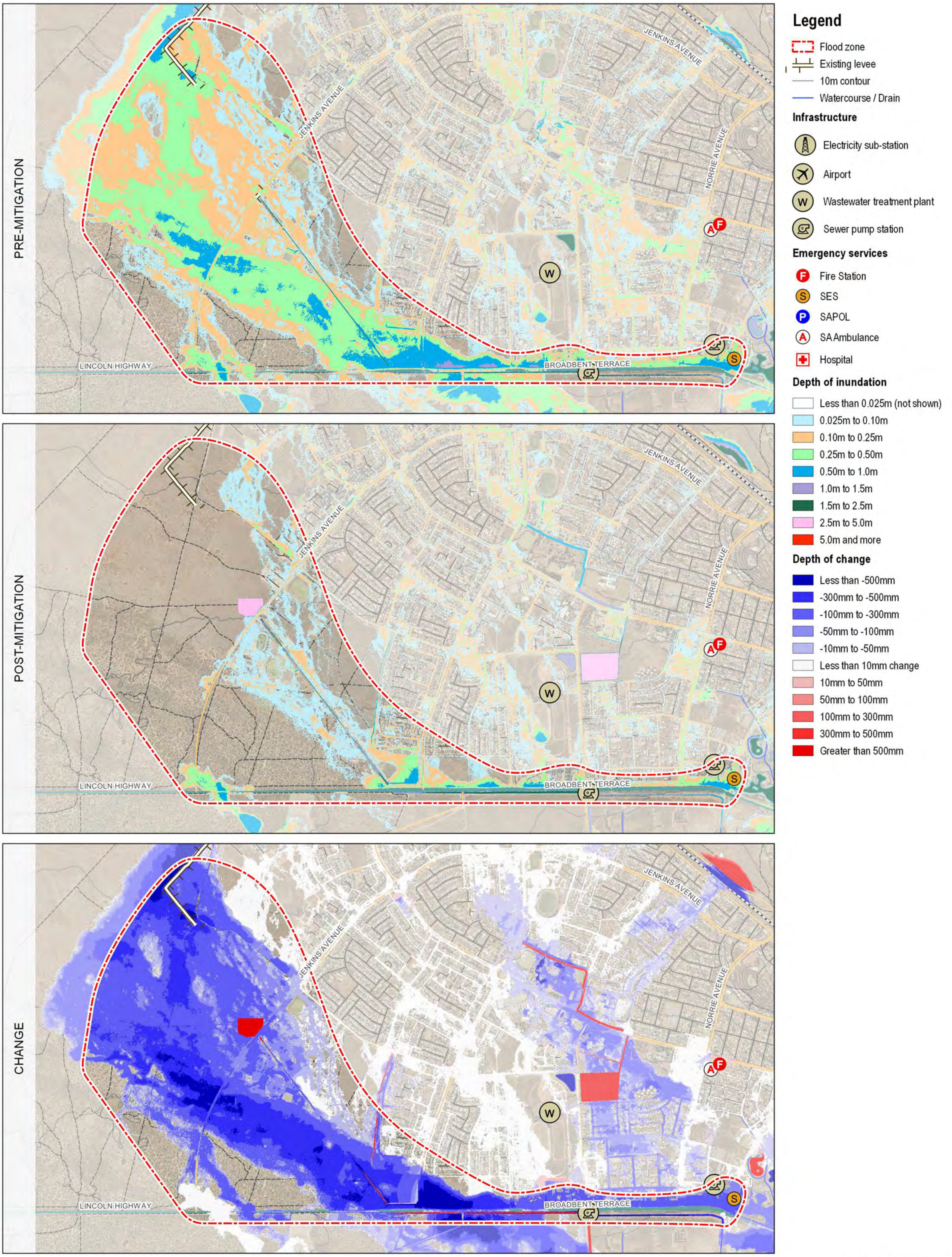
| Filename: | 20160064GQ031A |
| Revision: | Rev B |
| Date: | 2019-02-06 |
| Drawn: | DB |

Data Acknowledgement:
Aerial photography supplied by Council, 2013
Base data from DataSA

CITY OF WHYALLA

**WHYALLA STORMWATER MANAGEMENT PLAN**
**OCEAN EYRE BASIN**

Figure 5.13




250 0 250 500 750 m

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| Revision: | Rev A |
| Date: | 2019-02-06 |
| Drawn: | DB |

Data Acknowledgement:
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Base data from DataSA

CITY OF WHYALLA

**WHYALLA STORMWATER MANAGEMENT PLAN**
**100 YEAR ARI CHANGE MAP WITHIN OCEAN EYRE DEVELOPMENT AND BROADBENT TERRACE**

Figure 5.14

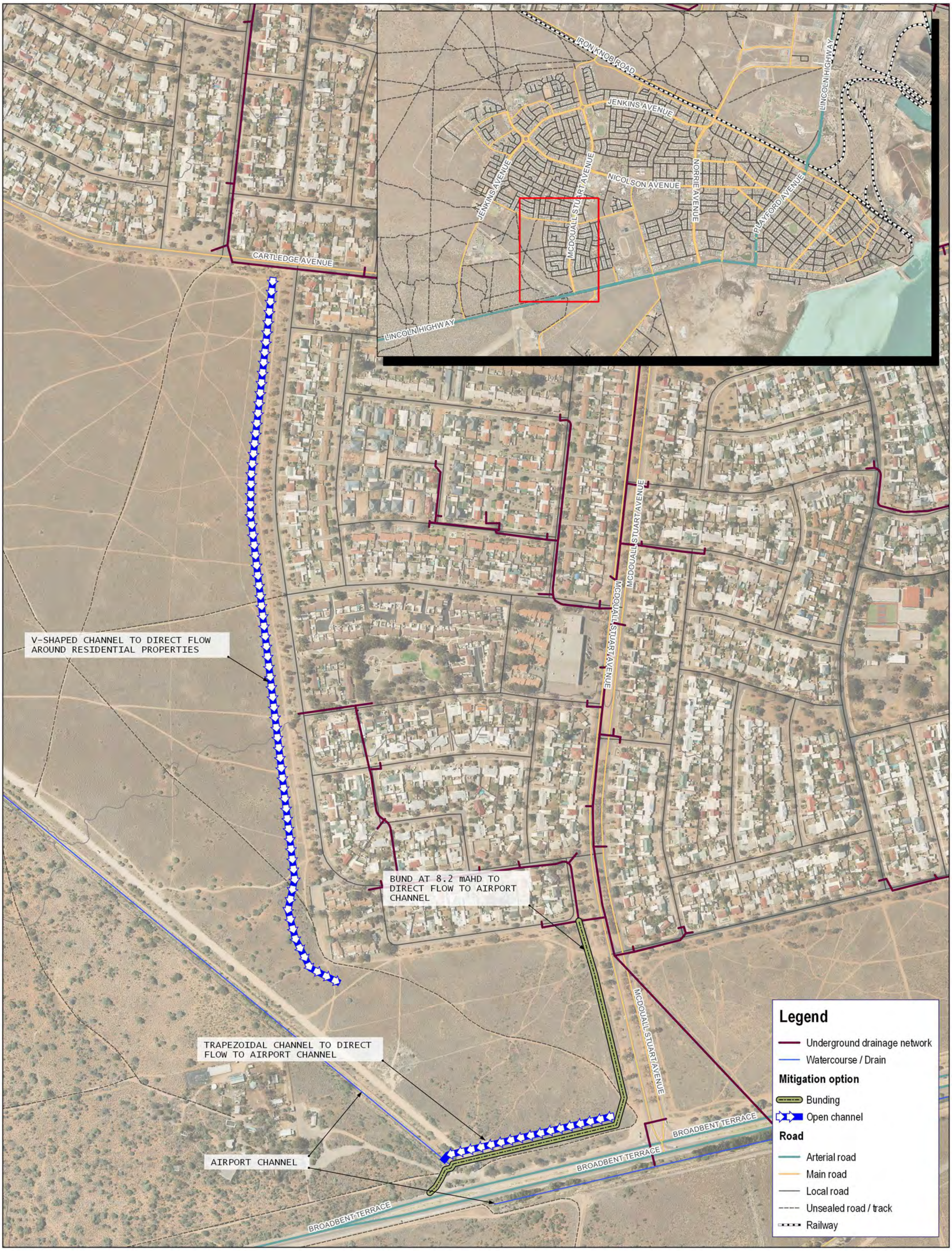
### 5.2.13 Sugarwood Crescent bund

To address flooding along Broadbent Terrace it is proposed to detain floodwater in the open land northwest of the intersection of McDouall Stuart Avenue and Broadbent Terrace. This location has previously been identified by other studies as a potential location to situate a flood detention basin. To minimise the volume of earthworks required, it is proposed to balance cut and fill, by placing a bund around the site at a height of 8.2 mAHD between Sugarwood Crescent and the Airport channel. An 8.0 m wide by 0.5 m deep trapezoidal channel is proposed to drain the bunded area into the Airport channel. Figure 5.15 shows the proposed layout on the site.

Further optimisation of this solution will be required prior to implementation.

