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Draft

Hallett Cove Creeks Stormwater Management Plan

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Draft

Hallett Cove Creeks Stormwater Management Plan

City of Marion

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G	20 Nov 2012	DJ	Complete Draft
H	18 Jan 2013	DJ	Final Draft

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Appendices

Executive Summary

This draft Stormwater Management Plan (SMP) for the Hallett Cove Creeks Catchment has been prepared in accordance with the requirements of the Stormwater Management Planning Guidelines (Stormwater Management Authority, 2007).

This document contains:

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

The Stormwater Management Plan catchment area totals 715 ha, which is comprised of four main areas draining to Gulf St Vincent. The land use is almost entirely residential, resulting from development of the area occurring predominantly through the 1970s and 1980s.

The Study Area is relatively steep, rising from its coastal western boundary to Lonsdale Highway. The most significant watercourse, Waterfall Creek, has a relatively steep average gradient of 4.2%, while a number of roads have longitudinal gradients approaching 10%.

The existing stormwater infrastructure was assessed to generally have a performance standard that meets current day expectations, with a few exceptions. The key issues that were identified with existing stormwater management practices in this catchment include:

- Erosion of the Waterfall Creek channel, along most of its length
- Lack of stormwater quality improvement measures, and the contributing effect that this has on the receiving marine environment
- Lack of stormwater harvesting and reuse within the catchment, other than individual site property owner practices

Relevant objectives contained within the City of Marion *Strategic Plan 2010-2020*, *Healthy Environment Plan 2010-2014* in addition to the State Government draft WSUD Consultation Paper were drawn on to develop a set of objectives specific to the Hallett Cove Creeks Catchment, addressing:

- Stormwater harvesting and reuse to reduce reliance on mains water
- Stormwater quality improvement to reduce impacts on the marine environment
- Flow reduction within Waterfall Creek to manage erosion
- Flood protection to reduce property inundation vulnerability

The draft plan has developed a range of actions by which these objectives can be achieved. In addition, the opportunity to substantially enhance existing biodiversity condition has been identified, for a number of measures located within the Waterfall Creek corridor. This would presented the opportunity to establish the Waterfall Creek corridor as a complimentary element to the Great Southern Urban Forest, providing a connection between the Hallett Cove Conservation Park and large areas of Hills Face Zone land.

High priority (0-2 year timeframe) actions identified by the Plan include:

- Waterfall Creek Restoration Stage 1 works

- Small inline detention storages in the upper sections of Waterfall Creek
- Ramrod Avenue stormwater upgrade

Medium priority (2-5 year timeframe) actions include:

- Glade Crescent Reserve Wetlands
- Conversion of Lucretia Dam into a wetland
- Waterfall Creek Restoration Stage 2 works
- Replacement of the GPT at Heron Way Reserve, and associated WSUD works
- Drainage works in Sandison Road, Mercedes Avenue, First Street and Second Street that address properry inundation vulnerability
- WSUD works in the Fryer Street Reserve that address an coastal outlet impact

Low priority (5-10+ year timeframe) actions include:

- Numerous miscellaneous stormwater drainage upgrades to address excessive gutter flows
- WSUD initiative at Shamrock Road Reserve, incorporating stormwater harvesting and reuse
- Gross Pollutant Trap in Barndoo Street
- Vegetated swales along some sections of Lonsdale Highway

This draft report has been prepared for the purpose of enabling consultation with the local community, interest groups, Council elected members and staff. Following the collation of feedback from this process, a final report will be prepared and submitted to the City of Marion, Adelaide & Mt Lofty Ranges NRM Board and the Stormwater Management Authority for final approval.

1 Introduction

This draft Stormwater Management Plan (SMP) for the Hallett Cove Creeks Catchment has been prepared in accordance with the requirements of the Stormwater Management Planning Guidelines (Stormwater Management Authority, 2007).

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

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

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

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

In addition to Council staff, the draft plan has been prepared in consultation with the Adelaide & Mt Lofty Ranges NRM Board and Department of Planning, Transport and Infrastructure.

This draft report has been prepared for the purpose of enabling consultation with the local community, interest groups, Council elected members and staff. Following the collation of feedback from this process, a final report will be prepared and submitted to the City of Marion, Adelaide & Mt Lofty Ranges NRM Board and the Stormwater Management Authority for final approval.

2 Catchment Features

2.1 Catchment Boundary

The catchment boundary adopted for this Stormwater Management Plan is shown in Figure 2.1.

The total catchment area is 715 ha, which is comprised of four main areas draining to Gulf St Vincent. Some catchments have numerous drain outfalls to the Gulf.

2.2 Topography

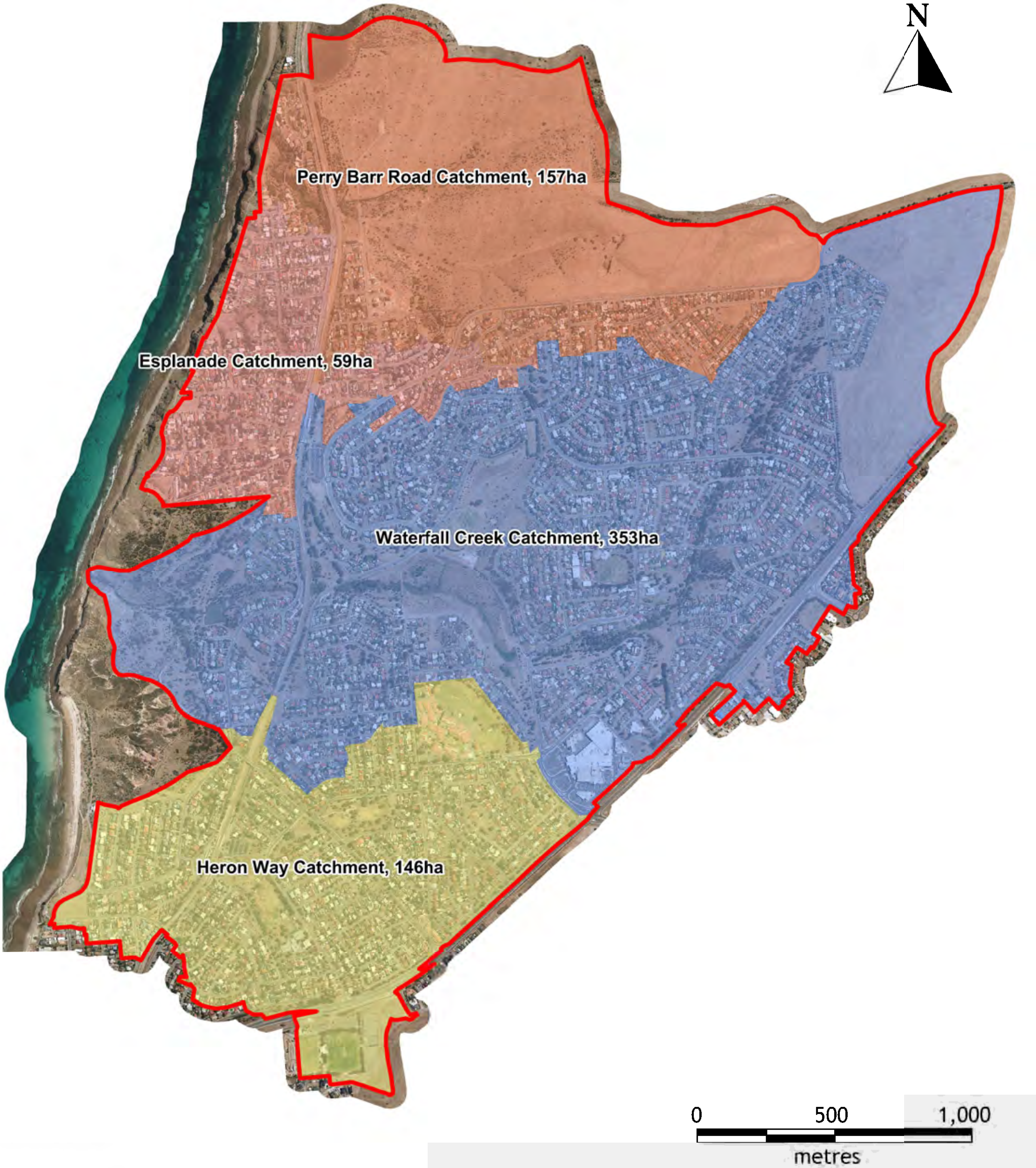
The Study Area is relatively steep, rising from its coastal western boundary to a maximum elevation of 193 mAHD near the intersection of Perry Barr Road and Lonsdale Highway. The most significant watercourse, Waterfall Creek, has an average gradient of 4.2% from the upper reach near Aroona Road to the coastal outfall, while a number of roads have longitudinal gradients approaching 10%.

The steepness of the land generally has also led to a number of roads being constructed with a 1-way crossfall, in locations where a conventional crowned road with 2-way crossfall could not be achieved.

A digital terrain model (DTM) of the Study Area was acquired to assist in various aspects of the preparation of this Stormwater Management Plan.

The survey points for the DTM were obtained from LiDAR (otherwise known as Airborne Laser Scanning) data collected in February 2008. The February 2008 LiDAR data has a vertical accuracy of 0.15m RMS, (1 sigma) on open clear flat surfaces. The vertical datum is referenced to the Australian Height Datum (AHD). The data was adjusted to AHD using a combination of AUSGeoid98 and field survey data.

The data was supplied as a ‘thinned’ dataset of XYZ points, from which a 3D mesh and 1m contours (depicted in Figure 2.2) was created.



Data Sources:
City of Marion (Aerial Photograph)
Southfront (Catchments)

Hallett Cove Creeks Catchment
Stormwater Management Plan

Figure 2.1
Catchment Plan

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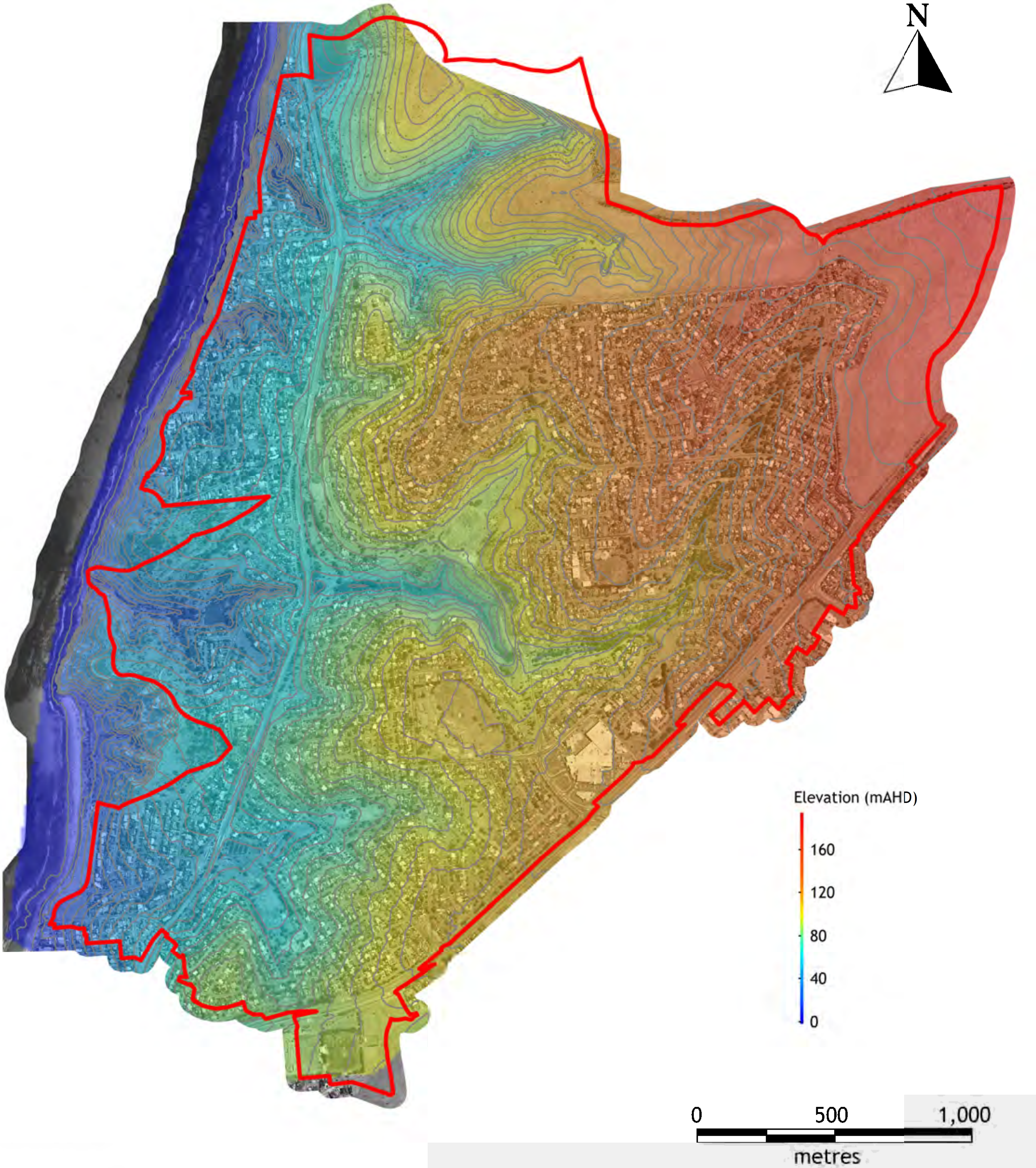


Data Sources:
City of Marion (Aerial Photograph)
Southfront (5m Contours, Digital Terrain Model)

Hallett Cove Creeks Catchment
Stormwater Management Plan

southfront

Figure 2.2
Contour Plan

2.3 Stormwater Infrastructure

2.3.1 Existing Infrastructure

The City of Marion maintains a GIS database of existing stormwater infrastructure, which has been utilised for a number of tasks undertaken for this plan. Figure 2.3 shows the location and extent of existing stormwater infrastructure within the catchment. A summary profile of existing infrastructure is provided in Table 2.1 below.

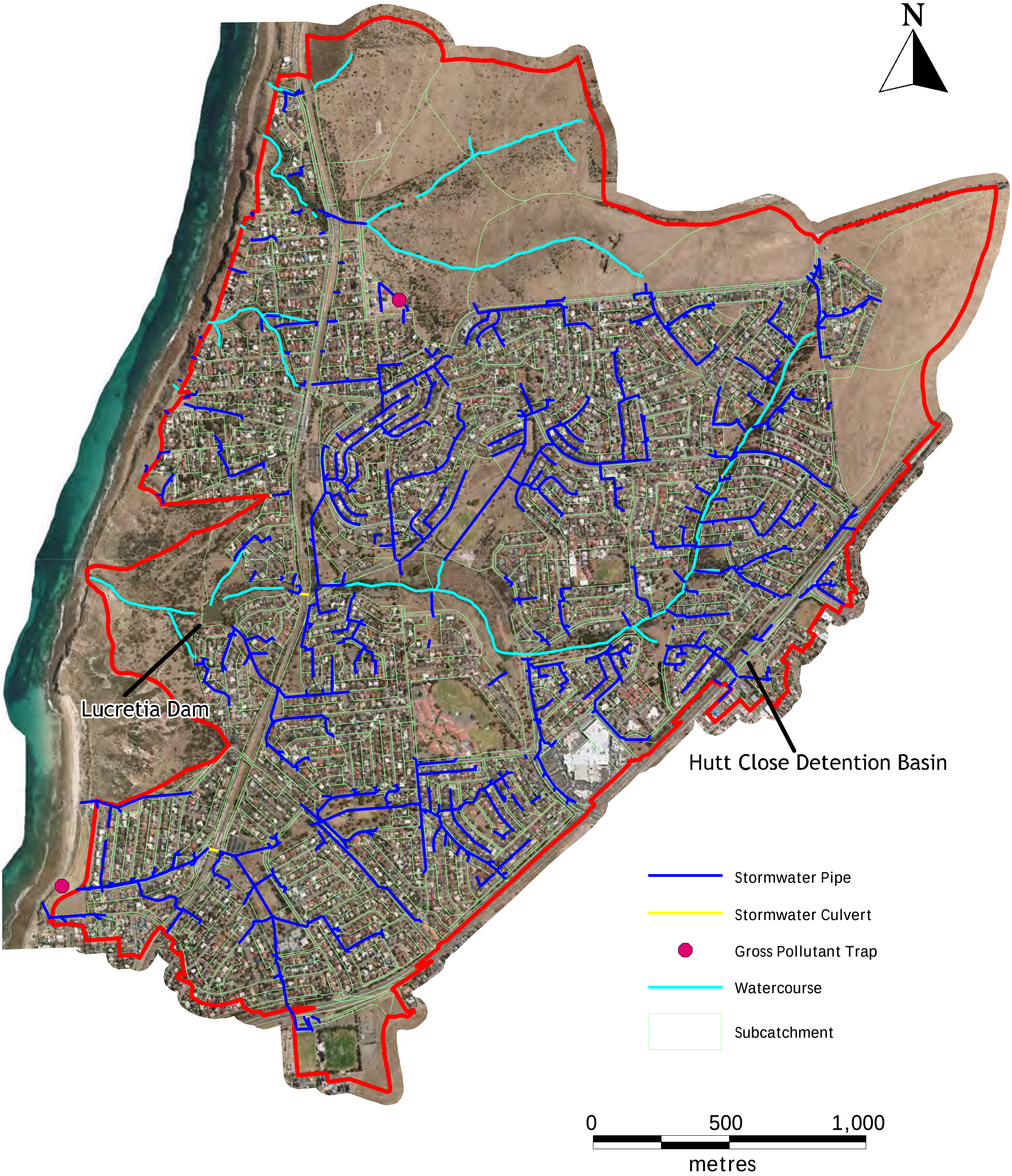
Table 2.1 Stormwater Infrastructure Profile Summary

Asset	Quantity
Pipes	38.0km
150 dia	*13%*
225 dia	*2%*
300 dia	*46%*
375 dia	*14%*
450 dia	*9%*
525 dia	*5%*
600 dia	*3%*
675 dia	*1%*
750 dia	*4%*
900 dia	*1%*
1050 dia	*2%*
Other sizes	*1%*
Culverts	133m
Inlets	758
Gross Pollutant Traps	2
Watercourse / open channel	7.6km
Detention Basin	1
Dam / Pond	1

There is one example (at the intersection of Quailo Avenue and Gledsdale Road) where a water sensitive urban design (WSUD) approach to stormwater management has been implemented, in the form of a bioretention area integrated into a traffic island. The gross pollutant trap shown near the intersection of Dutchman Drive and Heron Way is currently out of service due to a structural defect associated with the diversion weir within the trap.

A small detention basin is located adjacent to the intersection of Hutt Close and Lonsdale Highway, which provides a modest mitigating effect to flows from the upstream retail catchment prior to release into the drain under Lonsdale Highway. A small dam (known as Lucretia Dam) is located on Waterfall Creek, in a Council reserve adjacent to Barossa Crescent. The historical background to the dam is not known, however it is speculated that this was constructed to provide some erosion protection to the downstream creek section through the Hallett Cove Conservation Park at the time of upstream residential development.

There are no pump stations, wetlands or aquifer storage and recovery (ASR) schemes within the catchment.



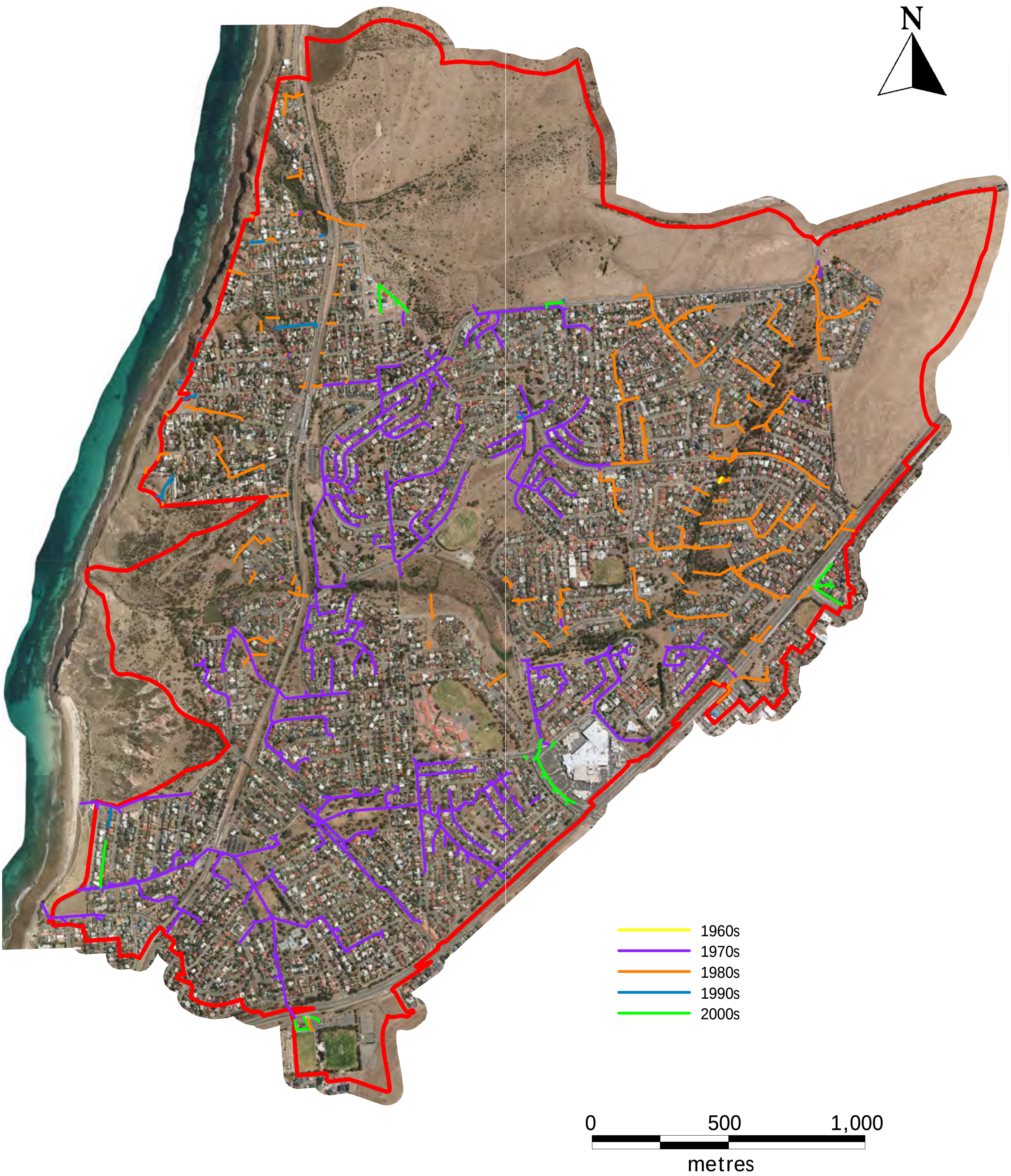
Data Sources:
City of Marion (Aerial Photograph, Stormwater)

Hallett Cove Creeks Catchment
Stormwater Management Plan

Figure 2.3

Existing Stormwater Infrastructure

southfront



Data Sources:
City of Marion (Aerial Photograph, Stormwater)

Hallett Cove Creeks Catchment
Stormwater Management Plan

Figure 2.4

Stormwater Infrastructure Age

2.3.2 Stormwater Asset Age

Data on the construction dates within Council's stormwater asset data is relatively complete, and is shown in Figure 2.4. This information confirms that the majority of the pipe network was constructed in the 1970s, and hence the stormwater network generally has a theoretical remaining useful life in excess of 60 years.

The oldest recorded stormwater asset is the Waterfall Creek culvert crossing at Arachne Drive (installed in 1968).

2.3.3 Previously Known Stormwater Management Issues

Information in relation to locations where drainage problems are experienced and stormwater management deficiencies exist across the Study Area was collated from City of Marion staff. The identified problems are as follows:

- Channel erosion of Waterfall Creek through the Hallett Cove Conservation Park
- Isolated erosion and scouring within creeks
- Maintenance options and responsibilities for a short section of Waterfall Creek that is aligned on the boundary of a Council reserve and residential property
- Under capacity drainage in Ramrod Avenue (adjacent to Hallett Cove Shopping Centre)
- Degraded biodiversity along watercourse corridors
- Lack of clarity in relation to the role of the Lucretia dam, and lack of environmental flows downstream to support watercourse revegetation efforts in the Hallett Cove Conservation Park
- 'Backing up' of Waterfall Creek upstream of the Quailo Avenue culvert, resulting in deep ponding within the reserve that threatens to spill onto the adjoining roadway.
- Flow from Lonsdale Highway into Ragamuffin Drive via a bare earth swale drain, resulting in deposition of silt and debris on Ragamuffin Drive
- No stormwater harvesting and reuse
- Limited Water Sensitive Urban Design elements to achieve water quality improvement prior to discharge to the Gulf

On the evening of 7 January 2012, a heavy rainfall event was recorded over southern metropolitan Adelaide. In response to this event, pluviometer data from surrounding rain gauges was collated, the catchment area was inspected for signs of drainage issues and Council staff provided feedback on any relevant correspondence with residents. This assessment determined that:

- The rainfall event over Hallett Cove was a 5 to 10 year ARI 30 minute duration storm event
- A complaint was received in relation to spill from Sovereign Street (near Taeping Street) into a low-lying property
- A complaint was received in relation to a spill from the First Street roadway into driveways leading down into a low-lying property
- Debris on Ragamuffin Drive was observed
- 'Backing up' of Waterfall Creek upstream of the Quailo Avenue culvert was again reported

The frequency of the recorded event (5 to 10 year ARI) is similar to the performance standard typically adopted for the design of underground drainage systems, and the duration of the event (30 minutes) is considered to be close to the critical duration for many of the larger drainage systems within the catchment. Therefore, the event was a very useful examination of the performance of the minor drainage system. That the event produced relatively few issues across the Study area indicates that the minor drainage system generally performs well, and / or safe overflow paths are available where system capacities are exceeded.