### 5.2.14 Farrell Street and Wood Terrace pipe systems

To help control flooding in the Farrell Street area, two new underground pipe systems are proposed. One system is proposed for Farrell Street starting at Cudmore Terrace and ending at McBryde Terrace. The second system is proposed for Wood Terrace starting at Cudmore Terrace and ending by connecting into the existing system at McBryde Terrace. Both systems would act to reduce surface flows along streets and laneways lessening nuisance flooding in the area and potentially reducing flood hazard during larger flood events. Figure 5.16 shows the layout of the new pipe systems.




0 25 50 75 100 m

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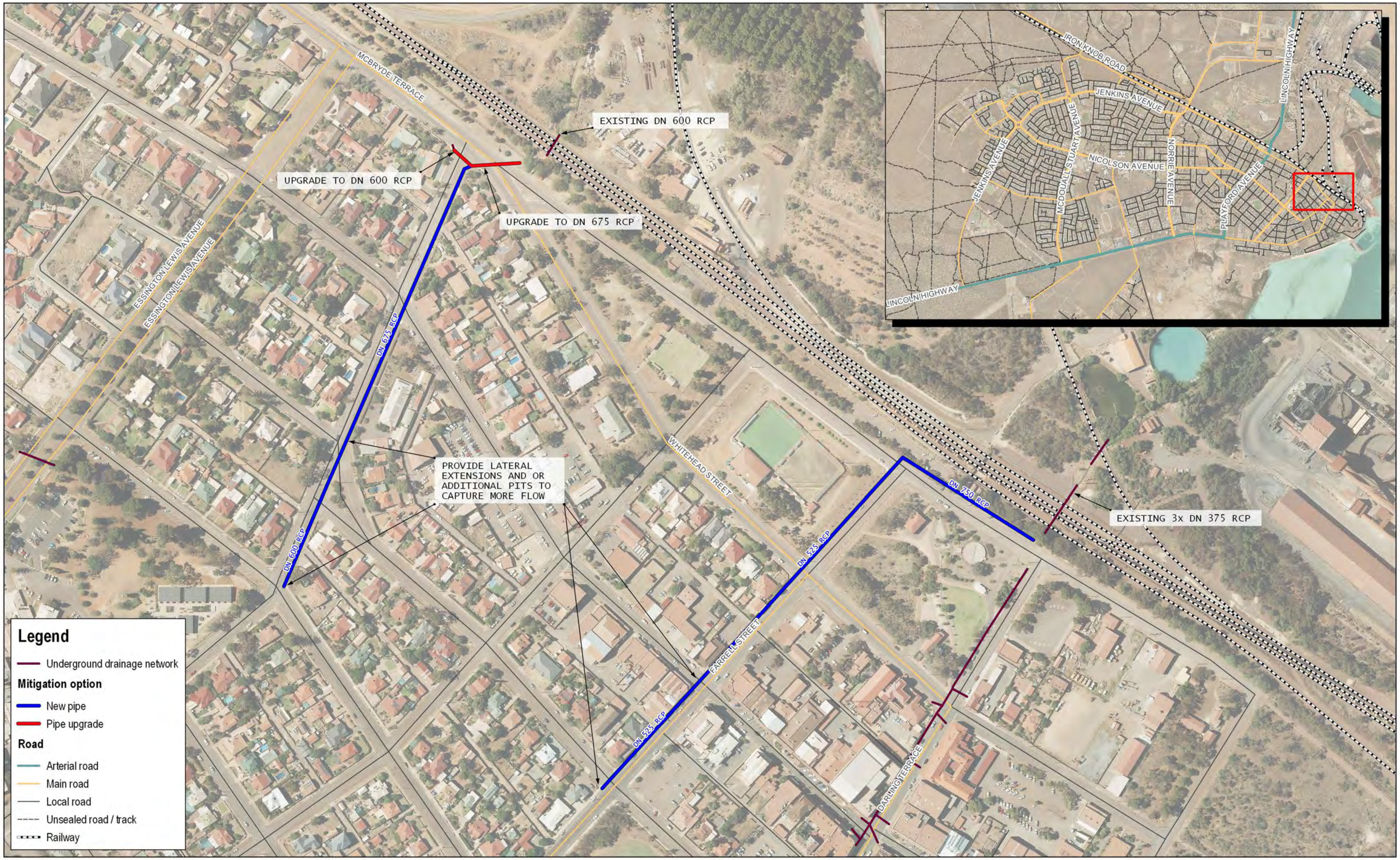
| Drawn: | DB |

Data Acknowledgement:
Aerial photography supplied by Council, 2013
Base data from DataSA

CITY OF WHYALLA

**WHYALLA STORMWATER MANAGEMENT PLAN**
**SUGARWOOD CRESCENT BUND**

Figure 5.15

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| Date: | 2019-02-06 |
| Drawn: | DB |

Data Acknowledgement:
Aerial photography supplied by Council, 2013
Base data from DataSA

CITY OF WHYALLA

**WHYALLA STORMWATER MANAGEMENT PLAN**
**FARRELL STREET AND WOOD TERRACE PIPE SYSTEMS**

Figure 5.16

## 5.3 Non-structural flood mitigation strategies

### 5.3.1 Planning controls

A number of planning controls could be implemented through amendment of Council's Development Plan to better manage flood risk within areas of new development or infill development. Controls include:

- Where new development occurs in areas where the capacity of the downstream stormwater infrastructure is limited, on-site detention should be mandated for discharge from all new developments over a certain size. The requirements should be to limit post-development peak discharge rates to pre-development discharge rates.
- Where it is not practicable to limit discharge to pre-development levels. (e.g. if the site of development is currently largely pervious), the policy should specify an acceptable level of runoff. The measures should consider the 20% AEP and 1% AEP floods. Example policy wording could include:

  *All new buildings and building extensions of 40 square metres or more in floor area in flood prone areas should incorporate sufficient on-site stormwater detention/retention to limit the rate of stormwater runoff from the subject land so that pre-development flows are not exceeded:*

  *(a) within residential zones*

  *(i) 5 year average return interval flood event (runoff coefficient 0.25)*

  *(ii) 100 year average return interval flood event (runoff coefficient 0.45)*

  *(b) within non-residential urban zones*

  *(i) 5 year average return interval flood event (runoff coefficient 0.65)*

  *(ii) 100 year average return interval flood event (runoff coefficient 0.85).*

- Minimum drainage standards for various development types should be specified within the Development Plan or Council Guidelines.
- The Development Plan should provide consistent guidance on maximum site coverage and levels of fill above the existing natural surface.
- The Development Plans should be updated to mandate that development within areas of high and medium hazard risk areas demonstrate safe access routes to higher ground for major flood events (note this is already covered in part within the existing Development Plan under *Principles of Development Control – Flooding*)
- The plan should be reviewed with the aim of providing greater policy flexibility within zones and policy areas that allows for integration of community facilities (such local parks, playgrounds and outdoor recreation spaces) with stormwater management flow-paths, basins, wetlands and recycling areas/works, subject to safety, orientation and structural requirements being achieved.
- Flood overlays within the existing Development Plan (Overlay Maps – Development Constraints) should be updated to reflect the most current information relating to flood prone land.
- Areas where the impacts or risks of flooding cannot be satisfactorily managed should be designated as drainage reserves where development is prohibited.
- Council should undertake spot checks to ensure that development complies with the development approval requirements.

### 5.3.2 Education and awareness

Detailed flood plain mapping of the catchment is available. To meet SMP objectives, this information should be made widely available to the community so that they understand where flooding is likely to occur. Awareness of flood risk can allow them to better manage the risk and reduce flood damages. This awareness could be in the form of mail-outs, making the maps publicly available (e.g. accessible via the internet) and having information available at public places such as libraries and Council offices.

Businesses and residents can be encouraged to develop flood action plans to reduce damages in the event of a flood and change the way in which valuable items are stored.

### 5.3.3 Flood warning and flood forecasting

Whilst the response time for the local drainage catchments is relatively short, if the community is given some warning of the potential for a flood the magnitude of the social and economic damages can be reduced significantly. People and emergency services would have more time to sand bag flood prone areas and valuable portable property could be moved away from areas that may have otherwise suffered flood damages. The potential reduction in flood damages when more than 12 hours of warning is provided, as opposed to less than two hours, can range from 20% up to 50% depending on the relative experience of the community in dealing with flooding (DNRE, 2000). Similar to education and awareness, these potential reductions are significant compared to the structural measures.

Given the relatively short response time of the industrial and city catchments (typically less than one hour) the only opportunity to provide a significant warning time would be to issue flood warnings based on predicted significant rainfall. However, if the reliability of this information becomes mistrusted by the community because the warnings are issued frequently without actual flood events occurring this strategy can become counterproductive.

The Salt Creek catchment has a much longer response time than the industrial or city catchments which may make it ideal for effective flood warnings to be issued.

## 5.4 Reduction in damages

Damages for the mitigated scenario, in which all of the structural flood mitigation strategies are implemented, were estimated using the approach detailed in Section 4.6. The damage estimates were used to determine the reduction in damages as a result of implementing these mitigation strategies. The reduction in damages correlates to the benefit related to the proposed mitigation strategies.

The total reduction in damages for the City and Airport catchments can be seen in Figure 5.17 for all events up to the 500 year ARI event. As there were no structural mitigation strategies proposed within the Industrial catchment, the damages remain constant and are not shown in the figure.

The reduction in damages within the City catchment increases as the rarity of the event increases. This is largely due to the effects of the northern levee repair and extension. Although only designed to provide a 100 year ARI level of protection, the levee is capable of providing protection in a 500 year ARI event; albeit with reduced freeboard. The levee essentially eliminates all flooding that was previously caused by flows coming from the Salt Creek catchment.

The areas most affected by flooding from the Salt Creek catchment were those zoned for future residential development. In eliminating flows from the Salt Creek catchment there is a significant reduction in flooding of these areas. The allotments that receive the least reduction in damages are those of high potential damage category (e.g. high density commercial and industrial allotments) as a lot of these areas are located within Zones 1 and 2 – away from the flooding caused by flows from the Salt Creek catchment.

The northern levee is not capable of providing protection in the PMF event. The levee is therefore overtopped in such an event, resulting in flood damages similar to those for the pre-mitigation (long-term) scenario. As a result, the reduction in damages in the PMF event is much less than that for both the 100 and 500 year ARI events.

The northern levee upgrades redirect floodwater from the Salt Creek catchment around the Airport and Mullaquana rural living area in all events up to the 500 year ARI event. This results in virtually no flooding to allotments within the Airport catchment. This is represented in Figure 5.17, as the damages within the Airport catchment are reduced to zero for the mitigated scenario.

Similar to the City catchment, some damages within the Airport catchment remain in the PMF event, as the northern levee cannot withstand flow rates from the Salt Creek catchment in such an event.

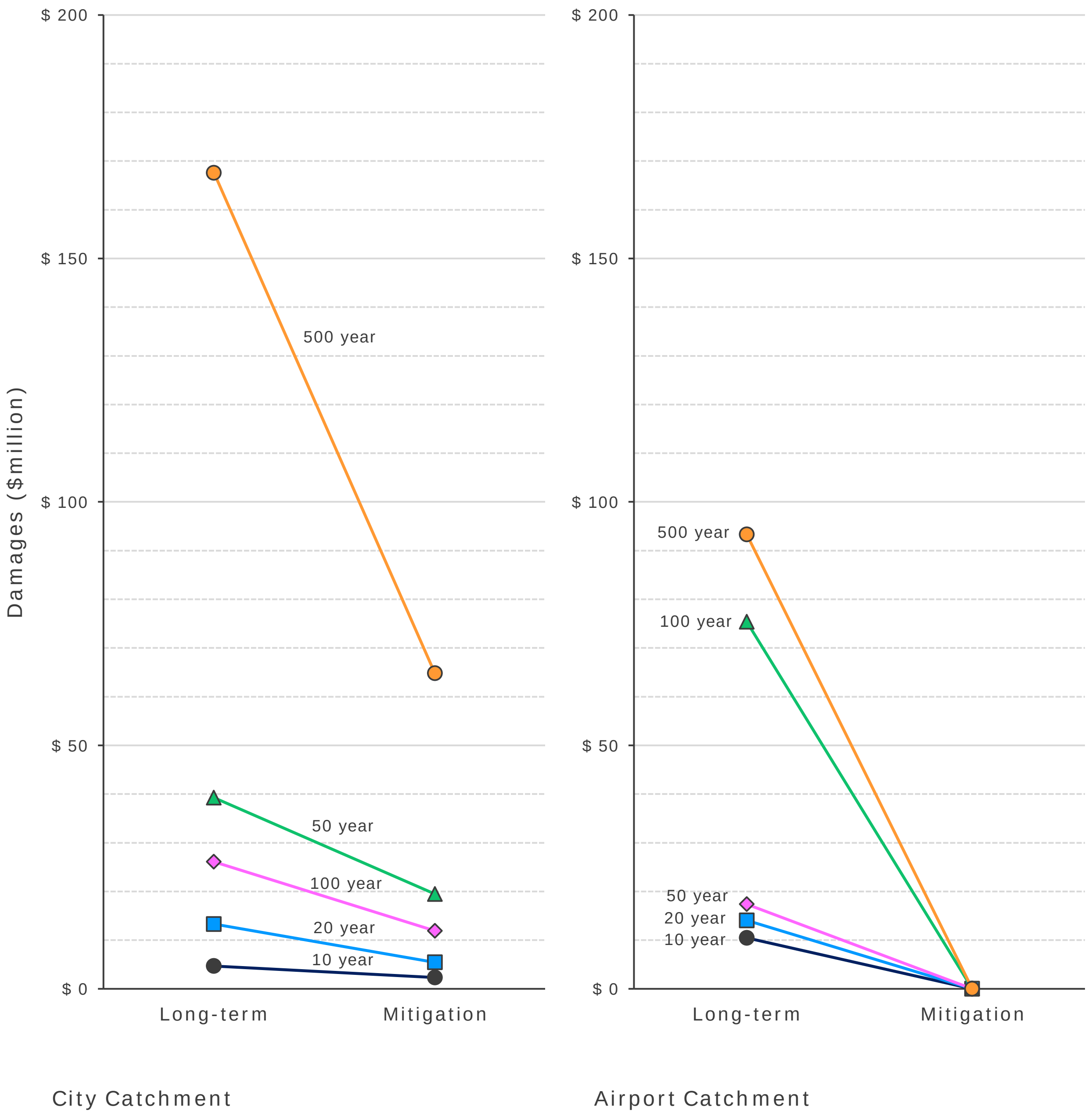



Figure 5.17 Reduction in damages for the City and Airport catchments

The reduction in the number of allotments affected by flooding within the City catchment in each of the damages assessment zones (refer Figure 4.16) is provided in Table 5.5. The reduction in damages in each of these zones is shown in Table 5.7. Note that there is no reduction in damages and flood affected allotments for the industrial area (Zone 6), as mitigation strategies were not proposed within this area.

The largest reduction in the number of affected properties and damages occurs within the central suburbs (Zone 3) and western suburbs (Zone 4). The significant reduction in damages within these areas represents the improvement in flooding as a result of implementing the many mitigation strategies across these zones. Most of the mitigation strategies were aimed at reducing flooding within zones 3 and 4 as there was significant flooding issues along Valley 1, Broadbent Terrace and through the Ocean Eyre development – all of which are located within these zones.

Table 5.5 Reduction in the number of flood affected allotments for the City catchment

| Zone | 10 year | 20 year | 50 year | 100 year | 500 year | PMF |
|---|---|---|---|---|---|---|
| 1 | 4 | 6 | 5 | 2 | 0 | 1 |
| 2 | 1 | 0 | 5 | 5 | 7 | 1 |
| 3 | 4 | 27 | 50 | 92 | 314 | 172 |
| 4 | 0 | 2 | 21 | 45 | 61 | 0 |
| 5 | 1 | 6 | 8 | 8 | 8 | 2 |
| 6 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 10 | 41 | 89 | 152 | 390 | 176 |

Table 5.6 Reduction in the total actual damages for the City catchment ($million)

| Zone | 10 year | 20 year | 50 year | 100 year | 500 year | PMF |
|---|---|---|---|---|---|---|
| 1 | $ 0.12 | $ 0.05 | $ 0.13 | $ 0.16 | $ 0.21 | $ 0.12 |
| 2 | $ 0.00 | $ 0.02 | $ 0.67 | $ 1.34 | $ 3.22 | $ 0.00 |
| 3 | $ 0.93 | $ 5.35 | $ 10.00 | $ 14.35 | $ 26.22 | $ 6.02 |
| 4 | $ 1.31 | $ 2.08 | $ 2.81 | $ 3.31 | $ 72.41 | $ 24.08 |
| 5 | $ 0.00 | $ 0.37 | $ 0.55 | $ 0.61 | $ 0.76 | $ 3.56 |
| 6 | $ 0.00 | $ 0.00 | $ 0.00 | $ 0.00 | $ 0.00 | $ 0.00 |
| Total | $ 2.36 | $ 7.88 | $ 14.17 | $ 19.78 | $ 102.81 | $ 33.65 |

Mitigation strategies within other zones, such as pipe upgrades within Zones 1 and 2, were aimed at reducing nuisance flooding around residential properties.

While there is not a significant reduction in the number of allotments affected by flooding, there is a significant reduction in the damages to these flood-affected allotments. This is likely due to a reduction in the flooded area and flood depth within these allotments. This shows that while the mitigation strategies may not completely eliminate flooding at a particular allotment, it will significantly improve it and subsequently reduce the damages associated with flooding.

Also, the number of affected allotments does not account for the thousands of properties within future residential development zones, as these areas were considered as individual allotments during the analysis.

As previously discussed, it can be seen that the reduction in damages and number of affected allotments increases for all events up to the 500 year ARI event. This indicates that the mitigation strategies are capable of improving flooding for all events up to a 500 year ARI event. These mitigation strategies will not be as effective in significantly larger and extremely rare events, such as the PMF event.

The reduction in the annual average damages for each of the damages assessment zones are shown in Table 5.7. These values represent the annual benefit of the proposed mitigation strategies within each zone.