2.3.4 Proposed Infrastructure

A number of stormwater management projects are in the planning, design or implementation phases, as summarised in Table 2.2 below.

Table 2.2 Proposed Stormwater Management Projects

Project	Brief Description	Est Cost	Status
Glade Crescent Wetland	Transformation of (degraded) Glade Crescent Reserve to a high quality open space incorporating inline wetlands on Waterfall Creek	$7m (landscaping and civil)	Detailed design complete, City of Marion budget allowance of $200K/yr in place but other funding partners sought
Ramrod Avenue Drain	Capacity and Structural condition of drain determined to be inadequate for existing development and future development of the Southern Community Centre		Investigation complete, works not budgeted
Waterfall Creek - Hallett Cove Conservation Park	Urgent works to address erosion of the creek channel within the Park	$150,000	In construction, works funded by City of Marion and AMLR NRM Board

Further detail on these projects, and recommendations on how each of these projects are proposed to be integrated into the broader catchment-wide strategies is provided in Sections 4, 6 and 6.2.1.

2.4 Existing Land Use

Settlement in Hallett Cove dates from the late 1930s with the land used mainly for farming and quarrying. Until 1970s development consisted of a few scattered holiday shacks and houses connected by dirt tracks (refer Figure 2.5 below).

Figure 2.5 Historical Aerial Photograph (January 1969)

Urban growth in the area was slow due to the area being isolated. Significant and rapid urban growth took place during the early 1970s to 1980 as part of the development boom in Adelaide. Since the 1980s urban development has continued at a reduced rate. As shown in Figure 2.6 below, development within Hallett Cove is relatively new within the City of Marion context.

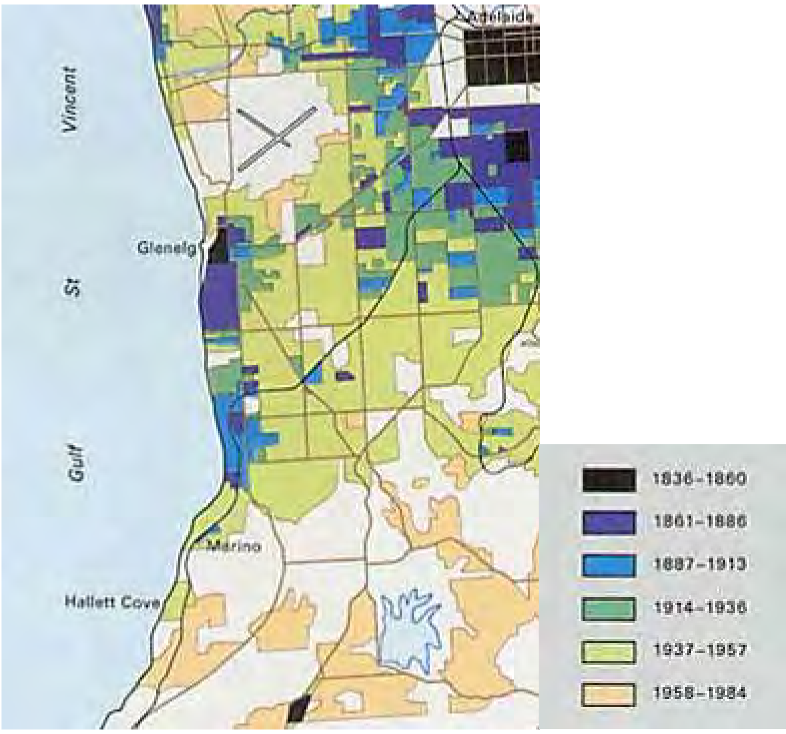
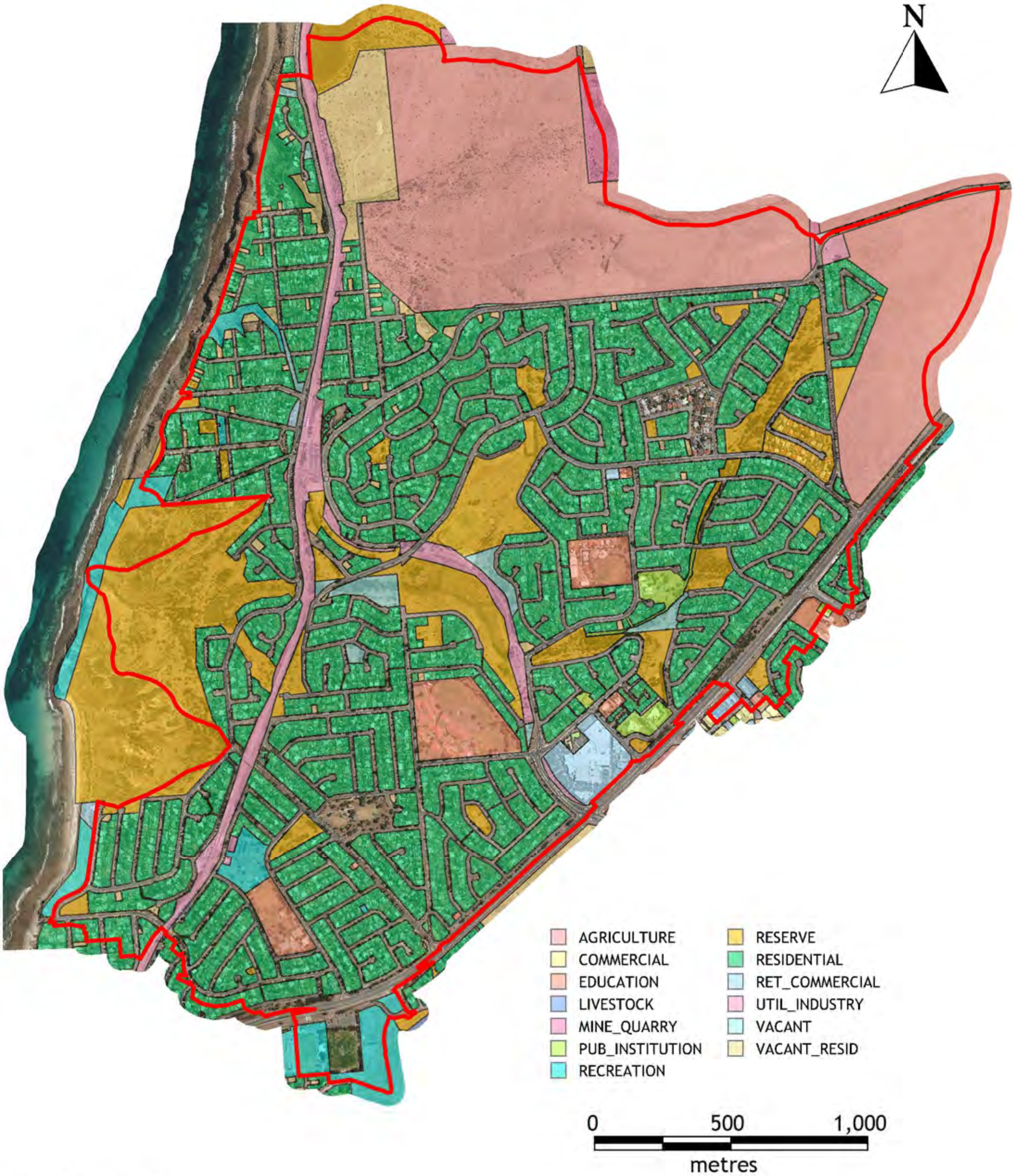


Figure 2.6 Adelaide Urban Development 1836-1984 (from atlas.sa.gov.au)

The Hallett Cove Creeks catchment area is now predominantly residential, with only limited retail areas (chiefly associated with the Hallett Cove Shopping Centre) and no industrial or commercial development (refer Figure 2.7). Agricultural areas north of Perry Barr Road and east of Aroona Road are within the 'Hills Face' development plan zone (refer Figure 2.8) and hence are not currently subject to future residential development.

Large areas of reserve (principally the Hallett Cove Conservation Park, and watercourse corridors) have been quarantined from development which is reflective of more contemporary planning principles and stormwater management requirements (incorporating the minor / major drainage system design approach) that are likely to have been applied to the development of these residential areas. This is in contrast to older metropolitan areas where watercourse corridors are generally not in public ownership or have been significantly modified to provide flood protection.



Data Sources:
City of Marion (Aerial Photograph)
DPLG(Land Use)

Hallett Cove Creeks Catchment
Stormwater Management Plan

southfront

Figure 2.7

Generalised Land Use

2.5 Land Development Potential

2.5.1 Introduction

The way in which stormwater is currently managed in the Hallett Cove area is the product of the way in which urban development has unfolded in years gone by. In addition, the way in which urban development continues to occur in the area will significantly impact upon stormwater challenges.

To help understand these issues, an assessment of development potential has been undertaken to identify recent and anticipated development trends in the study area. The assessment is based upon analysis of:

- The existing development plan policy
- Recent trends (i.e. what is happening on the ground)
- 2006-2026 population projections prepared by the Department of Planning and Local Government in 2011
- Analysis of Housing Consumption and Opportunities in the City of Marion prepared by i.d. Consulting in March 2011
- Anticipated changes to development policy in line with Council and State Government urban growth goals.

This assessment also includes a review of Council's Development Plan to identify any potential barriers to the effective implementation of the Stormwater Management Plan. This assessment has been prepared on the basis of a desktop review of key State and Local Government planning documents, supplemented by targeted consultation with real estate agents in the area (see Appendix A for details).

2.5.2 Existing Development Policy Context

The majority of land within the study area is located in the Residential Zone of the Marion (City) Development Plan. Within the Residential Zone, there are two "Policy Areas" which cover different parts of the study area, for which there are different development controls.

Residentially zoned land between the coast and the railway line is located in the Hills Policy Area 11. The Development Plan guidelines for this area anticipate development at very low densities due to the sloping topography and desire to maintain an open character and coastal views. The minimum allotment size in this Policy Area ranges from 700 to 1100 square metres depending on the slope of the land. In addition, all forms of dwellings except 'detached dwellings' and 'group dwellings' are 'non complying' forms of development. This means that the existing Development Plan policy for this area discourages urban infill development, meaning that most development is likely to be the replacement of detached dwellings with the same.

The Development Plan guidelines that apply to residential land east of the railway (Southern Policy Area 18) are more accommodating of urban infill development. While separate homes on large allotments are currently the dominant housing type, the Development Plan anticipates new development at higher densities so as to provide a more diverse mix of housing options. This is reflected in how a range of dwelling types (e.g. semi detached dwellings, row dwellings and group dwellings) are envisaged in the area, and the minimum allotment sizes, which vary from 250sqm to 420sqm depending on the dwelling type. As such, the Development Plan anticipates a degree of transformation of the urban from in this Policy Area with redevelopment occurring at generally higher densities to what currently exists. This sort of development generally increases the impervious site coverage and thus stormwater runoff.

Due to the age of the housing stock, there are no historic conservation, heritage or character areas within the study area that otherwise might provide a constraint for redevelopment. There is one Local and one State Heritage Place in the study area.

The study area contains a District Centre Zone on Lonsdale Road, which contains the recently redeveloped Hallett Cove Shopping Centre and a range of community facilities. The Development Plan anticipates medium density housing (to a maximum of two storeys in height) at some locations within the District Centre, which is likely to increase the impervious site coverage and thus stormwater runoff.

The other planning zones which apply to land in the study area are the Conversation, Coastal Conservation and Coastal Open Space Zones. While each of these zones has a slightly different function, they are similar from a development control perspective in that most forms of buildings and other forms of development that increase impervious site coverage are not appropriate.

Finally, the Marion Development Plan has undergone its conversion to the South Australian Planning Policy Library (SAPPL) format. This means it has adopted the standardised planning polices from the State Government's "library" of planning policy.

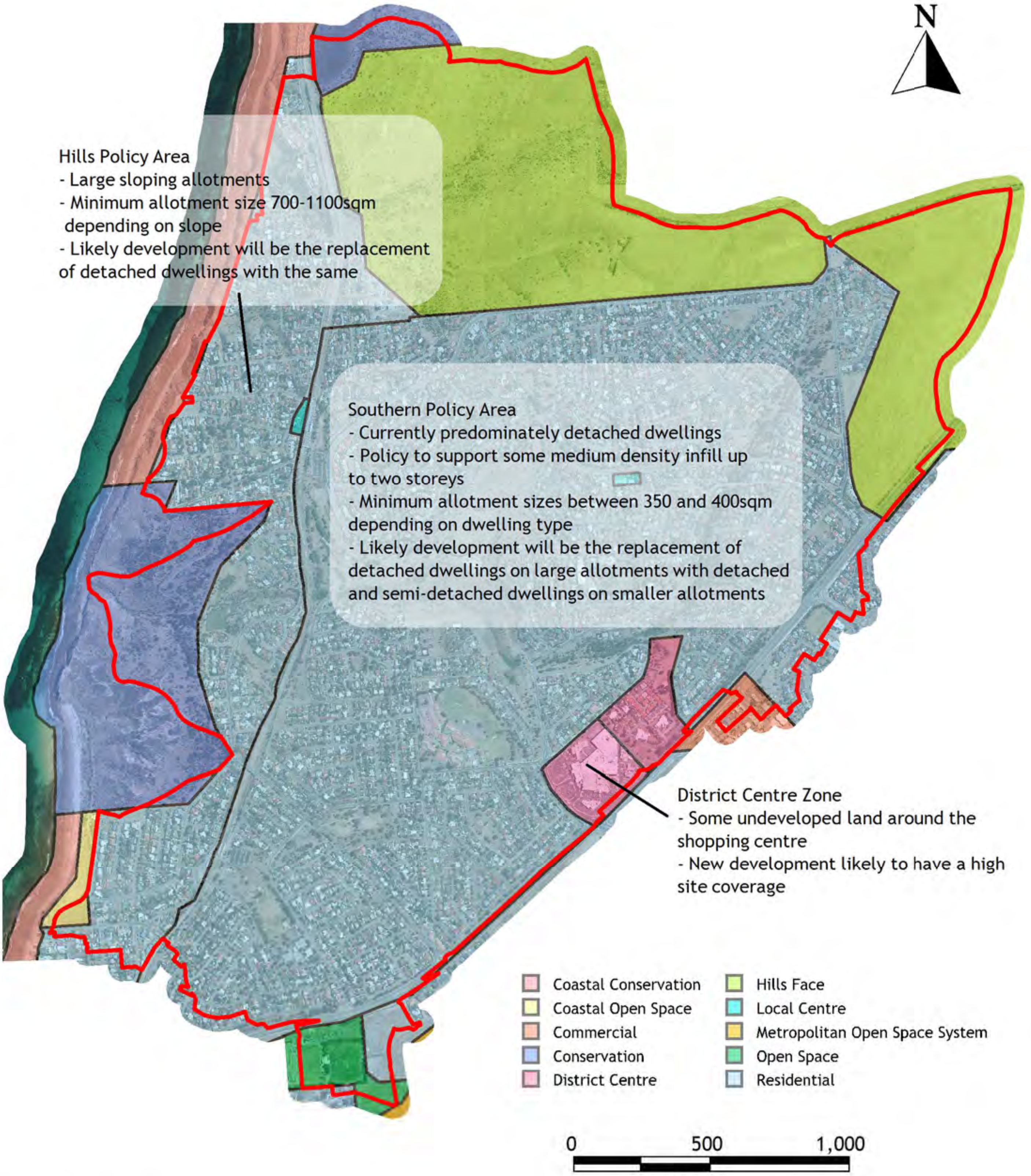
These include provisions under the heading of "natural resources" that address a range of stormwater issues, including ensuring that development maximises the use of water resources, protects stormwater from pollution, protects and enhances the quality of receiving waters and prevents the risk of downstream flooding. As such, there are comprehensive planning guidelines in the Marion Development Plan that seek to manage the stormwater impacts of new development and also will support the implementation of works resulting from the Stormwater Management Plan.

The conversion of Marion's Development Plan to the SAPPL format was done at a time when "Water Sensitive Urban Design" had not yet been explicitly incorporated into the planning policy library. It is likely that the Development Plan will be updated in coming years in line with the clear State Government policy agenda on water sensitive urban design. That being said, the provisions in the Marion Development Plan do support the concept of "water sensitive urban design" in new development, albeit without explicitly using the term.

Figure 2.8 provides a summary of the existing Development Policy Context.

Summary and Implications for Stormwater Management

- Under the current Development Plan policy, there will be very little redevelopment west of the railway line that increases stormwater runoff
- There is likely to be some infill development east of the railway line that increases stormwater runoff
- Development within the Hallett Cove District Centre Zone is likely to increase stormwater runoff.



Data Sources:
City of Marion (Aerial Photograph)
DPLG (Development Zones)
URPS (Policy Context Summary)

Hallett Cove Creeks Catchment
Stormwater Management Plan

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Figure 2.8
Existing Development Policy Context

2.5.3 Recent Development Trends

The then Department of Planning and Local Government's 2010 Report of the Housing and Employment Land Supply Program (HELSP) contains mapping which documents land division proposals and new dwellings constructions across Greater Adelaide since 2005.

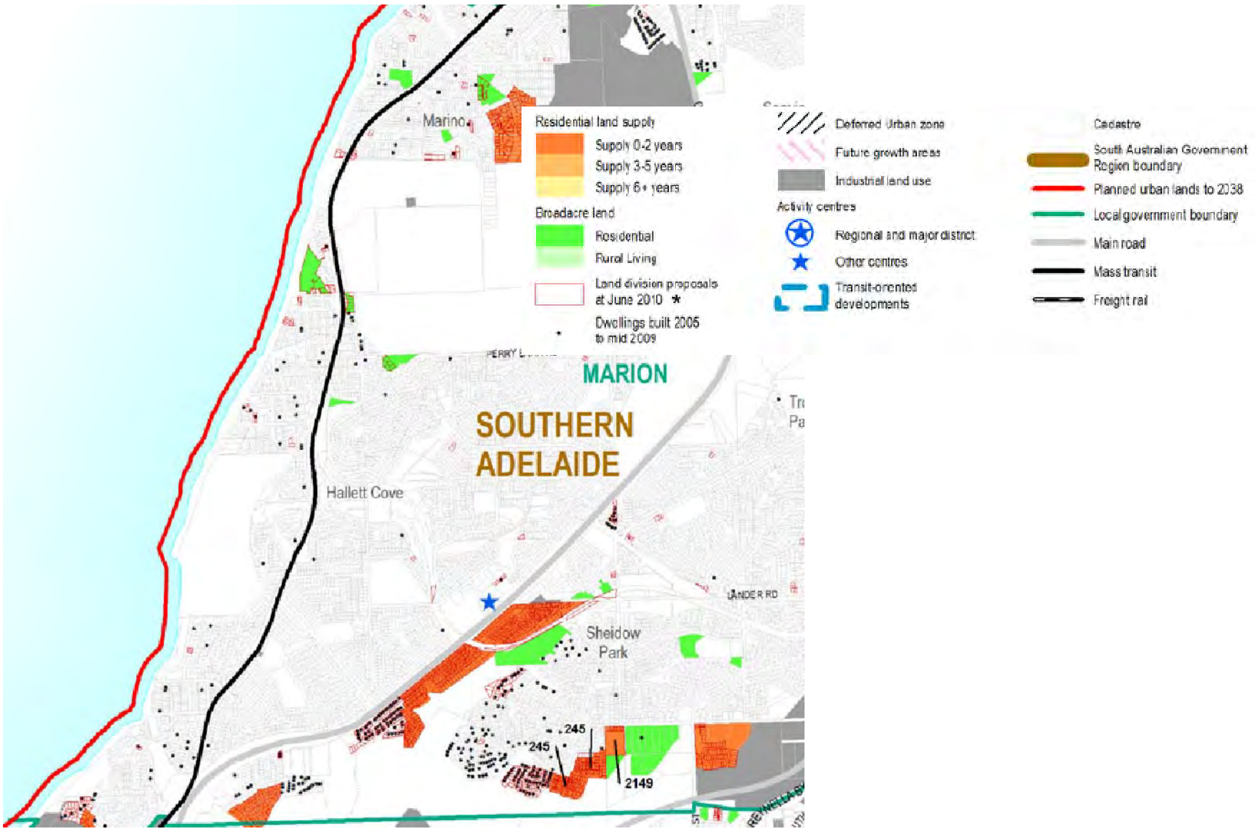


Figure 2.9 Southern Adelaide Region Map extract (DPLG, 2010)

The Southern Adelaide Region Map (refer to shows that there has been very little new development activity in the study area since 2005. There is an observable absence of land division proposals in the study area and a small number of recently constructed dwellings, which are generally located close to the coast, where higher land values may support redevelopment of older homes. The lack of land division proposals associated with these new dwellings suggests that this redevelopment is likely to be the replacement of existing detached dwellings with the same, or the construction of new dwellings on previously undeveloped allotments.

It is likely that there has been very little land division activity and 'infill' development in the study area because most homes were constructed between 20 and 40 years ago, and therefore the capital value of properties are relatively high with respect to the site (land) values. As a general rule, redevelopment of established properties will only occur on sites where the capital values of properties are not significantly higher than the site values.

The lack of residential development in the study area is somewhat unique when considering the broader City of Marion context. Other mapping in the HELSP Report reveals that there has been a large amount of land division and new dwelling constructions (i.e. urban infill development) in the older parts of the Council area, such as in Dover Gardens, Seacombe Gardens and Oaklands Park. Other parts of the Council area, such as the southern parts of

Sheidow Park, contain pockets of undeveloped land, which are being developed as greenfields development.

These trends were also noted by i.d. Consulting in their Analysis of Housing Consumption and Opportunities which was prepared in March 2011. This report states that there has been very little redevelopment in the southern parts of the Council area in recent times, which contrasts to the northern and central parts of the Council area which are in a different stage of the "suburban life cycle". The i.d. analysis also identified that while couple families with children have historically been the dominant housing type in the Council area (including in Hallett Cove), there has been significant growth in middle aged lone person households, which has implications for the sorts of housing that may be developed into the future.

These development trends in Hallett Cove were 'ground truthed' through interviews with developers and estate agents. Informants commented that in the past few years there has been a few instances of the older properties in the area (i.e. those constructed between 1970 and 1975) being redeveloped as 2 detached or semi-detached dwellings. However, it was generally thought that this sort of infill development is not likely to 'take off' in the area for another 10 years due to the relative value of the properties. Informants explained that currently, most dwellings on the market in the study area are on-sold to families.

Informants identified that there is a lack of smaller housing, and housing on smaller allotments. It was identified that it is generally not difficult to sell units and homettes in the study area, because these are in high demand due to the dominance of large homes on large allotments in the area. One informant noted that demand for housing for older people is expected to grow in coming years, as housing options for older people are currently very limited. Finally, most informants considered that there would be demand for more compact forms of housing around the two train stations and the Hallett Cove District Centre, although they thought that townhouses to a maximum of two storeys are more likely to be developed, than more substantial apartment complexes.

Summary and Implications for Stormwater Management

- There has been very limited infill development in recent times that has increased stormwater runoff
- It is expected that there will be increased demand for some infill development in the future, especially around the District Centre and train stations.

2.5.4 Anticipated Changes to Development Policy

The 30 Year Plan for Greater Adelaide outlines the State Government's spatial land use framework to accommodate an anticipated population growth of 560,000 people over the next 30 years. Broadly, the Plan seeks to grow the city "upwards, not outwards" by focusing growth in new urban developments at higher densities/scale in the city and locations well serviced by public transport and other facilities.

The Southern Adelaide region is expected to grow by 82,000 people in the next 30 years, 48,400 of whom are expected to live "within corridors", that is, within close proximity to the Noarlunga/Tonsley train lines and the Glenelg tram.