Table 5.7 Reduction in annual average damages

| Zone | Airport | City | Industrial | Total |
|---|---|---|---|---|
| 1 | $ 0 | $ 27,000 | $ 0 | $ 27,000 |
| 2 | $ 167,000 | $ 41,000 | $ 0 | $ 208,000 |
| 3 | $ 1,027,000 | $ 820,000 | $ 0 | $ 1,847,000 |
| 4 | $ 1,271,000 | $ 773,000 | $ 0 | $ 2,044,000 |
| 5 | $ 1,445,000 | $ 38,000 | $ 0 | $ 1,483,000 |
| 6 | $ 0 | $ 0 | $ 0 | $ 0 |
| Total | $ 3,910,000 | $ 1,699,000 | $ 0 | $ 5,609,000 |

## 5.5 Cost benefit ratios

To assist understanding of the relative economic benefits of offsetting flood damages via structural mitigation measures, a benefit–cost ratio (BCR) has been determined for each damage zone. It was not possible to determine BCRs for individual measures as the majority of the measures are interlinked and influence the performance of other measures.

In determining the BCRs for each zone it was found that the northern levee was so effective that it was difficult to discern the relative benefits of the other proposed measures. Consequently, it was decided that the northern levee should be excluded from the BCR estimation of the other mitigation measures. A BCR was determined for the levee alone based on the damages reduction it produces. A BCR for the other measures was then determined based on the additional reduction of damages assuming the northern levee is already in place.

The BCRs were calculated using a discount rate of 4% across a 50-year period, as recommended by Deans (2018). The BCR of each zone (after removing the effect of the northern levee) is shown in Table 5.8. The BCR of the northern levee was determined to be 36.2.

Table 5.8 Benefit-cost ratio for each damage zone

| Zone | Benefit–cost ratio | Flood mitigation strategies |
|---|---|---|
| 1 | 0.72 | Farrell Street and Wood Terrace pipe systems |
| 2 | 0.83 | McConville Street pipe upgrades |
| 3 | 1.06 | McRitchie Crescent pipe upgrades, McLennan Avenue drain upgrades, Future education precinct, Cabin park levee, Iron Knob Road bunding, McBryde Terrace bunding and Broadbent Terrace pipe upgrades |
| 4 & 5 | 0.57 | Airport channel upgrades, Ocean Eyre basin and Sugarwood Crescent bund |
| 6 | n/a | * *No mitigation strategies proposed* |

Additionally, the BCR of each zone has been calculated for discount rates of 2% and 6%, over a 50-year period. The difference in BCR is represented in Figure 5.18.


Figure 5.18 Benefit-cost ratio for varied discount rates

## 5.6 Priorities

The majority of proposed actions in the City area, to the west of Norrie Avenue, impact on multiple 'zones' which have formed the basis of the calculation of flood damages and damages avoided. These have been modelled as a single 'flood mitigation strategy' rather than as standalone actions as in most cases they are inter-related. This has made the determination of a benefit-cost ratio for individual strategies difficult. Should this economic analysis be required as part of future funding applications / business cases, additional modelling would be required.

Rather than assigning priority on the basis of a benefit-cost ratio, or more complex multi-criteria assessment, the following approach has been used:

High priority:

- high frequency flooding hot-spots
- actions, or part actions with timing potentially driven or influenced by external drivers (such as other development) with near-term implementation timeframes
- small-scale, relatively low-cost actions with interim benefits.

Medium Priority:

- actions addressing flooding from external catchments during rarer flood events

- actions addressing flood risk to private property indicated by modelling for rarer flood events (>20 year).

Low priority

- flood risk to a small number of properties or roads only.

## 5.7 Summary of actions

Table 5.9 provides a summary of the flood mitigation options described in the preceding sections. A priority and budget estimate are also given for each option.

Table 5.9 Summary of mitigation options

| Option | Description | Nominal design standard | Budget estimate | Priority | Benefit-cost ratio[2] |
|---|---|---|---|---|---|
| Northern levee repair | Repairs and short extension to strengthen existing levee. | 100 year ARI | $190,000 | High | 36.2 |
| Northern levee extension | Construct new 6.2 km extension of the northern levee to direct floodwater around the city and airport. | 100 year ARI | $2.58M | Medium | |
| Airport channel upgrade | Widening of the existing airport channel to increase capacity. Existing culverts to be enlarged to match new channel capacity. New channel outfall at Horseshoe Road. | 100 year ARI | $3.18M | Low | 0.57 |
| Ocean Eyre basin | Detention storage to manage runoff from potential future development of the Ocean Eyre residential areas. | 100 year ARI | $1.74M | TBD[1] | |
| Sugarwood Crescent bund | Detention of floodwater in undeveloped Council land to reduce flooding along Broadbent Terrace. | 100 year ARI | $360,000 | Low | |
| McRitchie Crescent pipe upgrades | Upgrade existing underground network to reduce residential flooding in McRitchie Crescent and Brook Street. | 20 year ARI | $1.88M | Medium | 1.06 |
| McLennan Avenue drain upgrades | Upgrade underground pipes to a 5 year ARI standard. Construct new open channel drain to manage surface floodwater in larger events (up to 100 year ARI). | 5 year ARI / 100 year ARI | $6.39M | High | |
| Future education precinct drainage system | Construct formal drainage system using open channels and detention basins to control surface floodwater. | 100 year ARI | $4.03M | High | |
| Cabin Park levee | Small levee to divert surface floodwater around temporary accommodation. | 20 year ARI | $20,000 | Low | |

| Option | Description | Nominal design standard | Budget estimate | Priority | Benefit-cost ratio[2] |
| --- | --- | --- | --- | --- | --- |
| Broadbent Terrace culverts | Additional culverts at regular intervals beneath Broadbent Terrace, discharging floodwater into the Airport Channel. Designed to reduce flooding on the north side of Broadbent Terrace. | 20 year ARI | $1.16M | Low | |
| Iron Knob Road bunding | Detention of rural floodwater north of Iron Knob Road to reduce residential flooding through Whyalla Norrie. | 100 year ARI | $900,000 | Medium | |
| McBryde Terrace bunding | Detention of rural floodwater north of McBryde Terrace to reduce residential flooding through Whyalla Norrie. | 100 year ARI | $330,000 | Medium | |
| McConnville Street | Upgraded underground pipe system to reduce residential flooding in Darragh Street, Ferry Street and Billing Street. | 20 year ARI | $1.16M | Medium | 0.83 |
| Farrell Street and Wood Terrace pipe systems | New underground drainage system along Farrell Street and Wood Terrace to reduce surface stormwater and improve public safety during minor flood events. | 5 year ARI | $810,000 | High | 0.72 |

1: Dependent on development timeline of Ocean Eyre residential area.

2: Based on a discount rate of 4% over a 50-year period.

# 6 Water quality

Consistent with the stormwater management planning guidelines, the status of existing stormwater quality within the city, along with opportunities for water quality improvement have been considered in the development of the Whyalla SMP.

The SMP objectives relevant to water quality (refer Section 3.2) are summarised in Table 6.1.

Table 6.1 SMP objectives relevant to water quality

| Objective | Goal |
|---|---|
| Improve water quality to meet the requirements for protection of the receiving environment. | Improve the quality of stormwater runoff discharging into the Spencer Gulf to achieve the following targets:<br>• Suspended solids 80%<br>• Total Phosphorus 60%<br>• Total Nitrogen 45%<br>• Gross Pollutants 90% |
| | Identify opportunities to achieve additional water quality improvement within proposed flood management infrastructure. |

For the purpose of assessing water quality, the city is split into three areas.

The majority of drainage from Whyalla (approximately 1,700 ha) is directed south via pits and pipes to a drainage channel on the southern border of the town. This drain then discharges to a large intertidal samphire flat area, which provides a buffer of approximately 1.5 km to the sea.

A predominantly residential catchment in the order of 120 ha drains to the main foreshore area to the south east, discharging to the beach via direct outfalls.

In the north eastern corner of the study area, an area (approximately 160 ha) drains to the north through the Whyalla steelworks (Liberty OneSteel) property. All flows from the city of Whyalla eventually end up in the Spencer Gulf.

This section defines the receiving water environment and provides a summary of the likely quality of water from the existing catchment. It then identifies strategies for the implementation of water quality improvement works to achieve the stated objectives.

## 6.1 Receiving waters

Stormwater from the Whyalla SMP study area discharges into the Upper Spencer Gulf Marine Park, which is located within the Northern Spencer Gulf. The area contains large areas of seagrass meadows, mangrove forests, mudflats and salt marshes that support a wide range of animals and plants. It is an important nursery and feeding area for many fish, molluscs and crustaceans, including commercially and recreationally important species (EPA 2018). The waters provide significant environmental, social and economic benefits to all South Australians.

The Marine Park includes a number of sanctuary zones that provide habitat for species of international importance. Every year between the months of May and August, thousands of Giant Australian Cuttlefish congregate on the rocky coastline between Fitzgerald bay and False Bay, north of Whyalla, to spawn. North of the city the coastline also includes the heritage listed Fitzgerald Bay Stranded Shingle

Ridge. The shingles, which were deposited almost 12,000 years ago are largely undisturbed and extremely rare, with only two other comparable examples in the world.

Stormwater from the study area does not directly discharge into these areas of significance and it is considered unlikely that discharges from the SMP study area would negatively impact on the marine environment at these locations. However, a significant proportion of stormwater is currently directed through the intertidal samphire flat area using the area as a buffer to filter the stormwater before discharging into the marine waters.

Temperate coastal saltmarsh communities are listed as Vulnerable under the *Environment Protection and Biodiversity Conservation (EPBC) Act 1999*. Saltmarsh ecosystems are important for providing habitats for many species, including migratory shorebirds, supporting commercial and recreational fishing, protecting inland areas from storm surges and sequestering carbon. Therefore, it is vitally important for both the adjacent inland, and marine environments to effectively manage and protect these transitional habitats between the ocean and land.

The presence of weeds, soil disturbance and water erosion within the samphire flat area, particularly at the existing airport drain outfall location, indicate that the current stormwater discharge points have had an impact on the samphire area. The ability of this area to continue to be the interface and filter the stormwater relies on the health and stability of the ecosystem. The capacity of the samphire flat area to provide these functions has not yet been determined. The Eyre Peninsula Natural Resource Management board have recommended that investigations be carried out to determine the impact of current and future stormwater (including proposed infrastructure) on the samphire flat area prior to implementing any new stormwater management measures that may affect the area.

The Eyre Peninsula Coastal Action Plan, which aimed to develop management and conservation priorities, concluded that the waters in the immediate vicinity of Whyalla have a 'medium to high' threat level. The identified threats include weed infestation, dune erosion, marine debris and industrial expansion.

The Eyre Peninsula Natural Resources Management Strategic Plan provides a framework for the management of natural resources within the Eyre Peninsula Natural Resources Management Region for 2017-2027. With a stated vision of managing resources "to support ecological sustainability, vibrant communities and thriving enterprises in a changing climate", it includes a stated goal of "healthy and resilient land, sea and water ecosystems by supporting management of land, sea and water to maintain and improve condition".

The listed required actions to achieve this goal are:

- Facilitate whole of catchment management planning and supporting works to restore riparian and wetland ecosystems and reduce water quality impacts.
- Partner with Local Government to undertake urban stormwater planning and implementation focusing on water sensitive urban design that reduces water quality impacts.

The plan recognises the need for improved stormwater management practices including water sensitive urban design and watercourse rehabilitation in Whyalla.

## 6.2 Water quality modelling – the existing catchment

The study area is heavily developed. The land use is mostly residential with pockets of commercial and industrial areas. The primary pollutants carried by stormwater from urban areas that may impact coastal receiving environments include:

- sediments (TSS)
- nutrients (TP and TN)
- pathogens

- oxygen demanding substances
- gross pollutants (GP).

The quality of runoff from the study area was modelled using the eWater Model for Urban Stormwater Improvement Conceptualisation (MUSIC). There are currently no official guidelines for the use of MUSIC in South Australia. The adopted approach to modelling is therefore based on the recommendations made by the Goyder Institute in their recent report (Myers et al. 2015) which reviewed the use of MUSIC for the development of stormwater management plans. The report includes a comprehensive review of guidelines for the use of MUSIC in other regions and makes recommendations for MUSIC simulations in South Australia.

### 6.2.1 Model set-up

Development of a MUSIC model requires meteorological data, source node (catchment) data, and definition of drainage links and water quality improvement measures.

#### Meteorological data

The MUSIC model was run using five years (October 2000 – October 2005) of six-minute rainfall data recorded at the Whyalla Aero station (site number 018120).

#### Catchment data

The definition of catchment areas and characteristics (% impervious area) was based on the catchments in the DRAINS model, used for hydrological and hydraulic analysis. The DRAINS model included approximately 2,400 catchments. Reflecting the conceptual nature of the MUSIC model, the DRAINS catchments were lumped together to create 11 catchments.

The effective impervious area (EIA) for each lumped catchment was calculated using the proportional average of the directly connected impervious areas, as defined in the DRAINS model.

The catchment zoning/surface type was based on a review of the land use layers. Many catchments were identified as residential, with some being a combination of residential and commercial. The associated pollutant load parameters are consistent with the recommendations in Myers et al. (2015) for lumped catchment modelling for South Australian stormwater management plans.

#### Drainage links

The drainage links within the MUSIC model were defined based on a review of the stormwater network. No routing was applied. This is considered conservative, consistent with the recommendations of Myers et al. (2015) which states "*routing is not required in South Australian MUSIC modelling undertaken for compliance with water quality targets to ensure results are conservative*".

#### Existing water quality improvement features

DesignFlow (2010) notes that the main focus for stormwater management within Whyalla is flood conveyance. There are, however, a number of features within that catchment which provide a water quality improvement function prior to discharge into the receiving waters.

The open, earth channel that receives runoff from the large city catchment has thick bands of vegetation which will filter the runoff and will help to facilitate the deposition of sediment prior to discharge into the intertidal zone. The channel discharges flows to a samphire flat area which also acts as a buffer, providing additional opportunities for sedimentation prior to discharge to the marine environment. It is difficult to accurately model the patchy nature of the vegetation within the channel. The model assumes a low (0.1 m) vegetation height along the channel. This is considered a conservative approach and is likely to underestimate the water quality improvement provided by the existing vegetation.

There is a constructed wetland on the northern side of the Lincoln Highway, opposite the outfall of the main drainage channel. The wetland receives runoff from a catchment area of approximately 250 ha. Since construction the wetland has encountered a number of operational issues including the ingress of saline ground water, soil salinity and poor establishment of vegetation. Despite not functioning as originally intended, the wetland still acts as a sedimentation basin, facilitating the removal of suspended solids and other pollutants that may be bound to particulate matter.

There is a basin located at the north eastern end of the racecourse which receives diverted urban runoff from upstream catchments. The basin was originally intended to be part of an aquifer storage and recovery scheme, but it is not known whether this scheme is still functional. It is understood that Council uses water from the basin to fill up tankers for the purpose of irrigating street trees.

DesignFlow (2010) stated that there were no features to improve water quality within the foreshore catchment. Review of flow patterns generated by the TUFLOW modelling undertaken as part of the SMP, suggest that flows generated by sub catchments north of Broadbent Terrace (approximate area 59 ha) are unlikely to be directly discharged to the marine environment. In frequent, low flow events, they will head in a westerly direction along Broadbent Terrace and will be discharged via a swale onto the intertidal samphire flat area.

The MUSIC model incorporates these existing mechanisms of water quality improvement.

### 6.2.2 Water quality modelling results

The MUSIC model was run to understand the patterns of flow and pollutant generation based on the current level of development and existing stormwater network. The results of the 'base case' model for the channel catchment and the foreshore catchment are summarised in Table 6.2 and Table 6.3. The loads that are discharged through the steelworks site are summarised in Table 6.4. The estimated loads for the city catchment are comparable to those estimated by AWE (2009).

Table 6.2 Annual loads for MUSIC base case model (channel outlet)

| | Sources | Residual Load | % reduction |
|---|---|---|---|
| Flow (ML/yr) | 864 | 746 | 13.7 |
| Total Suspended Solids (kg/yr) | 186,000 | 24,200 | 87 |
| Total Phosphorus (kg/yr) | 374 | 103 | 72.6 |
| Total Nitrogen (kg/yr) | 1880 | 1200 | 36.1 |
| Gross Pollutants (kg/yr) | 39,300 | 0 | 100.0 |

Table 6.3 Annual loads for MUSIC base case model (foreshore catchment)

| | Sources | Residual Load | % reduction |
|---|---|---|---|
| Flow (ML/yr) | 66.7 | 33 | 50.4 |
| Total Suspended Solids (kg/yr) | 14,200 | 7,020 | 50.6 |
| Total Phosphorus (kg/yr) | 28.6 | 14 | 51 |
| Total Nitrogen (kg/yr) | 140 | 67.1 | 52 |
| Gross Pollutants (kg/yr) | 3,130 | 1,550 | 50.4 |

Table 6.4 Annual loads for MUSIC base case model (Whyalla steel works catchment)

| | Sources | Residual Load | % reduction |
|---|---|---|---|
| Flow (ML/yr) | 94.9 | 94.9 | 0 |
| Total Suspended Solids (kg/yr) | 19,800 | 19,800 | 0 |
| Total Phosphorus (kg/yr) | 45.2 | 45.2 | 0 |
| Total Nitrogen (kg/yr) | 220 | 220 | 0 |
| Gross Pollutants (kg/yr) | 4,490 | 4,490 | 0 |

The MUSIC modelling of the existing water quality improvement features within the city catchment demonstrate a significant reduction in pollutant loads prior to discharge to the marine environment. The targeted pollutant reductions are met for TSS, TP and GP. There is also a significant (36%) reduction in TN. Review of the model outputs shows the majority of the modelled water quality improvement occurs as a result of sedimentation and evaporation from the pond and on the samphire flat. Minimal water quality improvement is attributed to the vegetation within the channel.

The recommended works for this catchment include channel maintenance works and planting of suitable species that will not only help to stabilise the banks but will also provide increased water quality improvement effectiveness and amenity value.

The 50% reduction in flow and pollutants modelled in the foreshore catchment represents the 50% of the catchment that is discharged to the marine environment via the samphire flat area. There are no water quality improvement features in the portion of the foreshore catchment that discharges directly to the marine environment.