The study area is dissected by the Adelaide-Noarlunga railway line. This railway is identified as a "major corridor" in the 30 Year Plan and the track itself will be electrified in coming years. The Hallett Cove and Hallett Cove Beach railway stations (located in the study area) have both been recently upgraded as part of the State Government's rail revitalisation project.

In line with the 30 Year Plan directions, it is likely that land around these stations will be structure planned and rezoned to support redevelopment of housing at higher densities. This will occur to increase the number of people living within walking distance of the upgraded rail infrastructure. Although the specific details are yet unknown, it is reasonable to assume that more intense development that increases dwelling yield and impervious site coverage will be located within a radius of approximately 400-800 metres around these two stations.

In addition, the 30 Year Plan identifies the land between the railway and coast at Hallett Cove as a "potential regeneration area", which may also increase dwelling yields. It is noted that this is inconsistent with the existing Development Plan policy in the Hills Policy Area 11 that encourages lower density development in the area due to the topography and expansive views.

The Analysis of Housing Consumption and Opportunities prepared by i.d. Consulting identifies that the suburb of Hallett Cove has the potential to accommodate infill development that yields approximately 471 new dwellings, and the land around the District Centre can be expected to yield approximately 68 new dwellings. As such, the anticipated growth in the study area is not significant.

Summary and Implications for Stormwater Management

- The population of the study area is projected to grow modestly
- It is likely that residential densities will increase around the Hallett Cove and Hallett Cove Beach stations in the future in line with the 30 Year Plan
- Potential dwelling yields have been modelled at 471 infill dwellings across Hallett Cove, and 68 dwellings around the District Centre
- New development at higher residential densities will increase stormwater runoff, however the magnitude of redevelopment is not significant.

2.6 Non-Potable Water Demand

A desktop assessment has been made of the locations and demands for non-potable water within the catchment. The locations identified (summarised in Table 2.3 below) are all irrigated ovals and reserves. The annual average irrigation demand has been calculated based on an assumed requirement of 3.6 ML/ha/yr, which is consistent with irrigation to a 'Turf Quality Visual Standard Classification No 3 - Local sports turf' standard (SA Water, 2007).

It is apparent from inspection of historical aerial photography that some areas are not irrigated sufficiently during summer, which highlights that stormwater harvesting for the purposes of irrigating these areas would not only have a direct stormwater management benefit, but would also create indirect benefits including an enhanced recreational experience for the local community, schools and sporting organisations.

Table 2.3 Non-potable water demand sites

Location	Irrigated Area (ha)	Estimated Demand (ML/yr)
Council Reserves		
Cove Sports and Community Club Oval and pitch	2.1	7.6
Pavana Avenue Reserve	0.5	1.8
Capella Drive Reserve	1.5	5.4
Heron Way Reserve	1.3	4.7
School Ovals		
Hallett Cove South Primary School	1.0	3.6
Hallett Cove East Primary School	0.9	3.2
Hallett Cove R-12 School	2.3	8.3
Total	9.6	34.6

2.7 Hydrogeology

Hydrogeological zones across the metropolitan Adelaide area have previously been defined on the basis of hydrogeological characteristics (DWLBC, 2006). The Hallett Cove area is nominated as part of a large area to the south and east of the Eden Fault referred to as Zone 1. This zone covers the basement rocks of the Adelaide Hills and contains fractured rock aquifers.

During the development of the Glade Crescent wetland design concept (PB, 2008), an assessment was made of the local geological conditions and the likelihood that an Aquifer Storage and Recovery (ASR) scheme could be established. This assessment reported the following:

> *"The site is underlain by bedrock, which consists of thick sequences of siltstone and shale. With the absence of a confined highly permeable aquifer it is considered highly unlikely that the site has suitable geological conditions for ASR.*
>
> *Fractured rock storage systems have a relatively small storage capacity and injection of water can carry considerable distances through the fracture network of the rock mass, which may result in a reduced recovery rate."*

It is apparent from this assessment that stormwater harvesting schemes within the Hallett Cove area will need to explore alternative storage options.

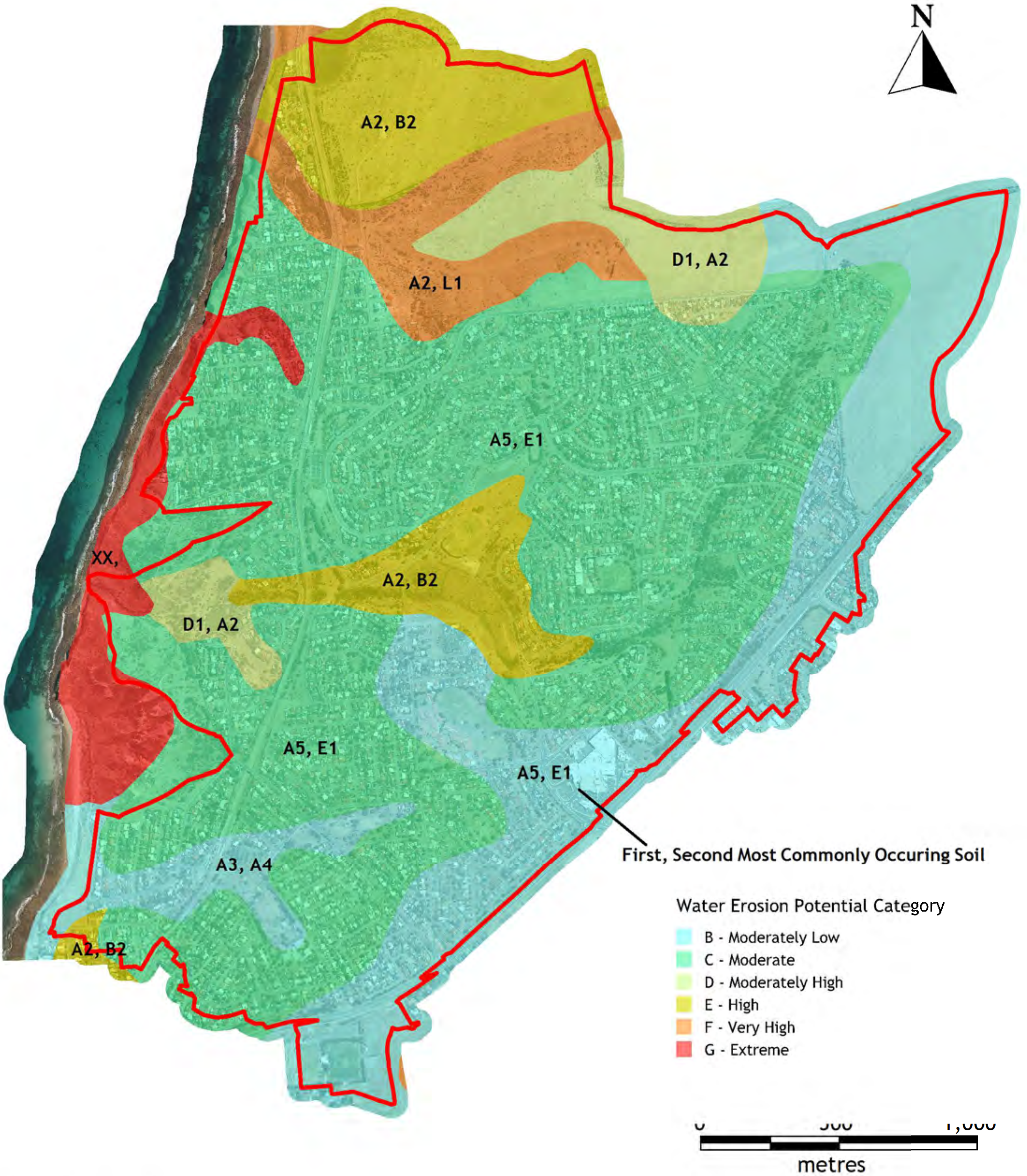
2.8 Soils

Soil Landscape map unit data has been obtained for the area from PIRSA. This data classifies areas according to the predominant soil group. The two most commonly occurring soils defined in this data set are shown in Figure 2.10. The definition of the depicted soil group categories are as follows:

A2	Calcareous loam on rock
A3	Moderately calcareous loam
A4	Calcareous loam
A5	Calcareous loam on clay
B2	Shallow calcareous loam on calcrete
D1	Loam over clay on rock
E1	Black cracking clay
L1	Shallow soil on rock
XX	Miscellaneous (Not applicable)

A range of generalised attributes have also been assigned to each of these delineated areas, and this includes a rating for water erosion potential. This generalised assessment is understood to be based on the predominant slope range and predominant soil erodibility. Land is assumed to be in a bare, clean cultivated state for the purpose of making a consistent interpretation.

The mapping seems to reflect the highly erodible nature of soils adjacent to the watercourse corridors and clearly this is a high risk issue within the catchment.



Data Sources:
City of Marion (Aerial Photograph)
PIRSA (Soils)

Hallett Cove Creeks Catchment
Stormwater Management Plan

southfront

Figure 2.10
Soil Groups, Water Erosion Potential

2.9 Local Marine Environment

2.9.1 Introduction

Stormwater from the Study Area discharges directly into Gulf St Vincent within the Adelaide Coastal Waters Study (ACWS) zone. The ACWS determined that nutrients, particularly nitrogen (N) from stormwater and wastewater are likely to be responsible for broad scale seagrass loss along the Adelaide metropolitan coast, with turbidity from sediments carried by stormwater possibly contributing, especially in the near-shore zone (Fox *et al.* 2007). Nutrients and sediment loads are also implicated in the loss of large brown canopy algae from temperate reefs, and a shift to turf-dominated assemblages (Gorgula and Connell 2004; Turner 2004).

The Draft Adelaide Coastal Waters Quality Improvement Plan (ACWQIP) has adopted the targets recommended by the ACWS, specifically, a 50% reduction in sediment loads and a 75% reduction in N from 2003 levels (McDowell and Pfennig 2011) from all flow inputs (wastewater, stormwater and industrial).

Heavy metals and other contaminants potentially carried in stormwater have periodically exceeded levels of concern in Adelaide waters; although not considered an important factor in historical seagrass decline (Fox *et al.* 2007), these may pose a risk to receiving environments if present in sufficient concentrations (Mills and Williamson 2008; Gaylard 2009).

This Stormwater Management Plan includes water quality management strategies for the study area, which have been developed to mitigate impacts on the receiving waters based on the level of risk from sediment, nutrients and other potential contaminants carried in stormwater, and with regard to the targets of the ACWQIP. To inform the risk assessment component of this process, knowledge of the marine benthic habitats located within the study region is required, as well as a description of the specific risks to these habitats from stormwater. The sections below describe the habitats of the region and summarises these risks.

2.9.2 Methods

Information on marine benthic habitats surrounding the Hallett Cove area was collated from existing data sources and a review of published literature. Data sources used include benthic habitat classifications and supporting video data used by the Department of Environment and Natural Resources (DENR, formerly Department for Environment and Heritage) to create marine benthic habitat maps for the Adelaide and Mount Lofty Ranges NRM region (DEH 2008), and data collected by the South Australian Research and Development Institute (SARDI) Aquatic Sciences during Reef Health surveys (Turner *et al.* 2007; Collings *et al.* 2008) and seagrass mapping of the Adelaide coast (Bryars and Rowling 2008). The location of these data points is shown in Figure 2.11. The region of interest was taken to be that within a 5 km radius of the Hallett Cove SMP area, from the shore to a maximum depth of 20 m, or to the extent of benthic habitat data where different (refer Figure 2.11). A literature review of potential impacts of stormwater on marine environments was then performed, with a focus on effects on the major habitats occurring in the region.

2.9.3 Marine Benthic Habitats of the Hallett Cove region

A map of the major marine benthic habitats surrounding the Hallett Cove SMP area is shown in Figure 1, with more detailed habitat composition shown in Figure 2.12. Low profile reef extends along most of the coast and comprises 7.1% or the total habitat in the area of interest, with medium profile reef comprising a further 0.6%; these reefs support a continuous cover of sparse to medium density macroalgae (shown in Figure 2.11 and Figure

2.12; DENR benthic habitat data). The remainder of the area of interest has unconsolidated substrate, with cover of seagrass to the north and patchy macroalgae to the south. Seagrass habitats comprise 44.0% of the total area, with seagrass cover in these areas being sparse and patchy off shore, but continuous and medium to dense near shore, particularly at 5-10m depth (shown in Figure 2.11 and Figure 2.12; DENR benthic habitat data). Sand or gravel substrate with sparse macroalgae comprises 35.2% of the area, with bare sand comprising 12.9% and sparse invertebrate communities 0.2% (Figures 1 & 2; DENR benthic habitat data). Invertebrate communities are defined as large invertebrates providing structure, e.g. *Pinna bicolor* (DEH 2008), but the specific nature of the communities off Hallett Cove is not known.

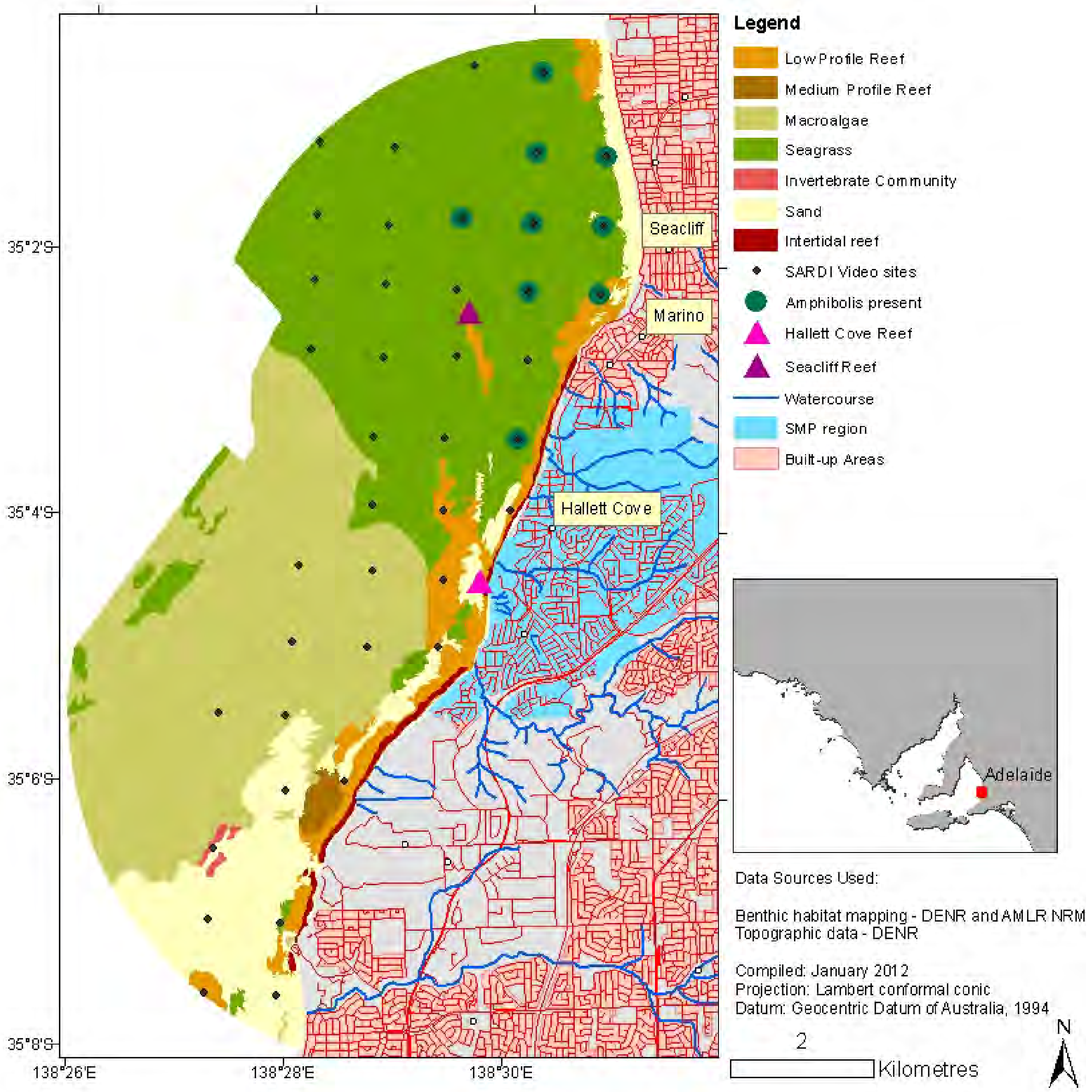


Figure 2.11 Benthic habitat classification

The majority of seagrass in the area is *Posidonia*, but a meadow of *Amphibolis antarctica* occurs in the northern part, offshore from Seacliff/Marino; this is one of only a few areas of *Amphibolis* in southern Adelaide metropolitan waters (Bryars and Rowling 2008; SARDI data; shown in Figure 2.11).

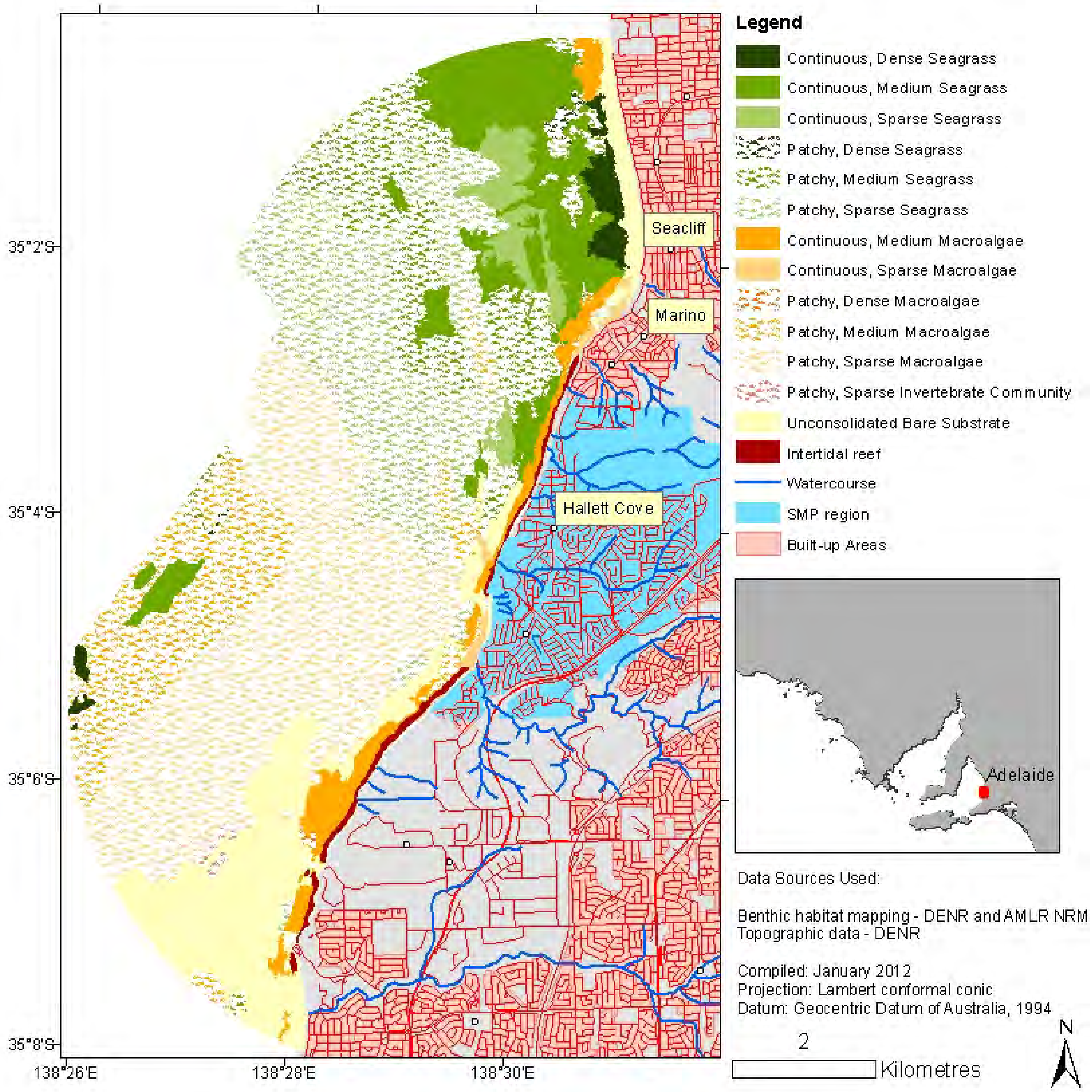


Figure 2.12 Benthic habitat structure and biota

Two reefs within the area, Hallett Cove and Seacliff, were surveyed as part of the Reef Health program (Turner *et al.* 2007; Collings *et al.* 2008). These two reefs were classed as "Good" and "Caution" respectively based on both the 2005 (Turner *et al.* 2007) and 2007 surveys (Collings *et al.* 2008). Hallett Cove reef had a cover of 99-100% canopy macroalgae over both survey years (Turner *et al.* 2007; Collings *et al.* 2008) with common kelp, *Ecklonia radiata*, and *Sargassum* spp, particularly *S. linearifolium*, dominant, and *Cystophora*, particularly *C. siliquosa*, also present (SARDI Reef Health data). Seacliff reef had 25% cover of canopy species in 2005 (Turner *et al.* 2007), increasing to 48% in 2007 (Collings *et al.* 2008). This deeper (~12m compared with 5m at Hallett Cove) reef was dominated by *Sargassum* (*S. paradoxum* and *S. linearifolium*), with *Cystophora* spp (mainly *C. monilifera*) and *Ecklonia radiata* also present (SARDI data).

Intertidal reef also occurs along the Hallett Cove coast (refer Figure 2.11 and Figure 2.12), extending to the south of the region of interest. This intertidal reef is a complex environment consisting of several habitat types, and supports a very high macroalgal diversity compared to other intertidal reefs of the Fleurieu Peninsula (Benkendorff and Thomas 2007).

2.9.4 Risks from stormwater outflows

Potential risks from stormwater are suspended sediments, which have impacts through light reduction (turbidity) and sedimentation, nutrients, other contaminants such as metals, pesticides, herbicides and hydrocarbons, and reduced salinity due to freshwater inputs (Gaylard 2009). The specific risks to reef and seagrass habitats are discussed below.

Suspended sediments

Sediments carried by stormwater are the main cause of turbidity in shallow waters (<5 m) along the Adelaide coast, and as discharged stormwater tends to move along shore with minimal mixing with deeper water, discoloration may persist for several days (Fox *et al.* 2007; Gaylard 2009). Turbidity increases light attenuation, leading to a lesser proportion of light penetrating to a given depth (Collings *et al.* 2006b). Light limitation is known to have negative impacts on seagrass such as reducing maximum depth range for growth (Abal and Dennison 1996), and causing decreased biomass, shoot density and productivity, and depletion of starch resources (Ruiz and Romero 2001; Ruiz and Romero 2003; Mackey *et al.* 2007). Macroalgae can be expected to be similarly impacted by light reduction due to turbidity (Turner and Collings 2008; Gaylard 2009). The growth rate of *Fucus* spp in the Baltic was found to be strongly dependent on light intensity, with reduction in light availability leading to loss of the algae from waters >6 m deep (Rohde *et al.* 2008). Turbidity reduces light penetration in Adelaide's shallow coastal waters (3-6 m deep); average light intensity is in the range sufficient for seagrass growth, but variability in available light due to the periodic nature of sediment influxes may reduce productivity and have contributed to loss of seagrass in this zone (Collings *et al.* 2006b). Interactive effects between turbidity and nutrients may also contribute to seagrass loss and shifts in benthic community composition (De Casabianca *et al.* 1997; Wear *et al.* 2006).

As well as reducing light in the water column, sediments have impacts through siltation. Sedimentation may restrict light at the level of seagrass leaves, and smother plants by preventing gas exchange (Ralph *et al.* 2006). Burial of shoots and seeds, and erosion by sediment movement can also cause loss of or damage to seagrass (Marba and Duarte 1995; Preen *et al.* 1995; Duarte *et al.* 1997; Bryars *et al.* 2008). Sedimentation has also been shown to have negative impacts on reef macroalgae and other biota through smothering, scour and a reduction in available hard substrate (Airoldi 2003). Deposition from a dredge plume resulted in a decrease in the recruitment of canopy algae species to southern Adelaide reefs (Turner 2004) and increased sedimentation from terrestrial sources has been shown to promote a shift toward macroalgal communities dominated by turfing rather than canopy species (Airoldi and Cinelli 1997; Gorgula and Connell 2004). Sedimentation can also cause changes in unvegetated soft bottom habitats due to alteration of sediment structure, smothering or burial of organisms, and clogging of gills and filter feeding structures (Mills and Williamson 2008; Gaylard 2009).

Hallett Cove reef experiences one of the highest levels of sedimentation of Adelaide's metropolitan reefs, with much of the sediment originating from the Field River and Christies Creek, as well as the Onkaparinga River and cliffs (Fernandes 2008; Fernandes *et al.* 2008), although the specific contribution of stormwater to this sediment load has not been assessed.