There are currently no large-scale water quality improvement features within the steelworks catchments. The drainage network from the steelworks catchment discharges into a channel which travels through the privately-owned site. The channel also conveys runoff from the steelworks itself. The steelworks site is beyond the boundary of the SMP study area. Details of the drainage within the privately-owned site, and the pollutant loads of runoff from the steelworks are not known. For these reasons potential water quality improvement measures for this catchment have not been considered. It is recommended that Council liaise with the owners of the steelworks to design and implement water quality improvement features within the site.

## 6.3 Water quality improvement strategies

It is recommended that the focus of additional water quality improvement works for Whyalla should be the residential catchments south of Broadbent Terrace within the foreshore catchment (refer Figure 6.3). Flows from these catchments are currently discharged directly to the marine environment either as surface flows or via pipes. DesignFlow (2010) notes that sediment plumes are visible from these outfalls following rainfall events.

Whilst this area is considered a priority for water quality improvement, opportunities elsewhere have also been explored, particularly where there is an opportunity to tie water quality improvement and reuse into flood mitigation works, thus achieving multi-objective outcomes.

### 6.3.1 Types of Water Sensitive Urban Design treatments

DesignFlow (2010) identified three types of Water Sensitive Urban Design (WSUD) treatments that may be suitable for the climate of the Eyre Peninsula – constructed wetlands (ephemeral or permanent), raingardens and infiltration basins. Given the problems of the intrusion of saline groundwater into the existing wetlands in Whyalla, rain gardens and infiltration basins are considered the most suitable WSUD treatments.

## Raingardens

Raingardens are typically shallow, planted depressions that can provide water quality improvement benefits via bio filtration mechanisms. Raingardens may be implemented at a range of scales from individual residential blocks up to the treatment of whole of catchment flows. Raingardens can reduce the quantity of sediment and nutrients exported to receiving waters.

Opportunities for small scale raingardens have been considered to improve stormwater water quality runoff and reduce the energy of flows prior to discharge to the marine environment. The raingardens receive gutter flows via gaps in the kerbing. Flows are then allowed to pond and infiltrate. A high-level overflow/outlet may be provided to discharge flows exceeding the storage capacity of the raingarden into the underground drainage network, or in the case of Whyalla, to the marine outfall.

Existing roads can be retrofitted with raingardens, which offer a range of benefits in addition to improved water quality including improved aesthetics, increased green space and cooler urban environment. They can also be integrated into traffic calming devices.

A typical layout for a small, streetscape raingarden is illustrated in Figure 6.1. It should be noted, that the presence of an underground drainage network is not essential.

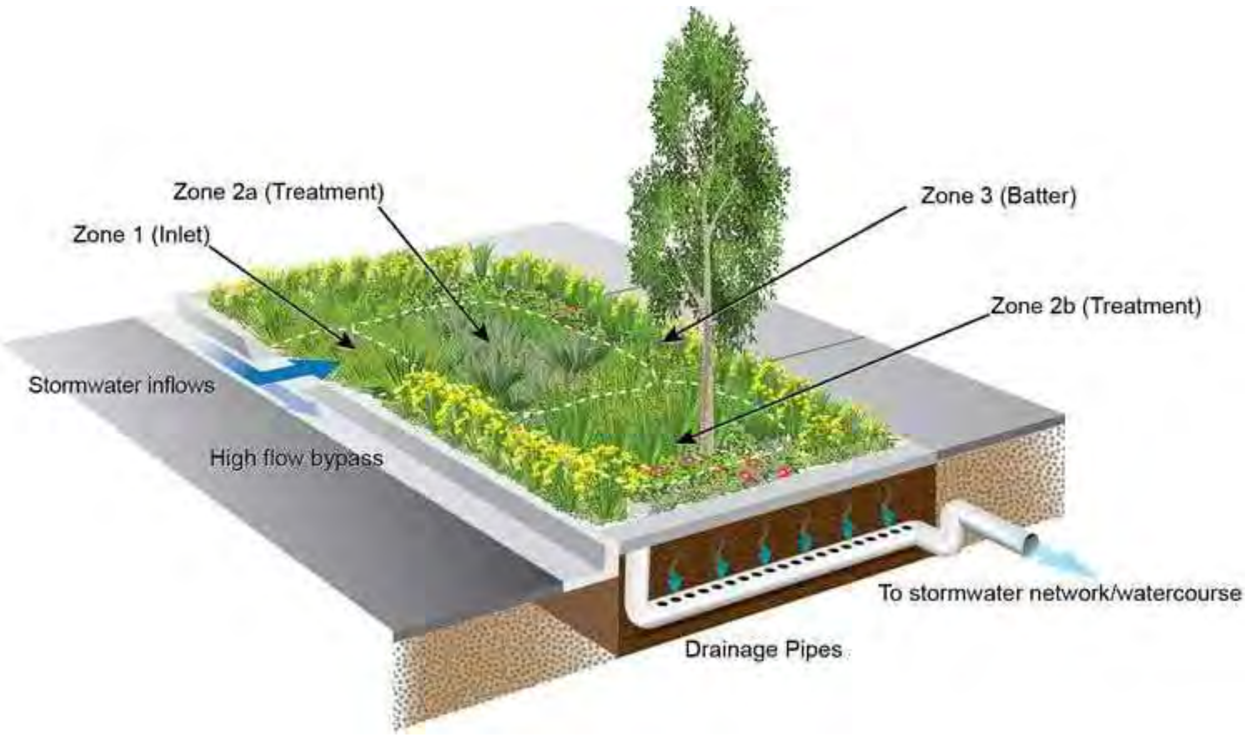



Figure 6.1 Typical layout of a raingarden (Water Sensitive SA)

## Infiltration basins

Infiltration basins are shallow depressions that capture water and allow it to infiltrate into the local soils, thereby reducing the volume of stormwater (and pollutants) discharged into the receiving waters. DesignFlow (2010) identified infiltration basins as suitable treatment measure for the coastal catchments of Whyalla, where the soils are predominantly sandy. An example of an infiltration basin in a coastal area is shown in Figure 6.2.

Figure 6.2 An example of an infiltration basin on the LeFevre Peninsula (City of Port Adelaide Enfield 2016)

### 6.3.2 Foreshore catchment

The soils close to the coast in the foreshore catchment are generally sandy and are suitable for infiltration (DesignFlow 2010). Infiltration basins are therefore proposed as the main method for improving water quality of runoff from the foreshore catchment. Small, streetscape raingardens are also recommended. The combination of these features will reduce the energy of flows (and hence erosion potential) prior to discharge and at the same time they will reduce sediment and pollutant loads to the gulf.

The proposed works are shown on Figure 6.3. Further information is provided in the following sections.

#### Dunstone Street – infiltration basin and minor road works

DesignFlow (2010) identified Dunstone Street, with a contributing catchment of 24 ha, as the main drainage outfall within the foreshore catchment. It was noted that sediment plumes are visible at the outfall. Review of the flood mapping undertaken as part of this SMP development suggests that the residential catchment contributing flows to the Dunstone Street outfall is limited to the area south of Broadbent Terrace and is only 3 ha in size.

Review of older (early 2017) aerial imagery shows that the downstream end of Dunstone Terrace had an unsealed surface, with flow paths clearly visible, indicating the export of sediment from this area. Review of more recent imagery shows that this area is now sealed. This would be expected to reduce the export of sediment from the area.

While the sealing of the road will have reduced the export of sediment at the Dunstone Terrace outfall, an infiltration basin is still recommended. The basin will reduce the energy of flows and allow particulate matter to settle, thereby reducing the loads discharged to the marine environment.

The recommended works include construction of an infiltration basin (area 100 $m^2$). Minor works may also be required to direct flows into the basin.

### Roberts Terrace – raingardens

The catchment contributing flows to Roberts Terrace south of Broadbent Terrace is relatively small (1.2 ha). It is recommended that raingardens be installed in the vicinity of existing inlet pits. Four potential locations have been identified.

For the purpose of modelling, the raingardens are assumed to have a combined total area of 40 $m^2$.

### Neagle Terrace Catchment – raingardens and infiltration basin

A residential catchment with an area of approximately 2.5 ha contributes flows to Neagle Terrace. There is an existing underground stormwater network that collects the flows and discharges them directly to a coastal outfall. The pipe currently crosses a reserve South of Neagle Terrace. It is recommended that an infiltration basin (area 100 $m^2$) be constructed within the reserve to provide water quality treatment prior to discharge to the marine environment.