2.9.5 Nutrients

Wastewater effluent is currently the major source of nutrients entering Adelaide coastal waters, but the contribution from stormwater is also significant (Gaylard 2009; McDowell and Pfennig 2011). Elevated nutrients promote the growth of epiphytic algae on seagrass, resulting eventually in loss of above ground seagrass biomass; *Amphibolis* appears more sensitive to this process than *Posidonia* which may explain why *Amphibolis* has been lost from Adelaide's coast to a greater extent (Collings *et al.* 2006a; Bryars and Rowling 2008). Eutrophication also promotes a shift in macroalgal community structure with increased cover of turfing species (Gorgula and Connell 2004). High concentrations of water column nutrients may cause acute toxic effects in seagrass (Collings *et al.* 2006a; Ralph *et al.* 2006) or promote algal blooms that reduce available light (De Casabianca *et al.* 1997; Ralph *et al.* 2006). Sediment-bound nutrients appear to have fewer toxic effects, but in high concentrations can lead to sediment anoxia and production of sulphides, both of which have been shown to negatively impact seagrasses (Ralph *et al.* 2006). Nutrients and sediments may have interactive impacts that are greater than either factor acting alone (Abal and Dennison 1996; De Casabianca *et al.* 1997; Gorgula and Connell 2004).

Other contaminants

Other contaminants often found in storm water are trace metals, hydrocarbons, including polycyclic aromatic hydrocarbons (PAH), pesticides, and herbicides. Stormwater may also have impacts through localised reduction in salinity (Mills and Williamson 2008; Gaylard 2009).

Metals, hydrocarbons, pesticides and herbicides may have acute or chronic toxic effects, and many can accumulate in sediments or in tissues, leading to bioaccumulation and magnification through the food chain (Mills and Williamson 2008; Gaylard 2009). Many toxicants bind to sediment or organic matter and are found at highest concentrations in stormwater that also carries high sediment and nutrient loads (Mills and Williamson 2008). Sediment-bound toxicants are generally less toxic to seagrass than soluble forms (Ralph *et al.* 2006), but may pose a risk to benthic fish and other organisms, e.g. flounder in a contaminated Auckland estuary had higher incidences of liver lesions than those from unpolluted sites (Mills and Williamson 2008). The toxic effects of many contaminants are described in ANZECC and ARMCANZ (2000b).

Marine organisms have variable tolerances to salinities above and below their optimal range, and these can vary within a species depending on genotype, acclimation and condition (Nell and Gibbs 1986; Nell and Holliday 1988; Westphalen *et al.* 2005; O'Loughlin *et al.* 2006; Gaylard 2009). Seagrasses are relatively tolerant of periods of lowered salinity, but long term exposure leads to reduced photosynthetic efficiency and eventually death (Westphalen *et al.* 2005; Touchette 2007). Many macroalgae are also tolerant of short term low salinity exposure, but this varies greatly between species; estuarine and intertidal species typically tolerate broader salinity ranges than subtidal species (Kirst 1990). Fish and invertebrates that live in estuaries and intertidal zones similarly show greater salinity tolerance than subtidal species (Nell and Holliday 1988; O'Loughlin *et al.* 2006). Australian water quality guidelines recommend that changes to salinity in marine environments should be less than 5% of back ground levels (ANZECC and ARMCANZ 2000a,b).

2.9.6 Summary

Marine benthic habitats of the Hallett Cove area consist of low to medium profile reef with continuous medium-density macroalgal cover, patchy to dense seagrass meadows, and areas of sparse seagrass and macroalgae, with a small proportion of unvegetated sandy substrate. The reefs located in the intertidal and subtidal adjacent to Hallett Cove are in good condition and support a very diverse community of macroalgae (Benkendorff and Thomas 2007; Turner *et al.* 2007; Collings *et al.* 2008). Seagrass in the northern part of the area, located off Marino/Seacliff, includes one of the few *Amphibolis* meadows remaining in southern Adelaide metropolitan waters (Bryars and Rowling 2008).

Potential risks to these habitats posed by stormwater include sediments, nutrient impacts, and contaminants such as metals, hydrocarbons, pesticides and herbicides. Stormwater is responsible for the majority of sediment input to Adelaide's coastal waters, and contributes significantly to nutrient loads (Gaylard 2009). The location of important reef habitats close to shore, including in the intertidal, means these habitats are at greatest risk, especially given that stormwater outflows may sometimes be retained in the near-shore zone (Fox *et al.* 2007; Gaylard 2009) and that both sediments and nutrients from stormwater may have detrimental impacts on canopy algae species through turbidity, siltation, eutrophication and interactive effects (Gorgula and Connell 2004; Turner 2004).

2.10 Climate Change

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

A number of studies and assessments have attempted to improve the understanding of the likely changes to the Adelaide climate brought about by climate change. For the purposes of this Stormwater Management Plan, the following figures have been adopted for the modelling of the future scenario to reflect a 2050 climate change scenario:

- Annual rainfall — 10% below recent averages
- Rainfall Intensity — no change

These assumptions are consistent with those adopted for the Holdfast Bay – Marion Stormwater Management Plan (Tonkin Consulting, 2012).

2.11 Rainfall

Rainfall isohyet maps prepared for the Adelaide region (DPLG, 2010 and DWLBC, 2006) indicate that the average annual rainfall at Hallett Cove is approximately 500 mm. Brighton is the closest coastal gauge site, with an annual average of 514mm.

A search for historical rainfall data (with a 6-minute time step) was undertaken. This data is required for the purposes of water quality and stormwater harvesting / reuse modelling, to both represent the existing scenario and future (climate change) scenario which is characterised by a lower average annual total.

A subset of the Noarlunga gauge record (for the period of 2001 to 2005 inclusive) was selected as the most representative rainfall record for the existing scenario. The average annual rainfall for this period of the rainfall record is 510mm. The remaining portion of the available record (2006 to 2010) was not selected as rainfall in this period was relatively very low (384mm annual average) and was considered to have an undue influence over the short record available.

The Adelaide Airport gauge (for the period 1967 to 2010) was selected as the most appropriate rainfall record for the future (climate change) scenario. The average annual rainfall for the rainfall record is 443mm (13% below the Noarlunga 2001-2005 average).

Figure 2.13 below compares the monthly averages for the Noarlunga gauge (over the selected 5 year period) with the Adelaide Airport gauge.

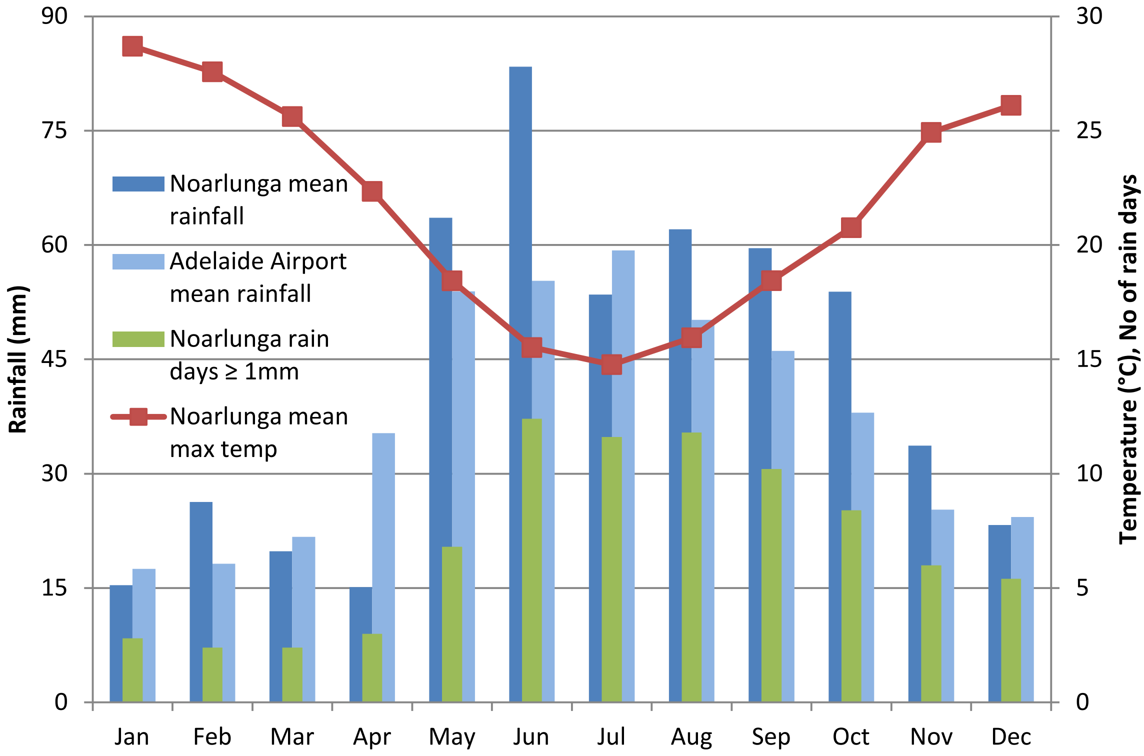


Figure 2.13 Monthly Rainfall Averages - Noarlunga (2001-2005), Adelaide Airport

3 Stormwater Management Plan Objectives

3.1 Stormwater Management Authority Guidelines

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

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

3.2 City of Marion Strategic Plan

The City of Marion has also committed to strategies and actions to "protect and restore natural assets, control impacts and adapt to change", as originally established in the *City of Marion Strategic Plan 2010-2020* (City of Marion, 2010), and further expanded in the *Healthy Environment Plan 2010-2014* (City of Marion, 2010).

Strategic directions and strategies outlined in these documents that are particularly relevant to stormwater management in Hallett Cove, and their linkages to the State Strategic Plan, are summarised in Table 3.1 below.

This objectives and strategies of this Stormwater Management Plan have been developed to be consistent with these overarching strategies. In subsequent sections of the report, reference has been made where actions recommended by this Plan directly contribute to the delivery of these strategies.

Table 3.1 City of Marion Healthy Environment Strategy Plans extract

Direction	Council-wide Target	Link with State Strategic Plan	Strategy	Objective	Action
HE 2 – Responsible management of water resources	600ML/yr stormwater reuse by 2020 All Council activities to use WSUD by 2020 Maintain mains water consumption at 40% below 2005/06 levels	Water - T3.9 Sustainable water supply	HE2.1 Investigate and implement alternative water sources and maximise water conservation, capture and reuse	2.1c - Develop Stormwater Master Plans to minimise flooding risk and maximise stormwater reuse	Develop and implement Stormwater Master Plans for all southern catchments of the Council area
				2.1d – Enhance public spaces through sustainable irrigation practices	Progressively replace water hungry Council plantings with more water efficient alternatives Develop a Sustainable Irrigation Plan for the Council which looks at water sensitive landscape design, water efficiency and use of alternative water sources
			HE2.2 Protect and improve surface water and groundwater quality	2.2a – Maintain and upgrade the Council's stormwater network to protect and improve stormwater quality	Trial and evaluate different Water Sensitive Urban Design (WSUD) techniques during infrastructure upgrades Develop and maintain stormwater infrastructure to protect water quality e.g. installing Gross Pollutant Traps (GPTs) Conduct regular streetsweeping across the Council to protect stormwater quality. Including responding to spills that have potential to impact on water quality.
				2.2c – Manage watercourses to maximise water quality and ecological	Work with the NRM Board to determine management needs of Waterfall Creek including protection of water quality and

				outcomes	maintenance of environmental flows Undertake maintenance and upgrade works at Waterfall Creek
HE3 – Enhanced landscapes, habitats and local biodiversity	No species loss as a result of human activity 90,000 local native plants planted in City of Marion by 2014 Establishment of the Great Southern Urban Forest	Biodiversity - T3.1 Lose no species - T3.2 Land biodiversity - T3.3 Soil protection - T3.4 Marine biodiversity	HE3.1 Protect, manage and restore inland coastal habitats	3.1b – Ensure development activities are compatible with protection and enhancement of biodiversity	
			HE3.2 Identify and develop ecological corridors	3.2a – Advocate for the development of the Great Southern Urban Forest	Support the retention of the Field River, Glenthorne Farm, Hallett Cove and Marino Conservation Parks and O'Halloran Hill Recreation Park as priority sites under the State Government's Urban Forests program. Support the expansion of State Government Parks (including Hallett Cove Conservation Park, Marino Conservation Park and O'Halloran Hill Recreation Park) to maximise connectivity to surrounding open space
			HE3.3 Increase the planting of local native plants in Marion's open spaces	3.3b – Increase local biodiversity through revegetation of key Council reserves	Conduct revegetation and maintenance at/along: - Glade Crescent / Capella Drive/ Coorabie Reserve, Hallett Cove
Strategic Projects Supporting a Healthy Environment: HESP 1 Enhance the Southern Environment					
HESP1.1 Facilitate the establishment of the Great Southern Urban Forest					
HESP1.2 Design and establish new wetlands at Glade Crescent, Hallett Cove					
HESP1.3 Develop Hallett Cove Beach Master Plan including provision of management of coastal erosion					

3.3 State Draft WSUD Objectives

In recent years, a number of documents have been published which have attempted to define desirable catchment-wide stormwater management performance measures, in relation to water quality improvements to manage marine impacts particularly along the Adelaide coastline (CSIRO, 2007 and EPA, 2011), and to mandate Water Sensitive Urban Design principles in new development (DPLG, 2010 and Department for Water, 2012).

The *Water Sensitive Urban Design Consultation Statement* (Department for Water, 2012) is a consultation document, and while this has not been adopted as State Government policy, it is a carefully considered document drawing on previously published investigations and commissioned research. Hence, the proposed State-wide objectives proposed by this document have been selected as a basis for objectives for this Stormwater Management Plan.

The proposed state-wide WSUD objectives are:

- *To support the sustainable use of natural water resources that provide our water supplies and to help ensure that our water supplies are resilient to climate variation, by conserving water:*
  - *Encourage leading practice in the use and management of water resources to minimise reliance on imported water.*
  - *Promote safe, sustainable use of rainwater, recycled stormwater and wastewater.*

- *To help to protect the health of water bodies and associated ecosystems in or downstream of urban areas, by managing runoff and maintaining or improving water quality:*
  - *Encourage a more natural runoff regime, for example by promoting local retention, detention and slowing urban runoff, where appropriate.*
  - *Maintain and where necessary enhance water quality, for example, by seeking to reduce catchment pollution; mitigating the entrainment of pollutants in surface flows, infiltrated soil and groundwater; and minimising the export and impact of contaminants in wastewater.*

- *To complement other measures (including at catchment scale) that aim to manage the potential flood-related risk associated with urbanisation, by managing runoff:*
  - *Encourage a more natural runoff regime, for example by promoting local retention, detention and slowing urban runoff, where appropriate.*

- *To promote the potential for WSUD to support other relevant State, regional, and local objectives, by encouraging integrated planning, design and management of WSUD measures that maximise the potential to achieve multiple outcomes:*
  - *Recognise the role WSUD can play in supporting other State, regional or local objectives.*
  - *Promote engagement between those responsible for planning, designing and managing WSUD measures and other relevant stakeholders so as to maximise the potential for WSUD to support multiple objectives, for example public amenity, environmental protection and enhancement, reduced water and energy consumption, and affordable living.*

3.4 Plan Objectives

The State-based WSUD objectives and performance targets have been considered and interpreted, for the purposes of guiding strategies and actions within the Hallett Cove Creeks catchment, as outlined below.

1 Water Conservation

- Harvest and reuse stormwater to assist in achieving best practice irrigation management of open spaces where viable (supports Council Strategic Objective 2.1d)

There are a number of Council reserves and school playing fields across the catchment area that have experienced a deterioration in standard, due to water restrictions during the recent drought period. There is an opportunity to consider other measures, such as sourcing water via stormwater harvesting, to reduce the reliance of mains water to support irrigation of these areas, and potentially to also support the revegetation of some reserve areas where there is scope for this to occur. This second outcome would lead to other associated benefits being realised, such as increased catchment biodiversity, amenity and buffering against the 'urban heat island effect' that is associated with climate change (Centre for Water Sensitive Cities, 2012).

2 Runoff Management – Quantity

- Provide detention for 1-2 year ARI urban peak flow rates within watercourses wherever this can be readily achieved to reduce these flow rates as far as possible (supports Council Strategic Objective 2.2c)

A stormwater runoff quantity target has been set with the objective of minimising in-stream erosion by limiting peak flows to the channel forming peak flow of the natural catchment (Goyder Institute, 2011). The target also reduces the disturbance caused by frequent small rainfall events to aquatic ecosystems.

Within the Hallett Cove Creeks catchment, this target is appropriate to provide flexibility in future management options for Waterfall Creek, and in particular sections where significant channel erosion has occurred and rehabilitation works will inevitably need to be undertaken.

Opportunities to mitigate peak flows generated by short duration (15 to 30 minute) low intensity (1 to 2 year ARI) storms should be considered wherever possible. This will provide for the return to a hydrological regime that resembles pre-European conditions within Waterfall Creek, particularly for low ARI events where the greatest impacts from urbanisation are experienced (Brisbane City Council, 2004).

These targets would not apply to catchments with piped drainage outfalls.

3 Runoff Management – Quality
Reduce the average annual loads of:

- total suspended solids by 80 per cent;
- total phosphorus by 60 per cent;
- total nitrogen by 45 per cent;
- litter/gross pollutants by 90 per cent;

as would be demonstrated based on modelling procedures which compare proposed catchment design with an equivalent, untreated catchment

These pollutant reduction targets will assist towards goal of reducing the amount of suspended solids, nitrogen, and other pollutants that enter Adelaide's coastal waters, which have been identified through the *Adelaide Coastal Waters Study* (CSIRO, 2007) as impacting on the health of Adelaide's coastal sea-grasses (Goyder Institute, 2011).

The assessment of the local marine environment (refer Section 2.9) identifies that while the Hallett Cove reef is still in good condition, sedimentation impact is high relative to other reefs along the coastline. While this impact is likely to be attributable (on a proportional basis) to the considerably larger discharges from the Field River and Christies Creek, adoption of these targets to reduce the impact from locally generated stormwater is appropriate.

4 Integrated Design

- Relevant stakeholders to be engaged at relevant stages of planning, designing, constructing, and managing WSUD measures so as to maximise the potential for WSUD to support and sustain multiple outcomes.

Within the Hallett Cove Creeks catchment area, relevant stakeholders may include, but are not necessarily limited to the City of Marion, the Adelaide & Mt Lofty Ranges Natural Resources Management Board, the Department of Environment, Water and Natural Resources, private land owners and local volunteer groups such as the Friends of Hallett Cove Conservation Park. Integrated effort within organisations, such as the City of Marion, is also required to ensure that input is received across the Open Space, Engineering, Planning and Biodiversity divisions.

The exploration of options to combat issues such as erosion of Waterfall Creek within the Hallett Cove Conservation Park has already provided evidence of the need for collaboration between these stakeholders.

5 Flood protection
With respect to drainage performance and flood protection, the proposed performance targets are for 5 year ARI minor and 100 year ARI major drainage systems.

It is apparent that the Hallett Cove area was generally developed with these design principles, and the maintenance of these performance standards remains appropriate.

southfront

4 Stormwater Drainage Infrastructure

4.1 Modelling Approach

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

As described in the model documentation (Watercom, 2011), DRAINS is a multi-purpose Windows program for designing and analysing urban stormwater drainage systems and catchments. DRAINS can model drainage systems of all sizes, from small to very large (up to 10 km^2 using subcatchments with ILSAX hydrology, and greater using storage routing model hydrology). Working through a number of time steps that occur during the course of a storm event, it simulates the conversion of rainfall patterns to stormwater runoff hydrographs and routes these through networks of pipes, channels and streams. In this process, it integrates:

- design and analysis tasks;
- hydrology (four alternative models) and hydraulics (two alternative procedures);
- closed conduit and open channel systems;
- headwalls, culverts and other structures;
- stormwater detention systems; and
- large-scale urban and rural catchments

Within a single package, DRAINS can carry out hydrological modelling using ILSAX, rational method and storage routing models, together with quasi-unsteady and unsteady hydraulic modelling of systems of pipes, open channels and surface overflow routes. It includes two automatic design procedures for piped drainage systems, and connections to CAD and GIS programs.

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

4.1.1 Drainage Data

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

- ‘Rationalisation’ of arc and polyline drain elements into single line segment elements
- Snapping end points of connecting drain segments together, and nodes to drain end points
- Assignment of surface levels to all inlet / junction box nodes, using the Digital Terrain Model information
- Generation of drain invert data (the majority of the dataset did not have this attribute), through the generalised assumption of 600mm cover to all drains, and a positive drain grade
- Completion or confirmation of drain size data (few in number) through referral to available construction drawings
- Addition of drainage systems in Lonsdale Highway and the Noarlunga railway line through referral to construction drawings made available by DPTI
- Addition of inlets where field inspection identified the omission of these from the Council data

Waterfall Creek was not modelled in detail, as this system is the subject of flood plain modelling (refer Section 5). Initially, the creek sections were modelled with an unrestricted capacity, with a Mannings roughness coefficient of 0.030. Following the flood plain modelling, which demonstrated the storage effects / overtopping behaviour at each of the culvert crossings, creek culverts were introduced into the model. This has provided for the reporting of creek channel peak flows for low ARI (1, 2 and 5 year ARI) events, while the flood plain model is considered to be a superior model for the reporting of peak channel flows in larger events.

4.1.2 Urban Catchment Areas

The study area is almost exclusively residential, with some commercial development associated with the Hallett Cove Shopping Centre. The residential development across the study area is reasonable uniform, with block sizes generally within a range of 600-700m^2. A number of sample areas were selected for an assessment of impervious site coverage. These areas are shown in Figure 4.1 below.

The analysis showed a reasonably consistent impervious fraction, in the low 50's.

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

- the Study area was largely developed during the 1970's and 1980's and hence a higher proportion of houses can be assumed to have 'conventional' drainage systems with direct connection to the street; and
- the Study area is reasonably steep, and there is a reasonable proportion of rear-of-allotment drainage, which again emphasises that a higher proportion of houses can be assumed to have 'conventional' drainage systems with direct connection to the Council drainage system.
- Few reported nuisance / inundation flooding issues

On balance these factors suggest a slightly higher impervious fraction than would normally be expected in older, inner metropolitan areas. For the purposes of a benchmark comparison, a study of a gauged catchment in Glenelg (Kemp & Lipp, 1999), adopted a directly connected fraction of 30 and indirectly connected fraction of 17. It should be noted that these results relate to an older developed area (developed in the 1940s and 1950s), prior to the infill development that has since occurred in that region since that Study was completed.

As a 'typical' residential subcatchment, a total impervious fraction of 52 has been adopted, comprised of a directly connected fraction of 38 and indirectly connected fraction of 14. These values have been varied on an individual subcatchment basis, where varying land uses are identified.

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

- paved = 1mm
- supplementary paved = 1mm
- grassed = 45mm

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

Figure 4.1 Total Impervious Fraction - Sample Areas

4.1.3 Rural (Hills Face Zone) Areas

A range of hydrological modelling approaches were reviewed for their suitability in modelling the rural catchments within the Study Area. A sample area (19.39 ha, located east of Antonia Circuit) was selected for the purposes of comparing the various approaches. This sample area is the only area that feeds into an urban drainage system of particular interest, with the hydrology of most of these catchments generally only of interest at railway culverts.

The RORB and extended rational method options were found to not produce suitable peak flows across a range of ARI, and an adjusted loss model was found to produce reasonable results. The rational method results included in Table 4.1 below are based on a (10 year ARI) runoff coefficient of 0.23, and time of concentration of 30 minutes.

Table 4.1 Sample Rural Catchment Calibration Summary

ARI (yrs)	Peak Flow - Rational Method (m^3/s)	ILSAX Initial Loss (mm)	Peak Flow - ILSAX (m^3/s)
1	0.18	8	0.22
2	0.26	12	0.29
5	0.40	18	0.37
100	1.09	40	0.99

The initial losses summarised above have been applied to the 'Rural' (Hills Face zone) catchments in the vicinity of Perry Barr Road.

4.1.4 Overflow Paths

Flow paths, defining the destination and travel time for overflow spilling from one inlet to the next, were assigned for all inlets based on field inspection and digital terrain model information.

4.1.5 IFD Rainfall Data

Design Intensity Frequency Duration (IFD) data has been prepared for the Study Area utilising the online procedure provided by the Bureau of Meteorology (http://www.bom.gov.au/water/designRainfalls/ifd/index.shtml). This data is presented in Table 4.2 below.