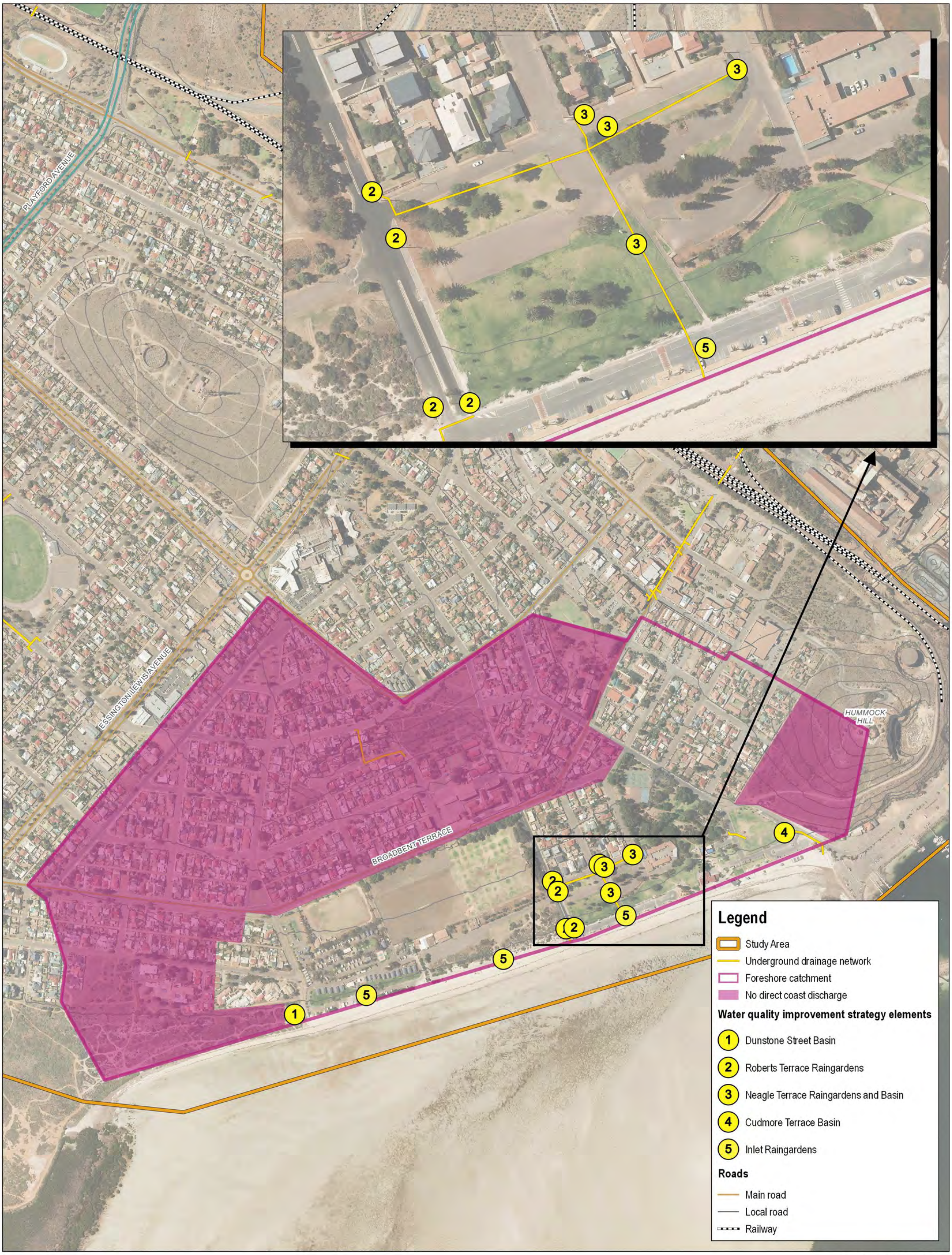
There is also the opportunity to install streetscape raingardens in the vicinity of the inlet pits on Neagle Terrace to provide further water quality improvement.

### Cudmore Terrace – infiltration basin

The Cudmore Terrace catchment has an area of approximately 11 ha. Flows are largely conveyed along the surface, with two existing pits collecting flows at the downstream end of the catchment and directing through a swale in the adjacent reserve, prior to discharge to the marine environment.

It is recommended that an infiltration basin be constructed in the reserve (500 $m^2$) to treat flows prior to discharge.

DesignFlow (2010) also recommended a basin in this area but note that the suitability of the soils in the reserve for infiltration will need to be verified.

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**WHYALLA STORMWATER MANAGEMENT PLAN**
**FORESHORE CATCHMENT WATER QUALITY IMPROVEMENT STRATEGY**

Figure 6.3

### 6.3.3 Modelled water quality improvement

The effectiveness of the proposed water quality improvement strategy has been assessed using the MUSIC model. The raingardens were modelled as lumped bio-filtration nodes and the infiltration basins infiltration nodes.

The raingardens were assumed to have a 0.1 m ponding depth. The filter media was assumed to have a total area of 150 $m^2$ with a depth of 0.5 m. The base of the raingarden was assumed to be lined and vegetated with plants effective at nutrient removal.

The modelling assumed that the infiltration basins had an extended detention depth of 0.5 m with an infiltration rate of 1000 mm/hr. The expected rate of infiltration for beach sands would be higher (up to 3,600 mm/hr), however the selection of the lower rate allows for clogging of the sand over time.

A summary of the modelled treatment effectiveness of the proposed raingardens and infiltration basins is provided in Table 6.5. The loads and associated reductions are reported only for the portion of the catchment that directly discharges to the coast. It excludes the 58 ha catchment discussed previously, which discharges to the samphire flat area via Broadbent Terrace.

The proposed treatment measures treat runoff from an area of approximately 18 ha, which is equivalent to approximately 31% of the foreshore area that discharges directly to the coast.

Review of the results shows that the infiltration basins have sufficient capacity to infiltrate almost 100% of runoff from the contributing catchments, thereby providing significant water quality benefits. The raingardens in Roberts Terrace also provide a significant reduction in flow and the export of pollutants from this catchment.

Works to reduce the discharge of flows from the catchment not only reduce the pollutant loads being discharged to the gulf but would also reduce the risk of erosion at the coastal outfalls.

Table 6.5 Treatment effectiveness of measures proposed for the outfalls of the foreshore catchment

| Parameter | Percentage reduction |
|---|---|
| Flow | 29.5% |
| Total Suspended Solids | 31.2% |
| Total Phosphorus | 29.7% |
| Total Nitrogen | 29.3% |
| Gross Pollutants | 30.7% |

It is acknowledged that the MUSIC modelling undertaken as part of the SMP is very high level. Should Council be interested in investigating the implementation of WSUD measures within the foreshore catchment, that a more detailed study be undertaken to optimise the locations and sizing of the WSUD measures.

### 6.3.4 Small scale inlet raingardens

The proposed water quality measures discussed in the preceding sections treat most of the runoff from the residential areas that have direct discharges to the marine environment. They do not treat runoff from Beach Road and the carpark on the foreshore.

Runoff from the car park is currently discharged directly to the coast via small inlets in the kerbing. Erosion of the beach in the vicinity of these outlets is visible in some aerial images. It is recommended that small scale raingardens be constructed at each discharge point to allow for sedimentation and to reduce the energy of the flows discharged to the beach. Opportunities for similar raingardens should also be considered at discharge points along Beach Road.

Construction of raingardens within the carpark will result in a loss of car parking spaces.

### 6.3.5 City catchment

The MUSIC modelling has focussed on the foreshore catchment as this was identified as presenting the highest risk to the receiving waters due to the direct coastal outfalls combined with limited existing water quality improvement within the catchment.

The modelling shows that the existing wetland (acting as a sedimentation basin) and samphire flat area provide significant reductions in pollutant loads discharged to the marine environment. The water quality improvement works, as recommended in the following sections, are based on realising opportunities associated with projects that are proposed for other reasons (such as flood mitigation). The location of these sites is shown on Figure 6.4.

#### Airport channel upgrade works

Erosion of the channel banks within the airport channel was noted during the site visit. It is also recommended that the drain be upgraded between Jenkins Avenue and Horseshoe Road to provide additional capacity, with a new outfall constructed along Horseshoe Road. In conjunction with the capacity upgrade, it is recommended that works be undertaken to improve bank stability along the drain and provide additional water quality improvement. These bank stability and landscaping works should also be undertaken between Horseshoe Road and the existing outfall location. Planting with appropriate native species along the channel will assist with bank stability, improve the effectiveness of pollutant removal and improve the channel's visual amenity.

#### Future Education precinct

It is recommended that as part of the planning process for the future education precinct, that opportunities for stormwater treatment and harvesting be considered, including water sensitive urban design elements. Yield modelling that has been undertaken as part of this SMP (refer Section 7.1) determined that it would be possible to capture in the order of 80 ML/year within the designated precinct. This modelling was based on supplying demands for non-potable water across the city. It is suggested that a more economically viable option may be a small-scale capture and reuse scheme that supplies water for irrigation use within the precinct and surrounding areas only. A connection to Council's existing basin on the opposite side of Racecourse Road could also be explored.