Table 4.2 Hallett Cove IFD Data

Duration	1	2	5	10	20	50	100
5 mins	43.4	58.6	81.4	98.3	121	156	187
6 mins	40.4	54.6	75.6	91.2	112	145	173
10 mins	32.6	43.9	60.5	72.7	89.4	115	137
20 mins	23.2	31.1	42.5	50.8	62.2	79.4	94.3
30 mins	18.5	24.8	33.6	40.1	48.9	62.2	73.7
1 hour	12.2	16.2	21.9	25.9	31.5	39.8	46.9
2 hours	7.80	10.4	13.9	16.4	19.8	25.0	29.4
3 hours	5.97	7.92	10.6	12.5	15.1	19.0	22.4
6 hours	3.76	4.99	6.65	7.84	9.47	11.9	14.0
12 hours	2.37	3.13	4.13	4.85	5.83	7.28	8.52
24 hours	1.48	1.94	2.50	2.89	3.44	4.22	4.89
48 hours	0.90	1.16	1.45	1.63	1.90	2.29	2.61
72 hours	0.65	0.83	1.02	1.14	1.31	1.56	1.76

4.2 Existing Drainage Performance

The DRAINS model of the existing drainage system has been executed for the 1, 2, 5, 10, 20, 50 and 100 year ARI storm events.

Drainage system 'failure' was defined as occurring whenever the hydraulic grade line level exceeds the corresponding surface level. The performance standard at drainage nodes (ie. the corresponding ARI at which the DRAINS model reported this to occur) is illustrated in Figure 4.2.

Generally, the underground drainage system was found to perform in line with current performance criteria. This result is not unexpected, given that:

- The area was largely developed during the 1970's and 1980's, during which time minor/major drainage engineering design principles began to be adopted, integrated with appropriate open space provision over major drainage corridors
- The area is relatively steep, providing generous gradients for efficient drainage

It should be noted that for the vast majority of locations where 'failure' is reported, that this is attributable to gutter approach flows exceeding the corresponding inlet capacity. Bypass of an inlet is not necessarily considered to be unacceptable, particularly in most instances where the road network does provide a safe overland flow path. Closer inspection of the model results reveals that low drainage capacity is producing 'failure' for low ARI events as follows:

- Ramrod Avenue drain

This drain, which services a portion of the Hallett Cove Shopping Centre and the proposed Southern Community Centre, has a 1 year ARI standard. This drain has also previously been identified (Tonkin Consulting, 2010) as having structural failures in a number of sections.

- Upper reach of the Heron Way main drain (upstream of Pavana Court)

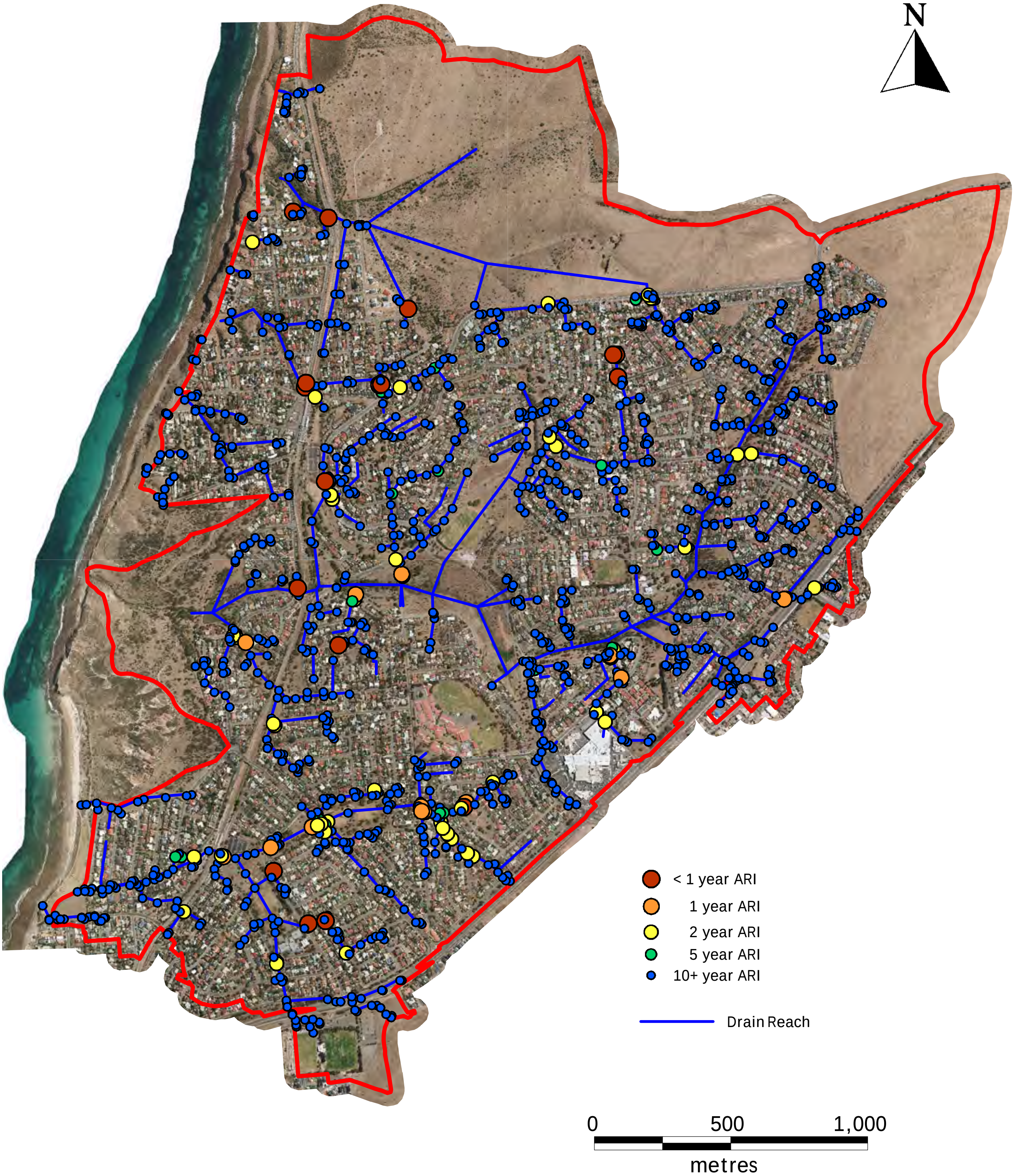
This section of drain is aligned through private property, in the alignment of a former watercourse. This system has a 2 – 5 year ARI standard, where a 100 year ARI standard would be desirable.

- Lower reach of the Heron Way main drain (downstream of Pavana Court)

This section of drain is aligned with reserves (above the railway line) and in Dutcham Drive (below the railway line), in the alignment of a former watercourse. Given that this drain is providing both a minor and major drainage role, and provides a less than 100 year ARI standard, this system was selected for further flood plain mapping analysis to determine whether any actions are required to manage the 100 year ARI flood plain within this catchment.

Overland flows produced by the exceedance of the capacity of the drainage system have been categorised, according to flow range, for the 5 and 100 year ARI events (refer to Figure 4.3 and Figure 4.4).

Those properties that are potentially at risk of inundation during a 100 year ARI event are also shown on Figure 4.4. Please note that these properties have been identified based on any instance where the modelling has demonstrated 100 year ARI flood flows in flow paths that pass through private property. The identification of these properties (and non-identification of other properties) is indicative only and is not an explicit statement with regard to the vulnerability to flooding of any particular dwelling or property.

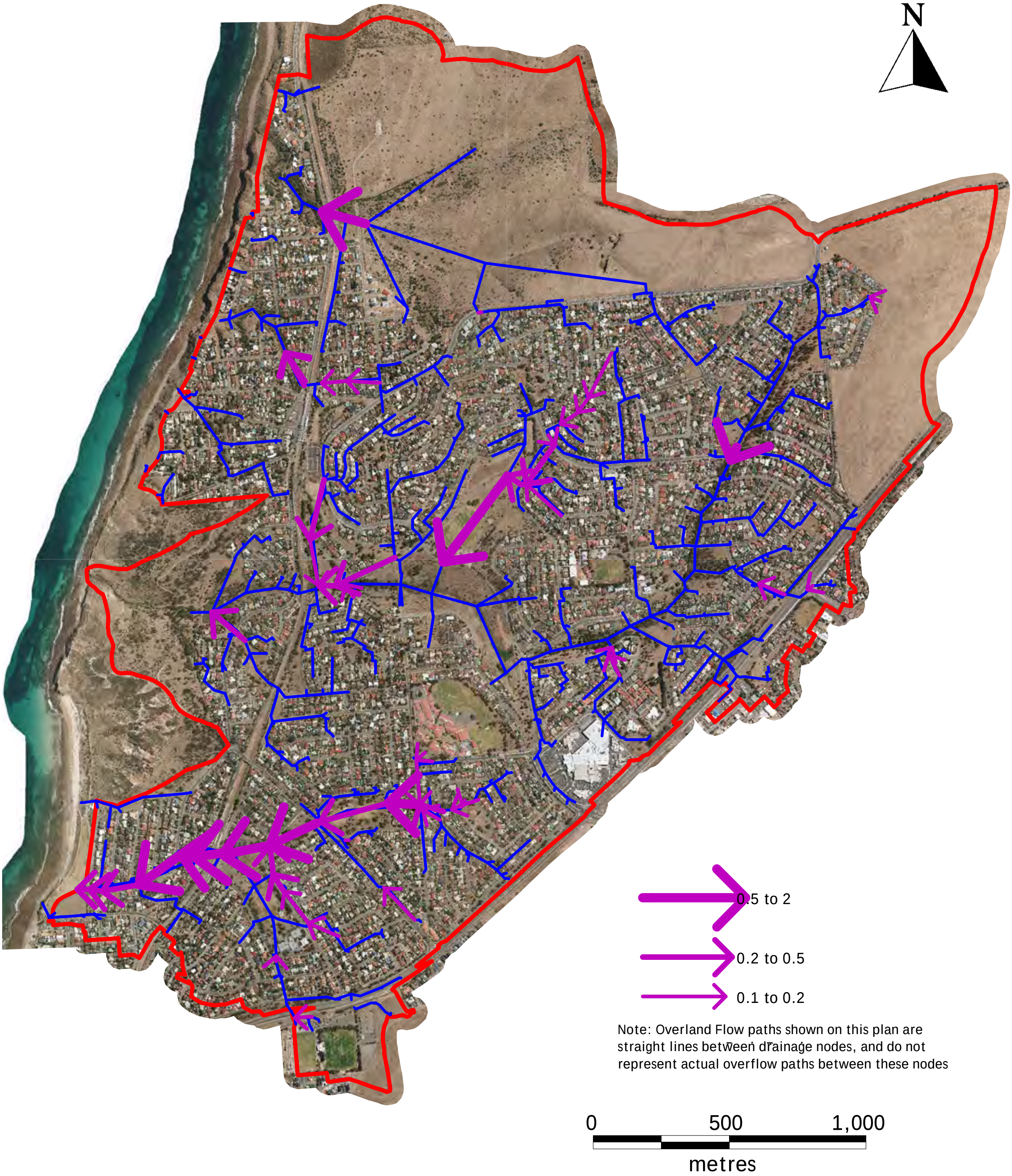


Data Sources:
City of Marion (Aerial Photograph)
Southfront (Stormwater)

Hallett Cove Creeks Catchment
Stormwater Management Plan

southfront

Figure 4.2
Existing Drainage Performance Standard



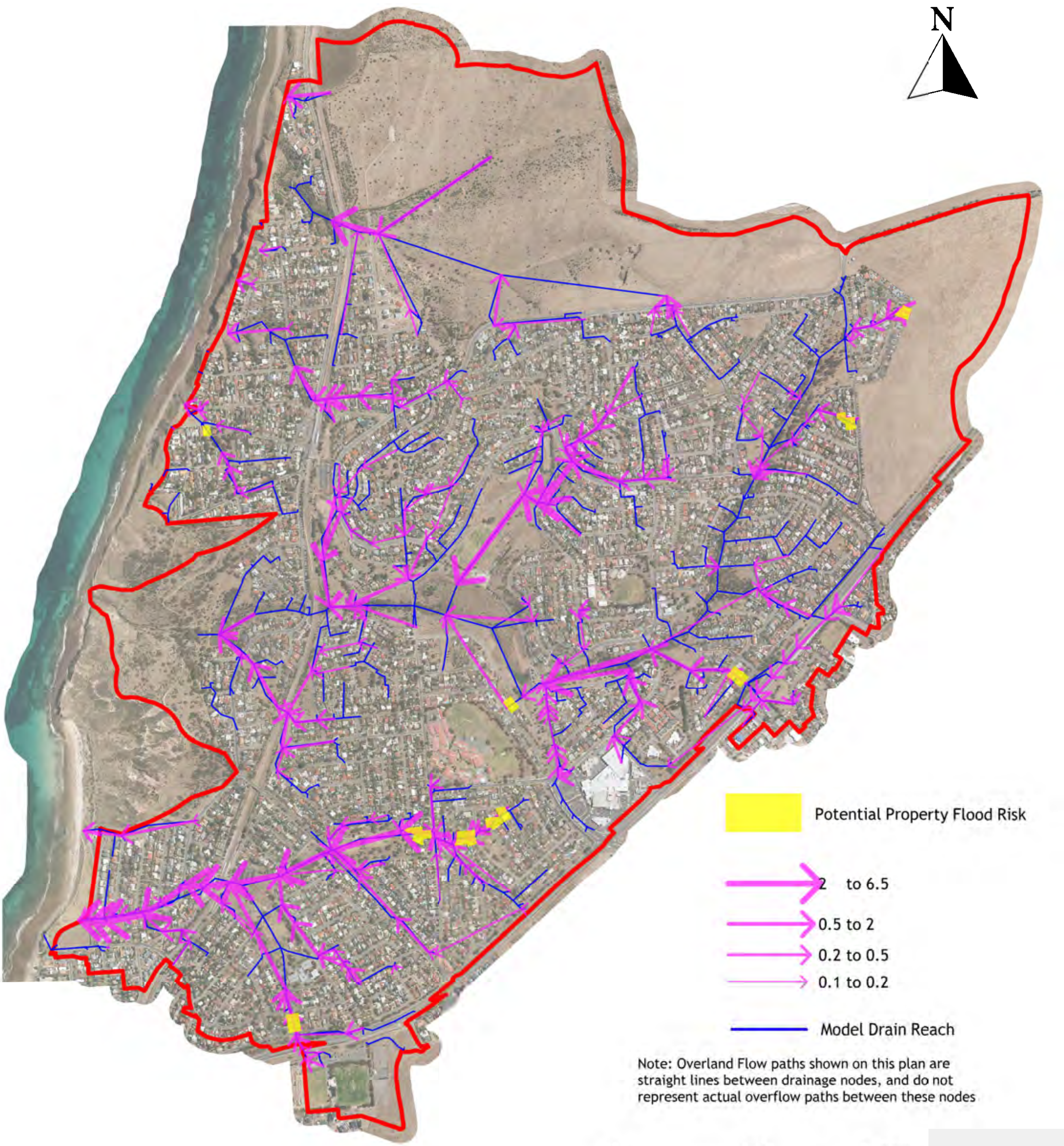
Data Sources:
City of Marion (Aerial Photograph)
Southfront (Stormwater, Overland Flows)

Hallett Cove Creeks Catchment
Stormwater Management Plan

southfront

Figure 4.3

Existing 5 year ARI Overland Flows



Data Sources:
City of Marion (Aerial Photograph)
Southfront (Stormwater, Overland Flows)

Hallett Cove Creeks Catchment
Stormwater Management Plan

southfront

Figure 4.4

Existing 100 year ARI Overland Flows

4.3 Coastal Outlets

While the significant majority of the Study Area is drained to watercourses or gullies that ultimately discharge into the Gulf, there are a number of the underground stormwater drainage systems that also discharge directly to the Gulf.

There has previously been concern regarding the erosion of cliffs and beaches due to many of these outfalls discharging well above beach level, with little or no erosion control or pollutant interception measures in place. A review of these outfalls (AWE, 2005) developed concept designs to address the issues identified.

There are 6 outfalls within the study area that were reviewed. The status of the concepts proposed within AWE (2005) are summarised in Table 4.3 below.

Table 4.3 Coastal Outlet Works

Location	AWE Ref	AWE Recommendation	Status
Westcliff Ct	11	No work required	-
Nungamoora St	13	Install GPT	Outstanding
Peera St	14	No work required	-
Fryer Street	16	Install GPT	Outstanding
Clifftop Cr	18	Install rock-lined overflow swale	Completed (refer photo below)
Grand Central Ave	21	Install GPT	Outstanding

The outstanding actions all relate to the installation of gross pollutant traps. These actions are now superseded by the Water Sensitive Urban Design proposed works presented in Section 6.2.1.

The City of Marion staff now undertake regular inspection, and standardised reporting of all outlet structures, both coastal and inland, to identify required maintenance activities. The most recent round of inspections was undertaken in September 2011.

4.4 Managing Higher Density Development

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

The analysis of development trends (presented in Section 2.5) identifies limited opportunity for additional development, based on a combination of current land zoning, residential zone policies, the relatively steep land and the relatively low age of existing housing stock. It should also be noted that high levels of impervious site coverage (say, relative to older inner metropolitan areas) have been adopted to represent the 'existing' scenario. However, the assessment of future development potential postulates that rezoning of land surrounding the Hallett Cove and Hallett Cove Beach railway stations may occur at some time in the future to allow higher density of development around these transport nodes.

As a part of any proposed rezoning, it is anticipated that an assessment would be undertaken to appropriately inform the process of relevant stormwater management constraints and opportunities. However, in relation to these areas, the following is noted:

- Hallett Cove Beach Railway Station
  - The Heron Way main drain bisects this area and would be the appropriate system for stormwater runoff to be directed to. Little or no detention of runoff could be considered given that this site is at the lower end of this drainage system.
  - There are some floodplain issues, particularly east of the railway line, that would need to be considered.
  - There are opportunities for Water Sensitive Urban Design and local-scale stormwater harvesting and reuse schemes to be achieved within the areas of open space east of the railway line

- Hallett Cove Railway Station
  - The area east of the railway station drains to Waterfall Creek. Some detention and/or upgrade to the drain between Waterfall Creek and Perry Barr Road would be required.
  - The area west of the railway station is drained by a number of small systems that discharge to the Gulf. Upgrading and extension of these drainage systems into the upstream ends of each drainage catchment(s) would be required to manage higher density development of these areas.

4.5 Action Summary

New underground drainage is proposed to be constructed in a number of locations to address identified deficiencies. These proposed upgrades have been modelled within the DRAINS model, to allow for preliminary sizing of drainage elements and budget cost estimation. It should be noted these works are not an exhaustive list of every drain upgrade required to achieve a minimum 5 year ARI standard, but rather that these works are those that can be justified against the relative benefits achieved.

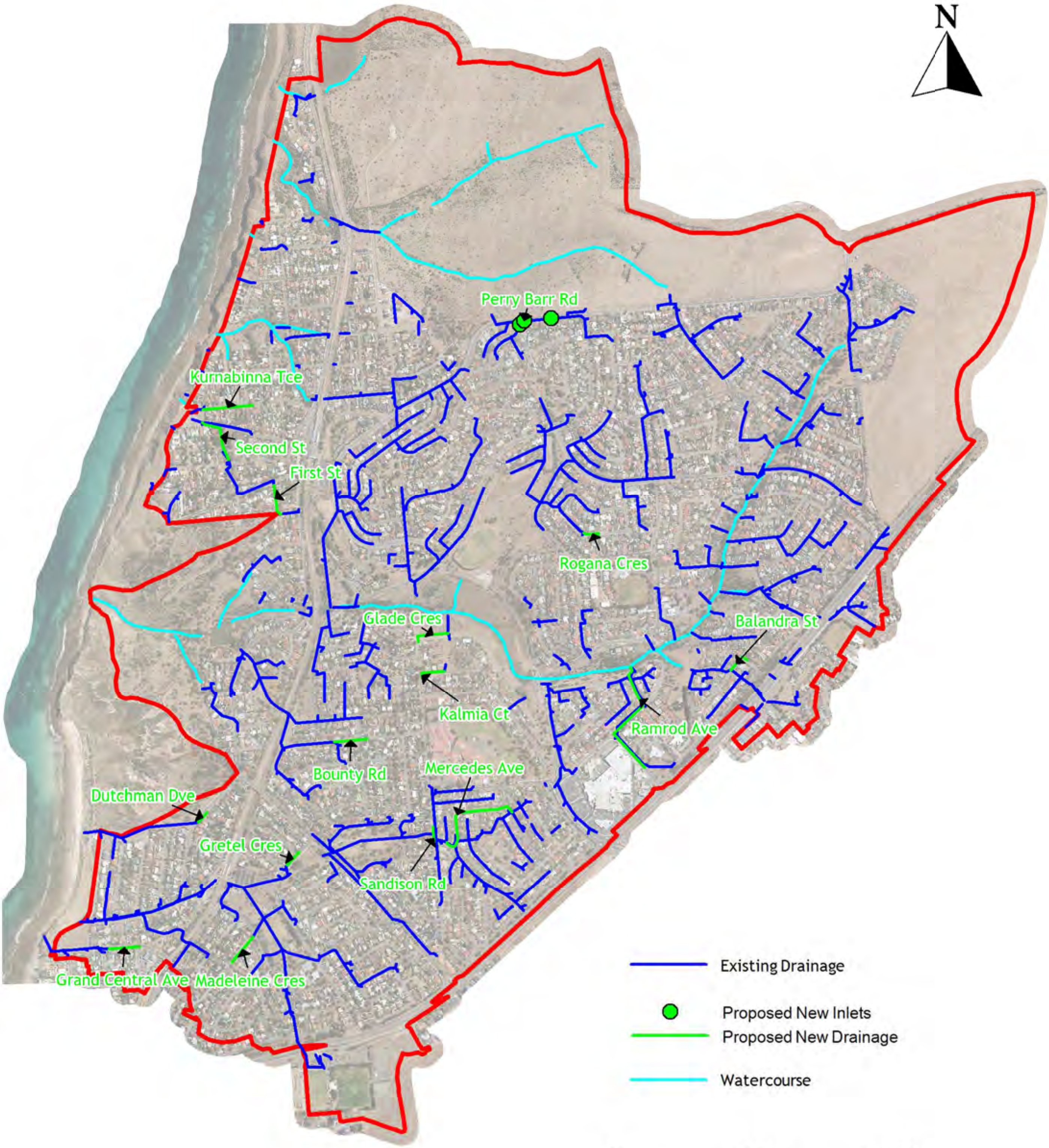
The proposed works and associated details are summarised in Table 4.4 and Figure 4.5.

None of the works would quality for Stormwater Management Authority funding, on the 40ha contributing catchment area criteria.

Table 4.4 Proposed Drainage Upgrades Summary

Location	Comments	Design ARI	Budget Estimate
Perry Barr Rd / Kanowna St	Additional inlets to provide improve capture to existing system	5	$ 40,000
Kurnabinna Tce	Extend drain to Boonga St to reduce gutter flows	5	$ 110,000
Second St Reserve	Realign drain from private property where it passes under a building	100	$ 190,000
First St	Connect easement drain to drainage in South Ave	100	$ 110,000
Rogana Cres	Extend drain to Goroke St to reduce gutter flows	5	$ 70,000
Ramrod Ave	Replace existing drain to provide improved capacity	5	$ 630,000
Balandra St	Construct lateral drain to Rubin St to reduce gutter flows	5	$ 80,000
Glade Cres	Construct lateral drain to prevent uncontrolled discharge from end of Sandison Road	5	$ 90,000
Kalmia Ct	Construct lateral drain to prevent uncontrolled discharge from end of Sandison Road	5	$ 80,000
Bounty Rd	Extend drain to Moonta St to reduce gutter flows	5	$ 90,000
Dutchman Dve	Extend drain to Moth Ct to reduce gutter flows	5	$ 50,000
Gretel Cres	Extend drain to Galatea St to reduce gutter flows	5	$ 80,000
Grand Central Ave	Extend drain to St Vincents Ave to reduce gutter flows	5	$ 80,000
Madeleine Cres	Extend drain 120m to reduce gutter flows	5	$ 80,000
Total			$ 1,780,000

[1] This budget estimate excludes costs associated with accommodating the proposed Southern Community Centre development. Total budget estimate inclusive of this is $1.1m.



Data Sources:
City of Marion (Aerial Photograph, Stormwater)
Southfront (Proposed Drains)

Hallett Cove Creeks Catchment
Stormwater Management Plan

Figure 4.5

Proposed Drainage Upgrades

southfront

5 Waterfall Creek, Heron Way Drain Floodplain Mapping

5.1 General

Floodplain mapping within the Hallett Cove Study Area was undertaken for Waterfall Creek as well as the Heron Way Catchment. These two catchments were identified early in the Study as being the most critical given their characteristics and potential for flood risk.

Waterfall Creek is the largest creek within Hallett Cove, and flows from Aroona Road to the Hallett Cove Conservation Park via the Lucretia Dam. The creek is a natural open channel along most of the alignment with culvert crossings under Barramundi Drive, Arachne Drive, Vennachar Drive, Quailo Avenue, Capella Drive and the Cove Road. Flows from Waterfall Creek discharge into the ocean downstream of the Conservation Park. The boundary of the floodplain model is shown in Figure 5.1.

Figure 5.1 Waterfall Creek Model Boundary

The Heron Way catchment comprises an urban floodplain serviced by an underground stormwater drainage network that ranges from a 300mm diameter drain in the upstream reaches to a 1200mm diameter drain at the outlet. This network extends from Crusade Court to Heron Way before passing through a Gross Pollutant Trap (GPT) and discharging into the ocean as shown in Figure 5.2.

Figure 5.2 Heron Way Drain Model Boundary

5.2 Modelling Software

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

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

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

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

The models were developed so that the underground stormwater drains and pits were modelled in 1D using ESTRY, while the floodplain on the surface was modelled in 2D using TUFLOW. The pit and pipe network was hydro-dynamically linked to the floodplain, allowing flows in both domains to interact.

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

5.3 Floodplain Modelling

5.3.1 Modelling Scope

The scope of this Study involved floodplain mapping the 10 year, 20 year, and 100 year ARI events. Various storm durations were modelled within each ARI event in order to determine the critical durations for each event. The storm durations modelled across all ARI's ranged from 20 minutes to 3 hours.

5.3.2 2D Cell Size

Determining an appropriate 2D cell size to be used by TUFLOW requires a compromise between the accuracy of modelling necessary to sufficiently reproduce the hydraulic behaviour of the floodplain as well as limitations in computing power and processing time. A detailed understanding of the requirements of the Study was also required. In this instance, the Study is a broad scale catchment wide analysis which aims to identify potential flooding hotspots. A detailed site specific analysis on flooding depths at individual property level was not required.

Waterfall Creek

A 2 metre cell size was chosen for the modelling as this size allowed for at least 4-5 cell widths to fit within most reaches of the creek. This resolution provided a sufficiently accurate representation of the creek cross-sectional profile and hence flow capacity. Given the size of the 3.4 km^2 model area, the 2D domain consisted of approximately 850,000 cells.

Using a smaller cell size such as 1 metre would increase the number of cells required to 3.4 million which would drastically increase run times and provide minimal benefit in terms of model resolution. Using a larger grid size such as 3 metres would reduce model run times, however it is expected that there would be an accompanying decrease in the creek capacity within the model which would likely cause an increase in flooding depths and extents across all events modelled.

Heron Way

A high resolution model with a 1 metre cell size was chosen for Heron Way as this size allowed for at least 6-7 cells to fit within the width of most major overland flow paths such as roads. Given the size of the 0.9 km^2 model area, the 2D domain consisted of approximately 900,000 cells.

5.3.3 Time Step

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

A general rule for TUFLOW models (although this is not a necessity) is to use a time step (in seconds) equal to approximately half the cell size (in metres). For the Waterfall Creek model, the time step used was 1 second. For the Heron Way model, the time step used was 0.5 seconds.

It should be noted that 99% of the computational effort is in solving the 2D surface flow equations and hence the impact of the time step on simulation times is negligible in the 1D domain. Thus the 1D ESTRY time step for all models was set to 1 second.

5.3.4 Topography

A DTM of the Hallett Cove catchment was provided by AAM Hatch as described in Section 2. The DTM was used to assign elevations to individual cells within the 2D domain. These elevations are assigned at the cell centres, corners and mid-sides to enable interaction with surrounding cells.

Waterfall Creek

The 1D domain for Waterfall Creek consists of the culvert crossings, with the open sections of creek being modelled in 2D. Information for the 1D domain including the form, invert levels and dimensions of each crossing was obtained from survey data provided by Adelaide Complete Surveys.

Heron Way

The 1D domain for Heron Way consists of the stormwater pits and pipes for the main drain as well as the downstream drain reach for each lateral connection into the trunk main. Information on the 1D domain was obtained from Council's pit and pipe GIS database and verified using design drawings of sections of the Heron Way system. We are confident that the drain diameters used in the modelling are accurate, however it should be noted that the available drainage invert information was not complete for all reaches. Missing invert information was supplemented with invert levels determined using engineering judgement that considered drain longitudinal gradients, minimum cover levels (relative to the DTM surface levels) and trying to match in to known drain inverts.

The commuter tunnel underneath the railway line at Hallett Cove Beach Station was also entered into the 1D domain in to allow surface flows to pass underneath the railway line.

5.3.5 Resistance Parameters

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

The bed resistance values used in the modelling for both the Waterfall Creek and Heron Way models are specified in Table 5.1.

Table 5.1 Bed Resistance Parameters

Type of Land Use	Manning's Roughness Coefficient
Residential / Commercial Development	0.200
Roads	0.030
Sparsely Vegetated Open Space	0.050
Railway	0.040
Densely Vegetated Open Space	0.070
Dam, ponds	0.025
Creek	0.060

It should be noted that relatively high values of Manning's n are used for residential and commercial development to compensate for the lack of building envelopes in the DTM.

The Manning's n value used for modelling of underground drains was 0.012.

5.3.6 Boundary Conditions

As part of the modelling, consideration was given to the boundary conditions within the 1D and 2D domains.

The Waterfall Creek model does not have 1D domain boundary conditions, as it is predominantly a 2D model.

Within the Heron Way model, the 1D boundary conditions are the side entry pits which allow flows to travel between the 1D domain (underground drainage system) and the 2D domain (ground surface defined by the DTM).

Within the 2D domain, the boundary condition is the edge of the model for both the Waterfall Creek and Heron Way models. The boundary condition adopted in the 2D domain was a "HQ" (stage-discharge) type boundary with a water surface slope of 1%.

The purpose of this approach was to allow water to “disappear” once flood flows reached the model boundaries and ensure that results in the floodplain were not affected at model edges.

It is important to note that the impact of flood flows from adjacent catchments was not assessed as part of the scope of works for this investigation.

5.3.7 Inflows

Waterfall Creek

Inflows to Waterfall Creek were entered in locations representing major drainage outlets to the creek. A total of 9 inflows were applied, in locations as shown in Figure 5.3.
The hydrographs for each outlet were derived from the DRAINS modelling. All inflows were applied directly into the creek in the 2D domain.

Figure 5.3 Waterfall Creek Inflow Locations

Heron Way

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

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

5.4 Flood Plain Mapping Results

5.4.1 Scenarios Presented

The results of the TUFLOW modelling were analysed to determine the critical durations for each ARI. It was found that the flooding extents in various parts of the catchment differed based on the storm duration that was modelled. Therefore, the results presented in the floodplain maps are based on a combination of critical events, and can be assumed to represent the worst case scenario for each ARI. The critical storm durations for each ARI are shown in Table 5.2.

Table 5.2 Critical Storm Durations for each ARI

Average Recurrence Interval	Critical Storm Durations	
	Waterfall Creek	Heron Way
10 year	25 minutes, 90 minutes	20 minutes, 2 hours
20 years	25 minutes, 90 minutes	20 minutes, 2 hours
100 years	20 minutes, 2 hours	20 minutes, 2 hours

5.4.2 Floodplain Maps

A3 format floodplain maps for each ARI have been prepared and are presented in Appendix A. The maps show flooding depths and extents overlaid over information such as aerial photography, cadastral boundaries, roads, and the existing underground stormwater network.

5.4.3 Flood Inundation Extents

For both the Waterfall Creek and Heron Way catchments, flood flows travel downstream in line with the major flow corridors. As expected, the modelling results indicate that flooding depths and extents become more pronounced with an increase in the ARI. The extent of flooding is described below.

Waterfall Creek

The 10 and 20 year ARI maps show that flood flows are completely contained within the creek corridor from Aroona Road to the Lucretia Dam. Downstream of the dam, flood flows are contained within the creek banks and discharge directly into the ocean. The majority of flooding depths are less than 1 metre deep. The modelling results indicate that the culvert crossings cater for the 10 and 20 year ARI events.

The 100 year ARI map shows greater flooding extents than the lower ARI events, however flows are still almost entirely contained within the creek corridor. The culvert crossing under Quailo Avenue does not cater for the 100 year ARI flow and overtopping occurs from Zwerner Drive Reserve to Glade Crescent Reserve.

Ponding of flows upstream of most culvert crossings is apparent in the 100 year ARI event, with peak depths up to 2.5 metres. This is likely to provide siginificant attenuation of creek flows.

The floodplain mapping did not identify any properties at risk of flooding within the Waterfall Creek catchment.

Heron Way

The 10 and 20 year ARI floodplain maps for the Heron Way catchment are very similar. Shallow flooding with depths up to 250mm is apparent between Freya Avenue and Sandison Road. Downstream of Sandison Road, flood flows travel along the surface towards Pavana Reserve and then within the 3 reserves upstream of the railway (Pavana, Gretel Crescent and Shamrock Road). Minor ponding with depths up to 0.5 m is apparent upstream of the railway. Downstream of the railway, the Heron way system caters for the 10 and 20 year ARI flows with only minor flooding downstream of Arafura Court to the outlet.

The 100 year ARI results show flooding in a similar pattern to the lower ARI events, however the flood depths and extents are greater. Shallow flooding on Dutchman Drive makes its way to the outlet. There is a much greater area of ponding upstream of the railway, with depths up to 2.5 metres. Floodwaters reach the entrance of the commuter tunnel crossing under the railway line, however no discharge occurs at the downstream end of the tunnel.

There are approximately 30 properties at risk of shallow flooding during the 100 year ARI event, with most of these at the upstream end between Crusade Court and Pavana Court.

5.4.4 Drainage Network Capacity

Peak flows in selected locations within the 1D drainage network have been presented in Tables 5.3 and 5.4.

Table 5.3 Peak Flows through Waterfall Creek Culvert Crossings

Location	Drain Dimensions	Peak Flows (m^3/s)		
		10yr	20yr	100yr
Barramundi Drive (ped. crossing)	1.5 x 2.4m RCBC	0.2	0.3	1.2
Barramundi Drive (culvert)	750 mm dia	1.0	1.1	1.4
Arachne Drive (twin culvert)	1.2 x 0.6m RCBC	0.9	1.0	1.3
Vennachar Drive	1500 mm dia	2.0	2.6	3.6
Quailo Avenue	900 mm dia	2.2	2.4	3.0
Glade Crescent Reserve	900 mm dia	3.1	3.2	3.5
Capella Drive	1500 mm dia	4.1	4.5	6.9
Railway Culvert	2.25 x 1.5m RCBC	4.6	5.5	7.7
The Cove Road	1050 mm dia	4.6	5.5	7.7

Lucretia Dam Spillway	3 x 0.75 RCBC	3.7	4.3	7.1

Table 5.4 Peak Flows in selected locations within the Heron Way Drain

Location	Drain Dimensions	Peak Flows (m^3/s)		
		10yr	20yr	100yr
Sandison Road	750 mm dia	0.8	0.8	0.8
Gretel Crescent Reserve	900 mm dia	2.6	2.7	2.7
Reliance Road (under railway)	1.8 x 1.35 m RCBC	3.7	3.8	3.8
Dutchman Drive (D/S section)	1050 mm dia	5.3	5.6	5.6

Tables 5.3 and 5.4 show that there is an increase in flows within the 1D network from upstream to downstream which is expected, given the increase in the contributing catchment area and the relative lack of flooding breakouts within both systems.

Within the Waterfall Creek system, there is a noticeable increase in flows through each structure with an increase in ARI. This is indicative of the fact that the culvert crossings along the creek have sufficient capacity to cater for events up to the 100 year ARI (with the exception of Quailo Avenue). The containment of flood flows within the creek corridor for all modelled scenarios further supports this notion. Notwithstanding this, the flood plain modelling has demonstrated significant peak flow attenuation through flood storage effects, particularly upstream of road culverts such as Quailo Avenue.

Within the Heron Way drain, the flows do not noticeably increase when comparing a 10 year to a 100 year ARI event. This is likely to be due to the fact that the Heron Way system has no capacity to cater for flows exceeding those generated during a 10 year ARI event.

5.5 Action Summary

The flood plain mapping of Waterfall Creek did not identify any flood issues requiring further consideration. Those works required within the Heron Way catchment are summarised in Table 5.5 below, and are illustrated along with other proposed stormwater drainage upgrades in Figure 4.5.

Table 5.5 Proposed Flood Mitigation Works Summary

Location	Comments	Design ARI	Budget Estimate
Sandison Rd	Construct several new inlets and connecting lateral drains on western side of the Sandison Road to collect surface flood flows	100	$ 60,000
Mercedes Ave	Construct new drain to take all flow from Freya Avenue, thereby improving the performance of the easement drain	100	$ 340,000

These works are not eligible for Stormwater Management Authority funding, on the basis of insufficient contributing catchment area.

6 Watercourse Corridors

6.1 Background

6.1.1 Flora and Fauna Assessment

A flora and fauna assessment of selected areas within the catchment has been undertaken (EBS, 2012) to assist in evaluating future management strategies associated with watercourse restoration. This Section includes key outcomes from this assessment.

The objectives of this work was to:

- broadly map vegetation communities
- identify any areas of conservation significance from a national, state and regional level
- identifying requirements (if any) for provision of low flows below the dam along Waterfall Creek, to support water dependant ecosystems
- identify and map key management issues (e.g. weeds, significant feral animal activity)
- identify opportunities to restore the creeklines to enhance biodiversity
- provide a broad cost estimate to undertake works across the management zones

A number of sources have been used to collate information for this report, including database searches (Protected Matters Search Tool (DSEWPaC 2011b) and the Biological Database of South Australian (BDBSA) (DENR 2011)), previous reports for the local area (Section 1.2.2), EBS Ecology field survey (October 2011) and local knowledge. The species lists that have been generated consist of numerous threatened and common fauna and flora species, as well as the exotic species found throughout the project area. Nationally threatened species and communities have been rated according to their conservation listing under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). State listed species are rated under the South Australian *National Parks and Wildlife Act 1972* (NPW Act) which protects flora and fauna located within reserved land (such as National Parks and Conservation Parks), and any species listed under Schedules 7 (endangered species), 8 (vulnerable species) and 9 (rare species). Regionally significant species have been assigned conservation ratings in the past, but in the Southern Lofty Ranges the ratings are currently regarded as out dated. However the ratings can still be used as a guide in determining conservation significance.

6.1.2 Existing Management Initiatives

A number of management plans and concepts have already been prepared for various areas situated within the project area. These include, but may not be limited to:

- City of Marion Healthy Environment Plan (2010)
- The Great Southern Urban Forest (Planning SA *et al.* 2005)
- Field River and Waterfall Creek Riparian Zone Biodiversity Action Plan (ECO Management Services & ID&A 2000)
- Hallett Cove and Marino Conservation Parks Management Plan (DEH 2010)
- Coastal Outfalls in the Marion Council Area – (AWE 2005)
- Waterfall Creek Erosion Advice – (AWE 2007)
- Glade Crescent Reserve Wetland Concept Design (AWE 2007)

- Glade Crescent Wetland and Recreation Reserve Development Concept Plan for Community Consultation (Oxigen, 2009)
- Glade Crescent Reserve Vegetation Survey (EBS 2008)
- City of Marion Indigenous Vegetation Assessments - Stage Two (J Smith 2008)

These documents have been reviewed, and any management issues or actions relevant to this project area have been considered in the preparation of this report. Broad issues and actions of relevance described in each of the reports and concept plans include:

- retaining existing remnant vegetation
- preserving and enhancing biodiversity
- increasing habitat for native fauna
- revegetation
- management of water resources
- weed control
- erosion mitigation, particularly in coastal environments
- feral animal control
- public amenities
- community engagement.

6.1.3 Great Southern Urban Forest

Sections of the Study Area form part of the Great Southern Urban Forest (GSUF) which was identified as a major open space and biodiversity corridor in southern Adelaide linking the coast to the Adelaide Hills from Hallett Cove to the Sturt Gorge extension at Craigburn Farm in the central Adelaide Hills. The GSUF comprises over 1000 ha of public and private land that presents significant potential with regional value for outdoor recreation and biodiversity reestablishment (Planning SA, Department for Environment and Heritage (DEH) and City of Marion, 2005).

The City of Marion contains some of the last large remnant areas of *Eucalyptus microcarpa* (Grey Box Woodland). This plant association once covered vast areas of the Adelaide plains and the foothills. Present estimates indicate that there is less than 4% of this woodland plant association that has been retained in a natural state. (COM, 2012)

The Waterfall Creek corridor is not identified as a 'core' or 'complimentary' area within the Great Southern Urban Forest, however since the development of the original plan it has been identified (pers comm., J Smith) as potentially offering an outstanding opportunity to establish a biodiversity link through to the Hallett Cove Conservation Park (refer Figure 6.1)

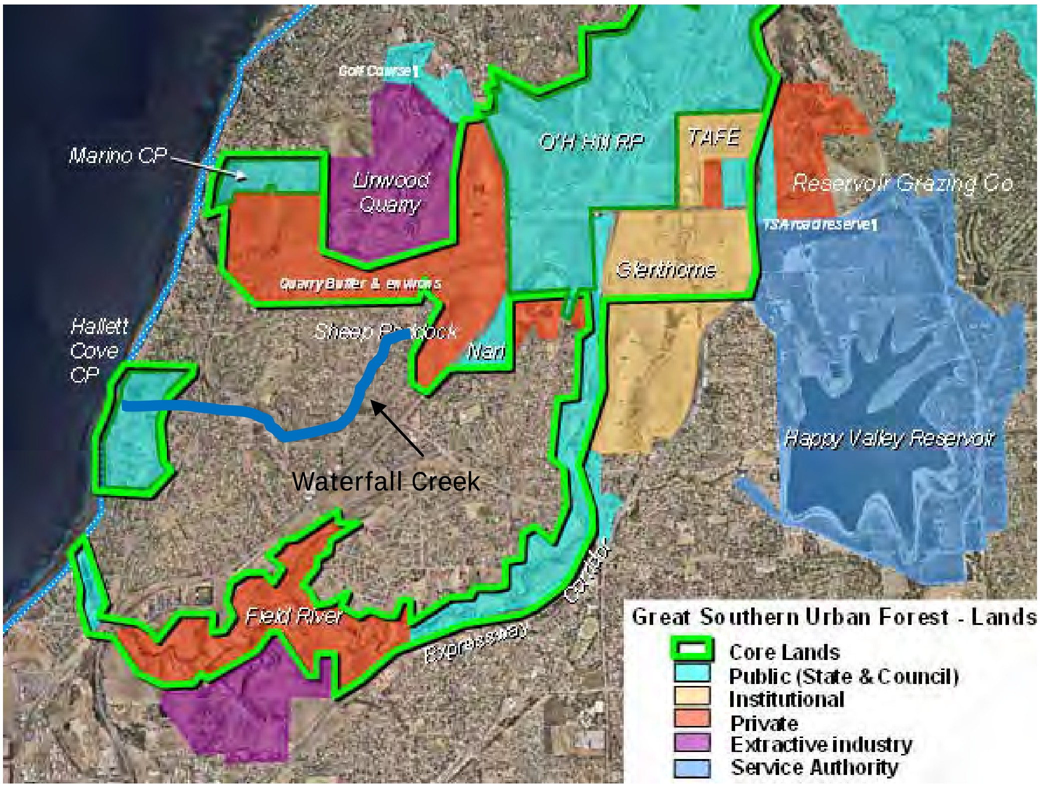


Figure 6.1 Waterfall Creek context to Great Southern Urban Forest

6.2 Project Area Management Zones

The watercourse reaches have been divided into five management zones, to assist with identifying key management issues and actions for specific areas. Each zone is described in Section 6.5 and mapped in Figure 6.2.

- Zone 1 - Waterfall Creek (upper)
- Zone 2 - Waterfall Creek (middle)
- Zone 3 - Waterfall Creek (lower)
- Zone 4 - Pindee Street drain
- Zone 5 - Narang Street drain

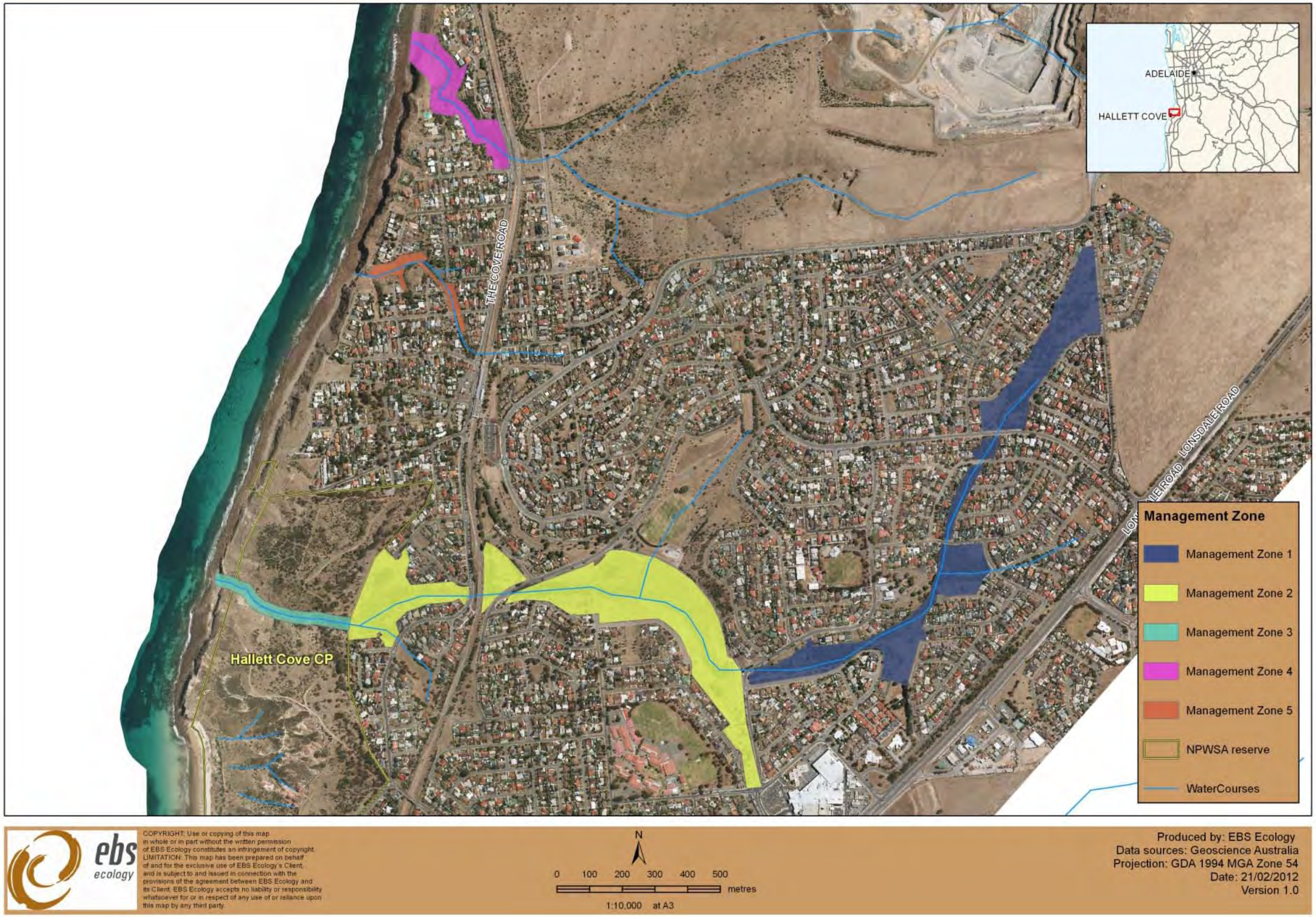


Figure 6.2 Watercourse Corridor Management Zones

6.2.1 Biodiversity Condition Assessment

Areas were assigned a 'Condition' rating based on a number the biodiversity values which recognised a number of factors such as threatened species, condition of vegetation, habitat value, proximity to reserves and other remnant areas, opportunities for restoration and levels of degradation by weeds and feral animals. See Table 6.1 for description of condition levels and Figure 6.3 for mapped locations.

Table 6.1 Condition Classification Criteria

Condition Level	Broad Assessment Criteria
High	Contains known habitat for threatened fauna and flora species, and Threatened species records exist within the past 20 years, and Suitable habitat available to common native fauna, and Close proximity to NPS reserve or other areas of remnant vegetation, and Contains high quality patches of native flora, and Low levels of weed invasion, and Opportunities for biodiversity restoration.
Moderate	Some areas of native flora, but largely dominated by exotics, and Retains some areas of likely habitat for native fauna species, and Close proximity to NPS reserve or other areas of remnant vegetation, and Opportunities for biodiversity restoration.
Low	High levels of weed infestation, and Some native vegetation areas (mostly planted), and Low levels of remnant species, and Low levels of forage/nesting/roosting habitat for birds and bats, and Mainly recreational use area, and Understorey mainly slashed exotic grasses, and Opportunities for biodiversity restoration.