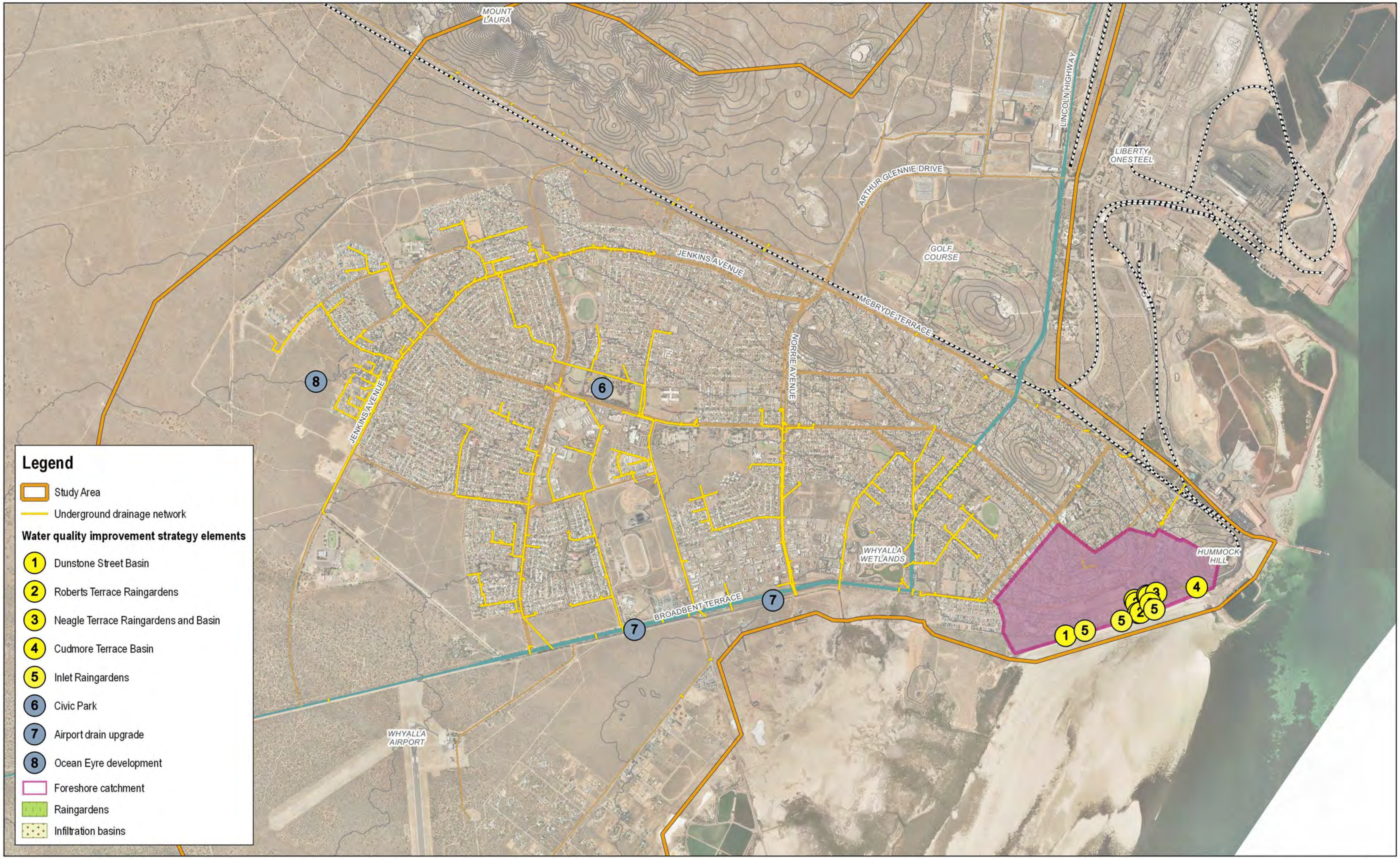
Integrating water sensitive urban design features and some degree of stormwater harvesting and reuse, either localised or wider-scale, into the precinct would reduce pollutant loads being discharged into the gulf and would reduce Council's reliance on the recycled water supplied by SA Water. It could also provide educational opportunities for local school students.

#### Small scale opportunities

Opportunities for the incorporation of streetscape features, such as raingardens should also be considered when civil works, such as kerb and guttering, are being planned.

### 6.3.6 Whyalla steelworks catchments

Flows from these catchments discharge to the marine environment via a channel through the Liberty OneSteel site. The channel is within private property and is beyond the bounds of the SMP study area. It is recommended that Council consider opportunities for working with the owners of the site to implement stormwater treatment measures to reduce the pollutant loads being discharged from the catchments (including directly from the industrial site) into the receiving waters.

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CITY OF WHYALLA

STORMWATER MANAGEMENT PLAN
CITY WATER QUALITY IMPROVEMENT STRATEGY

Figure 6.4

## 6.4 Water quality improvement strategies – areas of future development

There are a number of areas planned for development within Whyalla, particularly within the Ocean Eyre development site. As a condition of planning approval, Council should mandate that developers provide a stormwater management plan. The stormwater management plan for each development must include consideration of water quality and water sensitive urban design, and must demonstrate that the level of treatment applied to runoff from the development can achieve the SMP stated targets of:

- Suspended solids 80%
- Total Phosphorus 60%
- Total Nitrogen 45%
- Gross Pollutants 90%.

## 6.5 Non-structural strategies

In addition to the aforementioned capital works, it is recommended that council encourage 'WSUD in the backyard'. Examples of measures could include rainwater tanks (with effective reuse), permeable paving and small-scale raingardens. Potential benefits that could be achieved by a WSUD in your backyard approach include reduced peak flows and runoff volumes and improved water quality

Implementation of WSUD in the backyard will require community buy-in. It will require a community awareness and education campaign.

Water Sensitive SA has teamed up with the Living Smart program to deliver "WSUD in your home and backyard training for the community" (refer Figure 6.5). Further details can be found on their website at:

http://www.watersensitivesa.com/new-community-webpages-wsud-in-your-home-backyard/

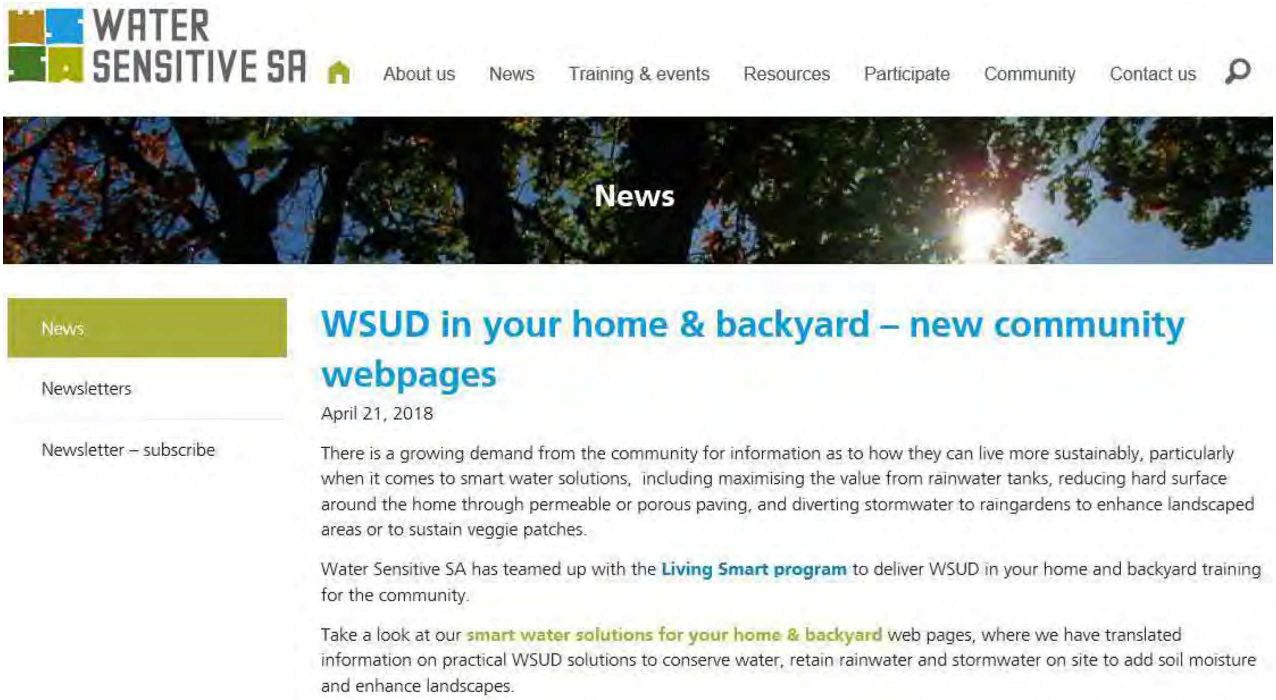


Figure 6.5 The home page for WSUD in your home and backyard (Water Sensitive SA

## 6.6 Summary of water quality strategies

A summary of the proposed water quality improvement strategies, a high-level estimate of cost and priority is provided in Table 6.6.

Table 6.6 Summary of water quality improvement strategies

| ID* | Strategy | Cost | Priority |
|---|---|---|---|
| 1 | Neagle Terrace raingardens and basin | $120,000 | High |
| 2 | Dunstone Street - infiltration basin | $35,000 | High |
| 3 | Development controls for new developments | n/a | High |
| 4 | Cudmore Terrace basin | $80,000 | Medium |
| 5 | Roberts Terrace raingardens | $110,000 | Low |
| 6 | Civic Park wetland (opportunistic) | n.a. | Low |
| 7 | Airport channel erosion and landscape works | | Medium |
| 8 | Ocean Eyre WSUD** | n.a. | High |
| – | Small inlet raingardens along Beach Road and in the foreshore carpark | $20,000 each | Low |
| – | WSUD in the backyard education campaign | $10,000 | Low |

* refer to Figure 6.3 and 6.4
** cost to be borne by developer