6.3 Biodiversity Values

6.3.1 Grassy Ecosystems

The most extensively cleared of the dominant ecosystems in pre-European times are the grassy woodlands and grasslands (approximately 93% and 99% respectively), within the Adelaide and Mount Lofty Ranges (AMLR) region. Grassy ecosystems are located on deep, fertile soils and were preferentially selected for agricultural purposes. Many of these areas, such as the grassy woodlands and grasslands that were located where metropolitan Adelaide now lies, were cleared shortly after European settlement (DEH, 2009). The small fragmented remnants should be targeted for conservation and restoration activities, whilst re-creation of grassy ecosystems (buffering) in and around existing remnant pockets, should also be a priority.

6.3.2 Vegetation associations and flora species

There were 14 vegetation associations and other vegetation types recorded across the project area:

1 Exotic Grassland
2 Planted amenity trees (*Eucalyptus leucoxylon / Eucalyptus camaldulensis*) over exotic grasses
3 *Callitris gracilis* / *Pinus* sp +/- *Eucalyptus camaldulensis* over exotic grasses
4 *Eucalyptus camaldulensis* over *Typha domingensis*
5 Scattered Olive, Artichoke Thistle, Desert Ash over *Typha domingensis* within drain
6 Olive Tall Shrubland over scattered patches of native grass, Artichoke Thistle and native revegetation
7 *Eucalyptus porosa / Allocasuarina verticillata / Dodonaea viscosa* mixed revegetation patch
8 *Olearia ramulosa +/- Myoporum insulare* Shrubland
9 *Eucalyptus leucoxylon / Eucalyptus camaldulensis / Eucalyptus porosa* Open Woodland riparian area
10 Exotic dominated creekline
11 *Sida petrophila* / *Leguminosae* sp. Low Shrubland
12 Olive / *Pinus* sp. / *Acacia paradoxa* over planted non-local natives
13 Olive Tall Shrubland with scattered Desert Ash over patchy *Austrostipa* sp. and *Enneapogon nigricans*
14 *Lomandra densiflora /* exotic grass Grassland

During the field survey, 134 flora species (59 native species and 75 exotic species) were recorded (EBS, 2012).

Threatened flora species

No nationally threatened flora species were detected during the field survey. One State Rare species was recorded during the EBS Ecology field survey regarded as regionally Vulnerable:

- *Myoporum parvifolium* (Creeping Boobialla) (rare) – likely to be remnant

There is also one record for *Maireana rohrlachii* (Rohrlach's Bluebush) which is rated Rare in SA and Vulnerable in the Southern Lofty Ranges (Smith *pers. comm*, 2012).

The following list contains the twelve regionally threatened plant species which were recorded by EBS Ecology from a previous survey of the project area and other species recorded during previous surveys:

- *Acacia cupularis* (Cup Wattle) – rated Rare
- *Acrotriche patula* (Prickly Ground-berry) – rated Rare
- *Alyxia buxifolia* (Sea Box) – rated Rare
- *Aristida behriana* (Brush Wire-grass) – rated Unknown
- *Austrostipa multispiculis* (found in Bush for Life site) – rated Rare for both SA and the Southern Lofty Ranges
- *Calandrinia volubilis* (Twining Purslane) - rated Threatened
- *Cullen australasicum* (Tall Scurf-pea) – rated Rare
- *Dissocarpus biflorus var. biflorus* (Two-horn Saltbush) - rated Vulnerable
- *Eucalyptus porosa* (Mallee Box) – rated Uncommon
- *Exocarpos aphyllus* (Leafless Cherry)- rated Vulnerable
- *Gahnia lanigera* (Black Grass Sawsedge) – rated Rare
- *Goodenia amplexans* (Clasping Goodenia) – rated Uncommon
- *Goodenia varia* (Sticky Goodenia) – rated Unknown
- *Lomandra effusa* (Scented Mat-rush) – rated Rare
- *Lotus australis* (Austral Trefoil) – rated Uncommon

- *Lycium australe* (Native Boxthorn) – rated Endangered
- *Maireana rohrlachii* (Rohrlach's Bluebush) – rated Rare in SA and Vulnerable Southern Lofty Ranges
- *Malva behriana* (Australian Hollyhock) – rated Uncommon
- *Melaleuca lanceolata* (Dryland Tea-tree) – rated Uncommon
- *Myoporum sp. petiolatum (R.Taylor 484)* (Sticky Boobialla) – rated Uncommon
- *Myoporum viscosum* (Sticky Boobialla) – rated Uncommon
- *Pimelea curviflora var. curviflora* (Curved Riceflower) – rated Rare
- *Pittosporum angustifolium* (Native Apricot) – rated Rare
- *Plantago gaudichaudii* (Narrow-leaf Plantain) – rated Uncommon
- *Pleurosorus rutifolius* (Blanket Fern) – rated Uncommon
- *Pomaderris paniculosa ssp. paniculosa* (Mallee Pomaderris) – rated Uncommon
- *Ptilotus nobilis var. nobilis* (Yellow-tails) - rated Vulnerable
- *Scaevola crassifolia* (Cushion Fanflower) – rated Rare
- *Scleranthus pungens* (Prickly Knawel) – rated Rare
- *Sida petrophila* (Rock Sida) – rated Unknown
- *Vittadinia blackii* (Narrow-leaf New Holland Daisy) – rated Rare
- *Zygophyllum confluens* (Forked Twinleaf) – rated Rare

6.3.3 Fauna

Threatened fauna

No nationally or state threatened fauna species were detected during the field survey, however the survey was not considered a comprehensive effort. A number of threatened fauna species are known to frequent the project area including the Black-chinned Honeyeater, Crested Shrike-tit and Yellow Tail Black Cockatoo. Additional threatened species may utilise the site, and further site visits prior to works being undertaken will help identify any further species and potential impacts.

6.3.4 High value habitat areas

The biodiversity value varies between specific areas within each management zone across the project area (refer Figure 6.3).

The project area provides a variety of high value habitats for native fauna:

- Areas of woodland – for birds (in the form of food resources, shelter, nesting and perching), and potentially the State rare Common Brushtail Possum (*Trichosurus vulpecula*)
- Wetlands – for waterbirds
- Coastal areas – seabirds/coastal birds

Part of the project area (within Zone 3) incorporates a section of Hallett Cove Conservation Park. Flora diversity in this area is relatively good, and the general area is likely to provide a refuge for native fauna.

Some degraded patches of *Lomandra* sp. Shrubland were recorded within Zones 3, 4 and 5 and could provide ideal restoration opportunities.

Pockets of understorey within the recreational areas of the project area could also represent opportunities for restorative activities.

The State rare *Myoporum parvifolium* (Creeping Boobialla) was recorded in a number of the coastal areas, mainly within Hallett Cove Conservation Park. It is likely that this species is remnant and should be protected.

Figure 6.3 Biodiversity Condition Rating

6.4 Threatening Processes

6.4.1 Weeds

One of the primary threats to the creekline environs within the project area is weed invasion. Many weed species compete with native species for resources and have the potential to exclude native species from the landscape, resulting in changes in the composition and structure of plant communities.

Weed invasion is evident throughout the entire project area; with numerous olives and mixed exotics present, as well as garden escapees. In some areas, property owners have also taken over public land with extensions of their gardens or for storage of various items. Numerous problems are being caused within the project area by weed invasion; including biodiversity loss, habitat modification and loss, loss of amenity value and loss of recreational value. As described in Table 6.2, many of the weed species recorded within the project area are also 'Declared' under the NRM Act or are considered important environmental weeds.

Immediate and long term action on weed control is required to reduce the impact of weeds on the ecological value of the area. Of the 75 exotic flora species recorded, 37 are declared under the *Natural Resources Management Act 2004*, and 10 are considered important environmental weeds. Each weed has been assigned a Priority Rating which reflects the significance of the weed across the project area.

Prioritisation of Weed Management

Weed infestations across the SEB areas and within the individual Management units have been prioritised using the following attributes to guide their level of importance:

- Listing (Declared under *NRM Act, 2004*)
- Size of infestation
- Overall abundance
- Level of invasiveness
- Accessibility

Table 6.2 Declared and environmental weed species recorded

Species name	Common name	Status	Priority Rating
Acacia saligna	Golden Wreath Wattle	Environmental	High
Arctotheca calendula	Cape Weed	Environmental	Low
Asparagus asparagoides f.	Bridal Creeper	Declared	Very High
Asphodelus fistulosus	Onion Weed	Declared	High
Avena sp.	Wild Oat	Environmental	Low
Casuarina glauca	Grey Buloke	Environmental	Medium
Chrysanthemoides monilifera ssp. monilifera	Boneseed	Environmental	Medium
Coprosma repens	New Zealand Mirror-bush	Environmental	Low
Cotoneaster glaucophyllus	Cotoneaster	Environmental	Low
Cynara cardunculus ssp. *flavescens*	Artichoke Thistle	Declared	Very high
Cynodon dactylon	Couch-grass	Environmental	Low

Species name	Common name	Status	Priority Rating
Echium plantagineum	Salvation Jane	Declared	High
Euphorbia terracina	False Caper	Declared	High
Foeniculum vulgare	Fennel	Environmental	Medium
Fraxinus angustifolia	Desert Ash	Environmental	High
Galium aparine	Cleavers	Environmental	Low
Hypochaeris radicata	Rough Cat's Ear	Environmental	Low
Lolium perenne	Perennial Ryegrass	Environmental	Low
Lycium ferocissimum	African Boxthorn	Declared	Very high
Olea europaea ssp. *europaea*	Olive	Declared	Very high
Opuntia spp.	Prickly Pear	Declared	Very high
Oxalis pes-caprae	Soursob	Declared	Low
Pennisetum clandestinum	Kikuyu	Environmental	Low
Pennisetum sp.		Environmental	Medium
Pinus halepensis	Aleppo Pine	Environmental	Low
Piptatherum miliaceum	Rice Millet	Environmental	Medium
Pittosporum undulatum	Sweet Pittosporum	Environmental	Low
Plantago lanceolata var.	Ribwort	Environmental	Low
Rapistrum rugosum ssp. rugosum	Turnip Weed	Environmental	Medium
Ricinus communis	Castor Oil Plant	Environmental	High
Rosa canina	Dog Rose	Declared	High
Salix sp.	Willow	Environmental	Medium
Salvia verbenaca	Wild Sage	Environmental	Low
Scabiosa atropurpurea	Pincushion	Environmental	Medium
Schinus molle	Pepper Tree	Environmental	Low
Solanum nigrum	Black Nightshade	Environmental	Low
Vicia sativa ssp.	Common Vetch	Environmental	Low

Declared = weed species listed under the South Australian *Natural Resource Management Act 2004*
Environmental = Serious Environmental Weed

Note the following principles should be considered when managing weed species across the project area.

Principles of Weed Management

- Tackle small, 'manageable' infestations to eliminate the risk of potential spread, before attempting large established infestations.
- Start in the bushland with good to excellent condition, and work towards those areas in poor condition.
- Contain further spread of large infestations before targeting eradication of infestation.

- The rate of weed management overall should be guided by the resources available for follow up activities.
- Target Declared and Environmental weed species which are known to have high levels of invasiveness.

6.4.2 Feral animals

Feral animals such as foxes, rats and cats (also domestic cats) impact on native fauna through predation, habitat availability and resources. Rabbits and hares can directly impact on native flora by over grazing and compete directly with native herbivores. Records indicate that foxes, cats, rabbits, hares, black Rats and house Mice have all been observed in the area, however few direct signs of feral animal activity were observed during the field survey. It is likely that numbers fluctuate in response to available resources and seasonal variation and therefore all are expected to utilise the habitats at various times.

6.4.3 Erosion

Erosion of the watercourses and steep banks is evident throughout the project area. Locations where erosion was observed during site inspections were recorded and are presented in Figure 6.6.

The digital terrain model for utilised to review the longitudinal gradient of Waterfall Creek (refer Figure 6.4). This determined that the average gradient is relatively steep at 3.6%, and this steep gradient is relatively consistent across the creek reaches.

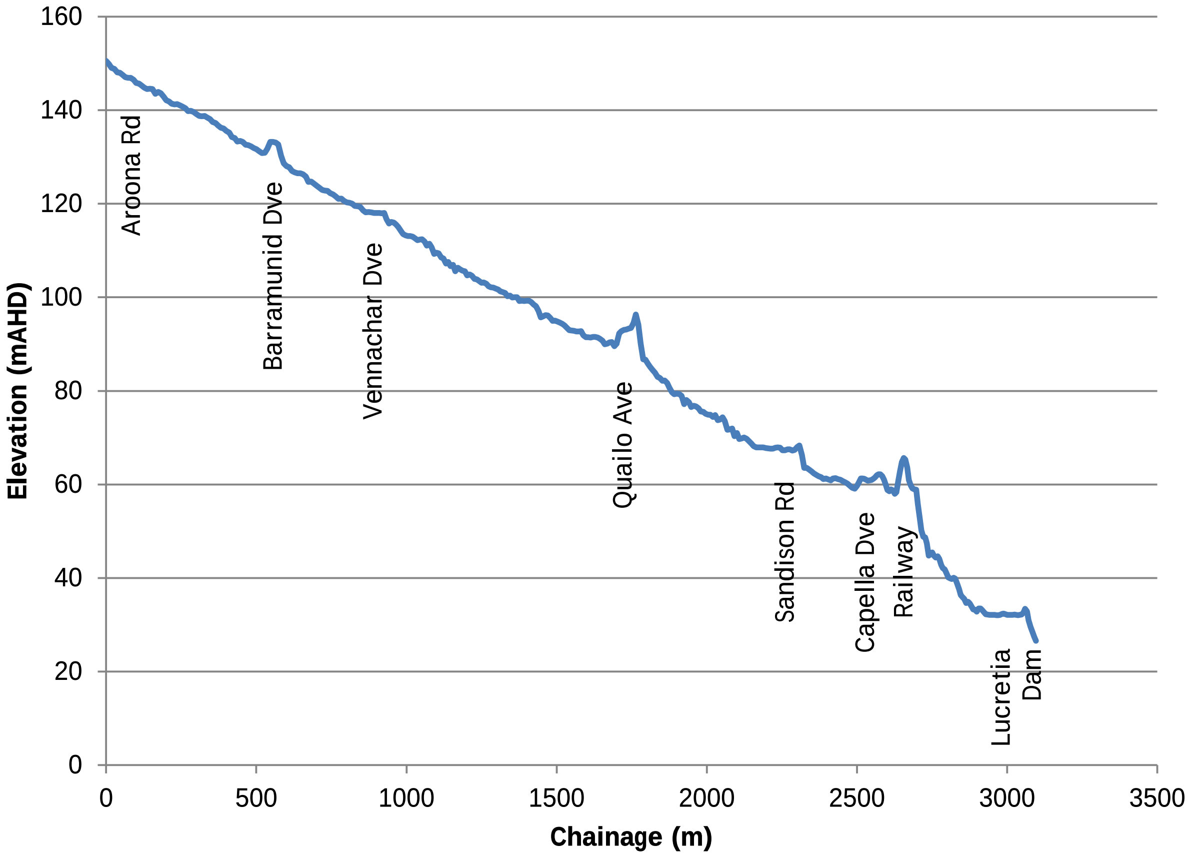
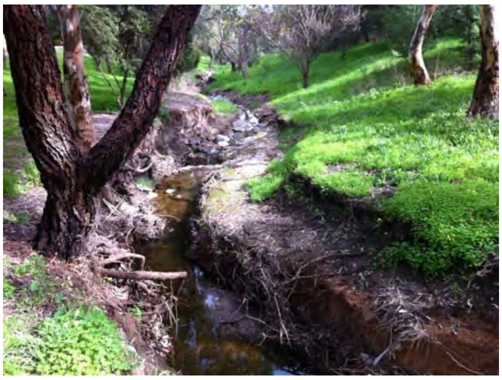


Figure 6.4 Waterfall Creek Longitudinal Profile

The catchment has now been almost completely urbanised, and developed with conventional underground drainage systems that efficiently deliver stormwater runoff to the creek channel. This has resulted in a substantial change to the 'pre-European' hydrological regime, whereby peak flows are increased and more frequent.

At various locations, the following erosion indicators have been observed:

- Discernible 'waterfall' in bed
- Bell-shaped scour hole in invert of creek
- Exposed foundations on structures such as bridge piers



These indicators are typical of 'bed scour' erosion. In response to the erosion that has occurred to date, a number of creek channel sections (predominantly in Management Zone 1) have been reconstructed with rock armouring, including a series of gabion weir drop structures installed in the most upstream section of this zone.

In recent years, an accelerated rate of erosion was observed within the Hallett Cove Conservation Park (Management Zone 3), downstream of the Lucretia Dam. The City of Marion, in partnership with the Adelaide & Mt Lofty Ranges NRM Board and the then Department for Environment and Natural Resources (DENR) were monitoring this closely and had commissioned the development of a detailed design to stabilise the channel erosion. Following a storm event in early 2012, further creek channel damage occurred (including failure of a vehicle bridge crossing), following which the design was updated and construction works (consisting of a series of rock chutes) were undertaken.

These measures, while suitable for the purposes of addressing the observed erosion indicators, are resulting in the progressive transformation of a natural water course into a rock lined open channel, with limited biodiversity value. Figure 6.5 below shows (highlighted in white) the extent of Waterfall Creek that has been reconstructed with rock armouring.

Figure 6.5 Existing Waterfall Creek channel rock armour measures

Watercourse Restoration / Erosion Control – Functional Design

The greatest erosion impact is from events less than the 2 year ARI event. These storms have the greatest influence on in-bank areas of creeks and are the most affected by urbanisation. To reduce the impact of urbanisation on creek systems, it will be necessary to design stormwater detention system(s) to reduce the 1-2 year ARI peak flows to significantly less than pre-development conditions. (ie detain as much as practicable). This approach will allow for some sections of the watercourse to be rehabilitated with a combination of rock scour protection and vegetation, thereby creating riparian biodiversity opportunities.

A low ARI peak flow reduction strategy has been developed for Waterfall Creek which is based on providing detention storages at the following locations:

- Downstream of Aroona Road
- Upstream of Barramundi Drive
- Upstream of Quailo Avenue
- Glade Crescent Reserve Wetlands (3 storages)
- Lucretia Wetland

Sketch plans describing the likely extent of works associated with achieving these storages (in integrated with delivering other works packages such as wetlands) are presented in Appendix B.

The design intent of the Aroona Road and Barramundi Drive storages is as follows:

- All flows up to an including the 1 year ARI to discharge via the low flow outlet

- Weir to be provided for flows to overtop the structure during events greater than a 1 year ARI (sized to cater for a 100 year ARI flow)

The design intent of the Quailo Avenue detention storage, and detention storage integrated into the Glade Crescent (Pond 3) and Lucretia wetlands is as follows:

- All flows up to an including the 1 year ARI to discharge via the low flow outlet
- Weir box structure to be provided to allow flows to discharge into the downstream culvert during events greater than a 1 year ARI (sized to cater for a 100 year ARI flow)

The design intent of the detention storage integrated into the Glade Crescent wetlands (Ponds 1 and 2) is as follows:

- All flows up to an including the 1 year ARI to discharge via a narrow weir section
- High flow weir to be provided for flows to overtop the structure during events greater than a 1 year ARI (sized to cater for a 100 year ARI flow)

The performance of these measures has been evaluated by utilising the floodplain model of Waterfall Creek. The embankments and culverts associated with these storages were entered into the model, and a 1 year ARI storm (for a number of durations) was executed to determine the required storage capacities and resultant peak flow reductions. A performance summary of the 1 year ARI event is presented in Table 6.3 below.

Table 6.3 Instream Detention Storages 1 yr ARI Performance

Location	Existing 1 yr ARI flow (m^3/s)	Existing 1 yr ARI flow (m^3/s)
Barramundi Drive (downstream Aroona Ro, Barramundi Rd storages)	0.5	0.3
Quailo Ave (downstream Quailo Ave storage)	1.1	0.6
Sandison Road (downstream Glade Crescent wetlands)	1.3	0.4
Railway Line	1.5	0.9
Conservation Park (downstream Lucretia wetland)	1.5	0.3

These results are encouraging as they indicate that there is the potential to halve peak flow rates along much of the creek length, and to reduce the 1 year ARI peak flow discharged into Hallett Cove Conservation Park by 80%. These flow reductions should provide a strong basis on which watercourse rehabilitation works (comprising revegetation and some engineering works) can achieve some environmental biodiversity.

The sections of Waterfall Creek identified as requiring ‘comprehensive’ restoration works are those sections above Quailo Avenue, where rock armouring of the channel has not been undertaken (ie Quailo Ave – Vennachar Dve, Vennachar Dve – Arachne Dve). Subject to further concept design development, these works are envisaged to be comprised of pools and riffles, rock chutes, and sections of regraded channel with native riparian vegetation.

References to examples elsewhere that incorporate some of the elements described are shown below.

Rehabilitated Stream (Second Creek, Michael Perry Reserve)

Rehabilitated Urban Creek (Brisbane City Council)

Pool and Riffle (Second Creek, Michael Perry Reserve)

6.4.4 Water Pollution

The watercourse reaches, particularly within Zones 1, 2, and 3 receive flows from large urban catchments, which is generally associated with poor water quality as described in Section 2.9.4. Further to this, some sections of the watercourses (particularly in the vicinity of the Lucretia Dam) were observed to receive overflows from adjacent sewer pump station systems. While the impacts associated with reduced water quality are less obvious than erosion, it is expected that the local biodiversity is negatively impacted. The proposed constructed wetlands (refer Section 7) will provide a significant improvement in stream water quality.

Areas of excessive reed growth were confined to Management Zones 1 and 2. It is possible that the dense growth may contribute to the accumulation of sediment, nutrients and rubbish at these locations. It is anticipated that the proposed detention basins, wetland developments and sediment / gross pollutant traps will allow for a reduced occurrence of this issue.

6.4.5 Current maintenance regimes

Mowing and slashing of exotic grasses in Management Zone 1 for aesthetic value is an ongoing maintenance activity. Native grasses also occur in these areas and the timing of these activities may be impacting seedling recruitment by limiting the species' ability to set seed within some areas.

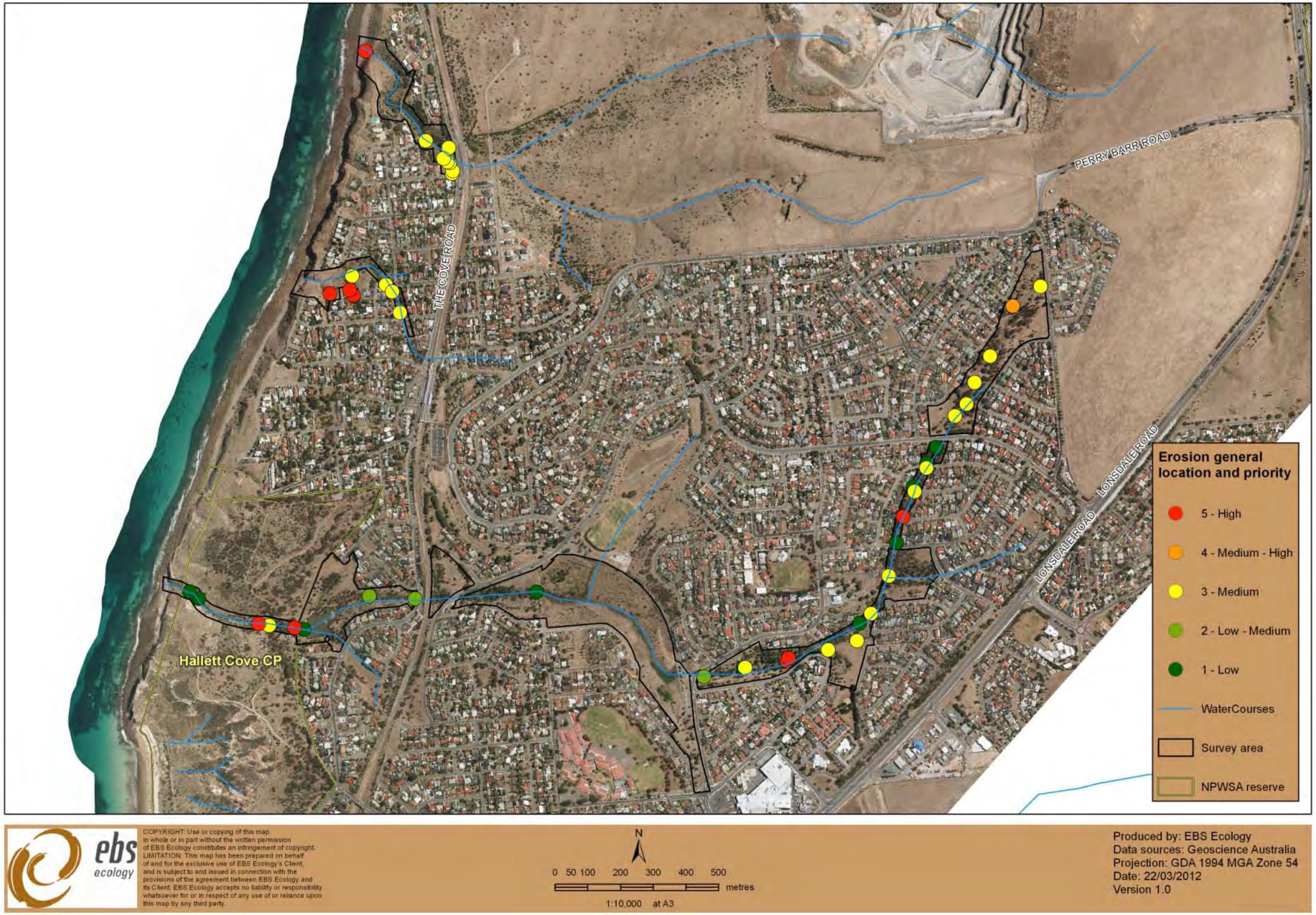


Figure 6.6 Observed Watercourse Erosion Locations

6.5 Management Zones

6.5.1 Zone 1- Waterfall Creek (upper)

Condition Rating
Low

Vegetation Associations

1. Exotic Grassland
2. Planted amenity trees (*Eucalyptus leucoxylon / Eucalyptus camaldulensis*) over exotic grasses
3. *Callitris gracilis / Pinus* sp +/- *Eucalyptus camaldulensis* over exotic grasses
4. *Eucalyptus camaldulensis* over *Typha domingensis*

General Description
Zone 1 incorporates the eastern portion of Waterfall Creek, within the Waterfall Creek Catchment. It is bordered by Quailo Avenue to the west and Aroona Road to the east. The western edge meets Glade Crescent. The land within Zone 1 is maintained for recreation, and consists of large trees with mowed grassy areas.

Erosion Issues
The section below Arachne Drive has incurred damage from water erosion and is continuing to experience erosion as a number of active scour heads move upstream. A short section of creek is aligned near the rear boundary of properties fronting Quailo Avenue (refer Figure 6.7). Council have expressed a desire to ensure that future creek maintenance works retain the creek channel within the public reserve, thereby avoiding confusion over future maintenance responsibilities and practices.

Note: Cadastral boundaries shown, not surveyed boundaries

Figure 6.7 Waterfall Creek Reserve Boundary, adj Quailo Avenue

Creek sections upstream of Arachne Drive are generally stable due to rock armouring of the channel.

Species of significance
No comprehensive survey was undertaken to determine presence of significant or formally threatened species. There may be some low level habitat available for fauna species, particularly birds, and potentially feeding habitat for Yellow-tailed Black Cockatoos. Other species such as the Black-chinned Honeyeater and Crested Shrike-tit are likely to utilise the site (Smith pers. Comm., 2012).

Biodiversity Values

- Habitat - Woodland areas (some remnant, some planted) provide low levels of roosting, nesting and foraging habitat to local native birds and bats
- Small pockets of native understorey which may provide opportunities for biodiversity conservation and restoration. Two areas near end of Madison Court that may be suitable

Threatening Processes

- High weed infestations (refer Table 6.4, Figure 6.8). Some issues with residential gardens expanding into the reserve.
- Regular slashing/mowing of native grass patches
- Erosion – many areas along creekline subject to erosive forces
- Feral animals – likely cats and foxes

Restoration Opportunities

- There is potential for revegetation of wooded areas in the long term, In particular, non-local natives and exotic tree species could be gradually replaced with local species, complimented with clumps of local native understorey.
- Native grasses could also be encouraged to recolonise small patches by undertaking a slashing and mowing regime which follows the species' seed set and thereby promotes natural regeneration.
- Very High priority weeds should be managed immediately (Artichoke Thistle and Olive)
- Enhance small pockets of native understorey with understorey infill planting and overstorey species (*Eucalyptus leucoxylon / Eucalyptus camaldulensis*) at end of Madison Square Court.

Table 6.4 Priority Weeds, Management Zone 1

Priority	Species	Common Name	Infestation description
Very High	*Cynara cardunculus ssp. flavescens*	Artichoke Thistle	Scattered individuals, small patches
Very High	*Olea europaea ssp. europaea*	Olive	Scattered individuals
High	*Acacia cyclops*	Western Coastal Wattle	Scattered individuals
High	*Acacia saligna*	Golden Wreath Wattle	Scattered individuals, small patches
High	*Asphodelus fistulosus*	Onion Weed	Scattered along majority or creek corridor
High	*Echium plantagineum*	Salvation Jane	Scattered individuals
High	*Fraxinus angustifolia ssp. angustifolia*	Desert Ash	Scattered along majority or creek corridor
Medium	*Casuarina glauca*	Grey Buloke	Scattered individuals, small patches
Medium	*Foeniculum vulgare*	Fennel	Small patches

Medium	*Gazania sp.*	Gazania	Small patches
Medium	*Phyllostachys sp.*	Bamboo	Medium size patch
Medium	*Rapistrum rugosum ssp. rugosum*	Turnip Weed	Small patches
Low	*Phoenix canariensis*	Canary Island Palm	Scattered individuals
Low	*Pinus halepensis*	Aleppo Pine	Scattered individuals, some possible development act
Low	*Schinus molle*	Pepper-tree	Scattered individuals

Table 6.5 Management Actions, Management Zone 1

Weed Management		
Issue	Strategy	Key Actions
Occurrence of Declared & Environmental weed species on site	Eradicate or control existing weed species on-site	Weeds have been categorized according to management priority with higher priority given to Declared and Environmental weeds that are known to have high levels of invasiveness. Contractors should be employed to implement best practice weed control techniques and the Principles of Weed Management to eradicate identified weeds. The method of control will vary according to the species and degree of infestation. Follow up weed control activities should be planned to prevent any re-establishment of weed species. Appropriately experienced and licensed contractors should be employed to implement all weed control activities and follow up activities.
	Employ sensitive methods of weed control	Best practice weed control methods and the use of Principles of Weed Management should be employed to prevent any off-target effects. This includes the correct storage of chemicals, appropriate weather conditions during spraying, and management of chemical run-off around drainage lines
Possible spread of weed species and plant pathogens to the site	Limit distribution and numbers of vectors for spread.	No declared or environmental weeds are to be mulched. Declared and environmental weeds to be disposed of at a licensed waste facility. Weed propagules or weed infested topsoil should not be imported to site. Cleaning of all machinery and equipment prior to site entry and exit in dedicated wash down. Water and waste collected from wash down bays to be disposed of appropriately. Ensure that any plants brought onto the site are free of *Phytophthora* and other plant pathogens.
Feral Animal Management		
Issue	Strategy	Key Actions
Potential increase in feral animal populations or	Prevent new feral animal populations or individuals from	Any new or increased rabbit activity observed on site is to be recorded to enable adaptive management to determine if control measures are necessary

individuals on site	inhabiting the site	Undertake fox baiting activities if necessary along creeklines but away from public access areas
Revegetation		
Issue	Strategy	Key Actions
Improve biodiversity and habitat value	Protect Native Grasses Revegetation of upper and understorey	Undertake slash and mowing regime to help retain native grasses and promote seed set. Replacement of local overstorey species with native tree species complimented with clumps of local native understorey species - Long term strategy. Revegetate small areas at end of Madison Square Court
Erosion		
Issue	Strategy	Key Actions
Low biodiversity within creekline	Promote natural regeneration	Manage weeds Revegetation along banks
Erosion issues	Mitigate against further erosion	Create in-line detention storages downsteam of Aroona Road and upstream of Barramundi Drive Rehabilitate creek sections utilising pools / riffles connected by vegetated channel sections with reduced longitudinal gradient Stage 1 – Quailo Ave to Vennachar Drive Stage 2 – Vennachar Drive to Arachne Drive
Erosion issues	Mitigate against further erosion	Construct cutoff drain in Quailo Ave to collect stormwater drains from Coorabie Crescent and Lighthouse Drive, that currently discharge down the steep gully slope
Future works		
Issue	Strategy	Key Actions
Clearance of valuable vegetation and potential habitat	Protect existing vegetation from accidental damage	Locate and map significant biodiversity values prior to works being undertaken.

Figure 6.8 Priority Weeds, Management Zone 1

6.5.2 Zone 2 - Waterfall Creek (middle)

Condition Rating
Moderate – Low (some of the areas within the "Moderate" category could potentially be considered as "High" based on the good flora diversity, habitat for native fauna, a bush for life site, and in close proximity to Hallett Cove Conservation Park. Further study of this area may lead to a finer scale mapping of the areas between moderate and high condition levels.)

Vegetation Associations

1 Scattered Olive, Artichoke Thistle, Desert Ash over Typha domingensis within drain
2 Olive Tall Shrubland over scattered patches of native grass, Artichoke Thistle and native revegetation
3 Planted amenity trees (Eucalyptus leucoxylon / Eucalyptus camaldulensis) over exotic grasses

General Description
Zone 2 incorporates the middle section of Waterfall Creek, within the Waterfall Creek Catchment. It also incorporates the Glade Crescent area. The sections of Zone 2 are intersected by the Noarlunga line railway, with the western segment bordered by Hallett Cove Conservation Park. Quailo Avenue forms the far eastern boundary of the eastern segment.

Erosion Issues
Isolated locations of scour were observed within the Glade Crescent Reserve, and between the Railway line and Lucretia Dam. A dense reed mass has established on the upstream side of the Sandison Road road reserve crossing, and it is likely that a considerable volume of silt and debris has accumulated at this location.

This zone has generally retained the 'character' of a natural watercourse and measures are recommended to maintain and enhance the existing values inherent to this reach.

Species of significance
No comprehensive fauna and flora survey was undertaken however the following species of regional significance were recorded:

- *Austrostipa multispiculis* (found in Bush for Life site) – rated Rare for SA and the Southern Lofty Ranges
- *Aristida behriana* (Brush Wire-grass) – rated Uncommon for Southern Lofty Ranges
- *Cullen australasicum* (Tall Scurf-pea) – rated Rare for Southern Lofty Ranges
- *Eucalyptus porosa* (Mallee Box) – rated Uncommon for Southern Lofty Ranges
- *Pimelea curviflora var. curviflora* (Curved Riceflower) – rated Rare for Southern Lofty Ranges
- *Ptilotus nobilis var. nobilis* (Yellow Tails) - rated Vulnerable for Southern Lofty Ranges

Other poorly represented species include:

- Goodenia albiflora (White Goodenia)
- Stackhousia monogyna (Creamy Candles)

There may be some low level habitat available for fauna species, particularly birds, and potentially feeding habitat for Yellow-tailed Black Cockatoos. Other species such as the Black-chinned Honeyeater and Crested Shrike-tit are likely to utilise the site (Smith pers. Comm., 2012).

The rating of this section could potentially be raised from moderate to high based upon threatened species, however the quality of the vegetation and the high levels of weeds within zone warrant a lower condition rating.

Biodiversity Values

- Good area for biodiversity, reasonable flora diversity and likely habitat for native fauna.
- Bush for Life site in this area.
- Habitat - Birds and frogs noted as using the area – would also be important for bats, small reptiles and mammals, and potentially aquatic fauna.
- Proximity – adjacent to Hallett Cove Conservation Park

Threatening Processes

- Erosion – isolated locations
- Feral animals – likely cats, foxes and rats
- Weed issues – Kikuyu grass and various other exotics (refer Table 6.6, Figure 6.9)
- *Typha* sp. is present in this area, while a native species may be an issue to manage as it is an aggressive coloniser (can also create barrier to water flows)

Restoration Opportunities

- Glade Crescent area is very steep and generally inaccessible for formal recreation, therefore is ideal for conserving biodiversity values and maintaining a refuge for native flora and fauna.
- There is some access to the dam and the banks are used by walkers. Some weed issues in here (willows holding banks up), also may be an opportunity for restoration works.
- Some of the scattered Declared weeds (Boxthorn and Bridal Creeper) can be removed along the gully faces immediately to halt further spread.

Table 6.6 Priority Weeds, Management Zone 2

Priority	Species	Common name	Infestation description
Very High	*Asparagus asparagoides f. asparagoides*	Bridal Creeper	Very scattered individuals
Very High	*Lycium ferocissimum*	African Boxthorn	Scattered individuals
Very High	*Olea europaea ssp. europaea*	Olive	Patches along gully faces
High	*Acacia cyclops*	Western Coastal Wattle	Very scattered individuals
High	*Cynara cardunculus ssp. flavescens*	Artichoke Thistle	Scattered individuals, small - large patches
High	*Foeniculum vulgare*	Fennel	Small patches
High	*Euphorbia terracina*	False Caper	Scattered individuals
High	*Casuarina glauca*	Grey Buloke	Scattered individuals, small patches
High	*Pennisetum sp.*	Feather Grass	Scattered individuals
High	*Ricinus communis*	Castor Oil	Scattered within creekline
High	*Fraxinus angustifolia ssp. angustifolia*	Desert Ash	Scattered along majority or creek corridor
Medium	*Chrysanthemoides monilifera ssp. monilifera*	Boneseed	Very scattered individuals

Priority	Species	Common name	Infestation description
Medium	*Phyllostachys sp.*	Bamboo	Medium size patch
Low	*Ficus carica*	Edible Fig	Very scattered individuals in creek
Low	*Pennisetum clandestinum*	Kikuyu	Dense within creekline
Low	*Pinus halepensis*	Aleppo Pine	Scattered individuals along gully faces
Low	*Salix sp.*	Willow	Located around edge of dam

Table 6.7 Management Priorities, Management Zone 2

Weed Management		
Issue	Strategy	Key Actions
Occurrence of Declared & Environmental weed species on site	Eradicate or control existing weed species on-site	Weeds have been categorized according to management priority with higher priority given to Declared and Environmental weeds that are known to have high levels of invasiveness. Contractors should be employed to implement best practice weed control techniques and the Principles of Weed Management to eradicate identified weeds. The method of control will vary according to the species and degree of infestation. Follow up weed control activities should be planned to prevent any re-establishment of weed species. Appropriately experienced and licensed contractors should be employed to implement all weed control activities and follow up activities.
	Employ sensitive methods of weed control	Best practice weed control methods and the use of Principles of Weed Management should be employed to prevent any off-target effects. This includes the correct storage of chemicals, appropriate weather conditions during spraying, and management of chemical run-off around drainage lines
Possible spread of weed species and plant pathogens to the site	Limit distribution and numbers of vectors for spread.	No declared or environmental weeds are to be mulched. Declared and environmental weeds to be disposed of at a licensed waste facility. Weed propagules or weed infested topsoil should not be imported to site. Cleaning of all machinery and equipment prior to site entry and exit in dedicated wash down. Water and waste collected from wash down bays to be disposed of appropriately. Ensure that any plants brought onto the site are free of *Phytophthora* and other plant pathogens.
Feral Animal Management		
Issue	Strategy	Key Actions
Potential increase in feral animal populations or	Prevent new feral animal populations or individuals from	Any new or increased rabbit activity observed on site is to be recorded to enable adaptive management to determine if control measures are necessary

individuals on site	inhabiting the site	Undertake fox baiting activities if necessary along creeklines but away from public access areas
Revegetation		
Issue	Strategy	Key Actions
Improve biodiversity and habitat value in steep inaccessible areas along Glade Crescent Improve biodiversity, habitat and aesthetic value around dam	Enhance existing revegetation activities	Undertake infill planting to compliment exiting revegetation attempts within Moderate value areas. Restore appropriate structure to the vegetation communities (ie. overstorey, mid and understorey) Revegetation activities associated with the Glade Crescent Wetland proposal
Erosion		
Issue	Strategy	Key Actions
Destabilisation of creek banks	Promote natural regeneration and revegetate	Manage weeds Revegetate with infill planting
Erosion issues	Mitigate against further erosion	Provide detention storage within Glade Crescent wetland and proposed reconstruction of Lucretia Dam to reduce downstream flows. Care must be taken to remove woody weeds gradually to reduce the impacts of destabilisation to banks (eg. willows).
Future works		
Issue	Strategy	Key Actions
Clearance of valuable vegetation and potential habitat	Protect existing vegetation from accidental damage	Locate and map significant biodiversity values prior to works being undertaken.

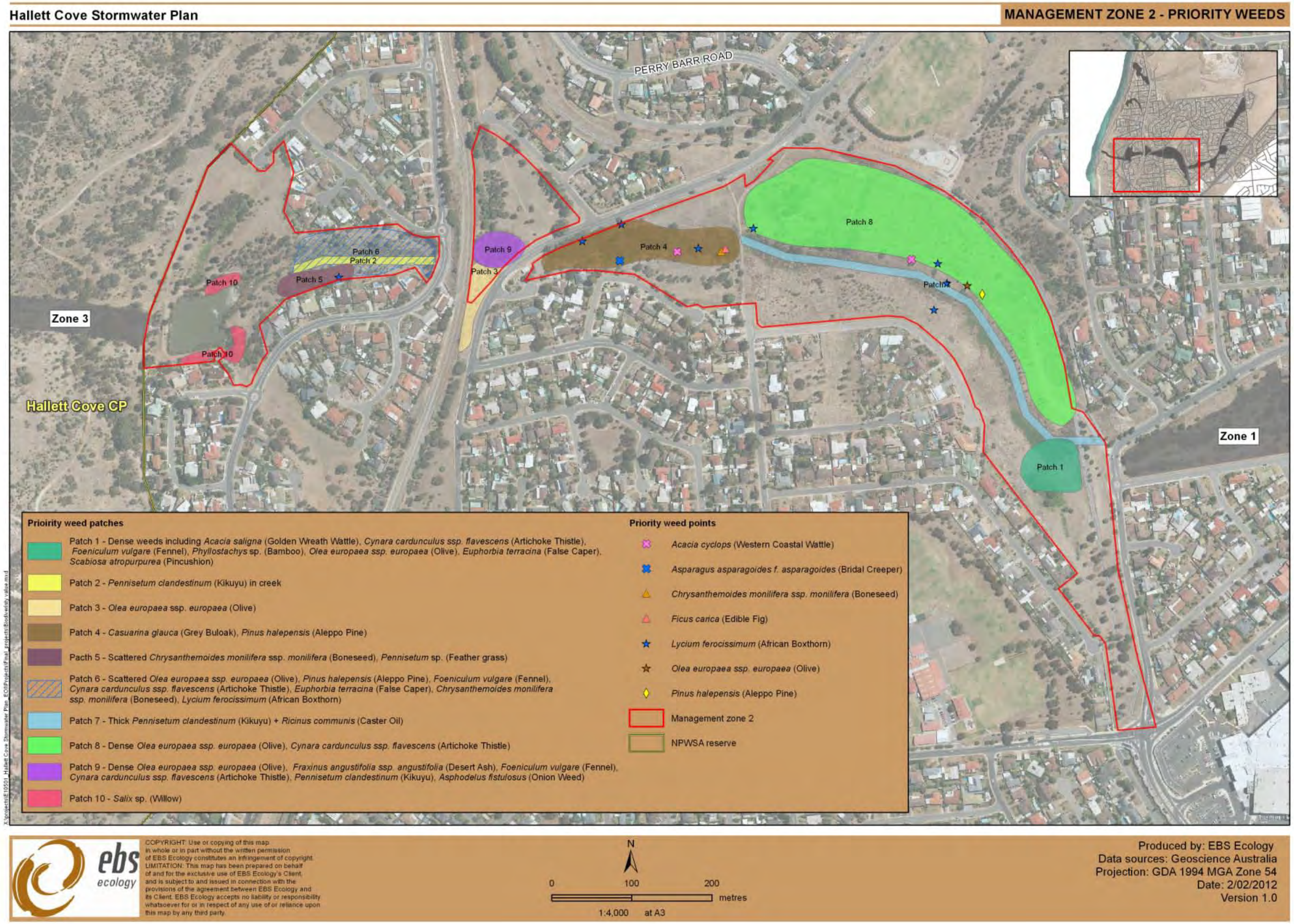


Figure 6.9 Priority Weeds, Management Zone 2

6.5.3 Zone 3 - Waterfall Creek (lower)

Condition Rating
High

Vegetation Associations

1. Olive Tall Shrubland over scattered patches of native grass, Artichoke Thistle and native revegetation
2. Eucalyptus porosa / Allocasuarina verticillata / Dodonaea viscosa mixed revegetation patch
3. Olearia ramulosa +/- Myoporum insulare Shrubland
4. Eucalyptus leucoxylon / Eucalyptus camaldulensis / Eucalyptus porosa Open Woodland riparian area
5. Lomandra densiflora / exotic grass Grassland

General Description
Zone 3 falls within the Hallett Cove Conservation Park and incorporates the western portion of Waterfall Creek. It is bordered by the sea to the west and Zone 2 to the east.

Erosion Issues
This area is in reasonable condition (particularly following the recent installation of a series of rock chutes) however there are some other locations that will require ongoing monitoring.

Small areas of wetland vegetation situated directly below the dam and fauna habitat would benefit from the release of small flows during extended dry periods. The remainder of creek in this section does not currently contain much biodiversity that requires a flow of water to be maintained (mainly comprising rock and bare earth), however this may change as revegetation efforts take hold. The successful development of this vegetation will assist in the stabilising the remainder of the creek channel in the long term.

Species of significance
State rare Myoporum parvifolium (Creeping Boobialla) was observed during the field survey, however it was not a comprehensive fauna and flora survey to determine presence of significant or formally threatened species. A number of regionally threatened flora species were also observed:

- *Aristida behriana* (Brush Wire-grass) – rated Uncommon
- *Cullen australasicum* (Tall Scurf-pea) – rated Rare
- *Eucalyptus porosa* (Mallee Box) – rated Uncommon
- *Pimelea curviflora var. curviflora* (Curved Riceflower) – rated Rare
- *Ptilotus nobilis var. nobilis* (Yellow Tails) - rated Vulnerable
- *Myoporum parvifolium* (Creeping Boobialla) - rated rare for SA and Vulnerable for Southern Lofty Ranges
- *Myoporum viscosum* (Sticky Boobialla) – rated Uncommon
- *Pittosporum angustifolium* (Native Apricot) – rated Rare
- *Lycium australe* (Australian Boxthorn) – rated Endangered
- *Melaleuca lanceolata* (Dryland Tea-tree) – rated Uncommon

Potential suitable habitat is available for fauna species, particularly birds, and potentially feeding habitat for Yellow-tailed Black Cockatoos. Other species such as the Black-chinned Honeyeater and Crested Shrike-tit are likely to utilise the site (Smith pers. Comm., 2012).

Biodiversity Values

- Proximity – forms part of Hallett Cove Conservation Park

- Good area for biodiversity, reasonable flora diversity and likely habitat for native fauna. Very low levels of weeds.
- Potential habitat for state threatened bird species
- State rare *Myoporum parvifolium* (Creeping Boobialla) recorded along the coast, should be avoided and protected. Opportunity for biodiversity restoration.
- Some patches of *Lomandra densiflora* Grassland along the coast. They should be considered as opportunities for biodiversity conservation – to enhance size (if appropriate) and diversity within the areas.

Threatening Processes

- Erosion – partially natural erosion in deep valleys and some is accelerated erosion. It is potentially a problem near the boardwalk in the future (however this area is currently in good condition).
- Feral animals – likely cats, foxes and rats
- Weed issues – Bridal Creeper (Scattered individuals along gully faces) (refer Table 6.8, Figure 6.10)

Restoration Opportunities

- Stabilise erosion areas to reduce further damage to infrastructure (board walks, footbridge)
- Undertake repairs to walking track infrastructure
- In the short term there is potential for restorative activities to be undertaken within the 'High Value' *Lomandra densiflora* Grassland patch along the coast. Consider increasing the size of the *Lomandra densiflora* Grassland patch (if appropriate) through revegetation to enhance biodiversity.
- Sensitively restore low open shrubland community along top of coastal cliffs with scattered native shrubs and grasses to create open shrubland similar to adjacent shrublands to the north
- Some of the scattered Declared weeds (Bridal Creeper) can be removed along the gully faces immediately to halt further spread.

Table 6.8 Priority Weeds, Management Zone 3

Priority	Species	Common name	Infestation description
Very High	*Asparagus asparagoides f. asparagoides*	Bridal Creeper	Scattered individuals along gully faces

Table 6.9 Management Priorities, Management Zone 3

Weed Management		
Issue	Strategy	Key Actions
Occurrence of Declared & Environmental weed species on site	Eradicate or control existing weed species on-site	The primary weed (Bridal Creeper) is a Declared species under the NRM Act and known to have a high level of invasiveness. See individual Table 15. All works will need to be arranged in collaboration with National Parks and Wildlife SA. Contractors should be employed to implement best practice weed control techniques and the Principles of Weed Management to eradicate identified weeds. The method of control will vary according to the species and degree of infestation. Follow up weed control activities should be planned to prevent

	Employ sensitive methods of weed control	any re-establishment of weed species. Appropriately experienced and licensed contractors should be employed to implement all weed control activities and follow up activities. Best practice weed control methods and the use of Principles of Weed Management should be employed to prevent any off-target effects. This includes the correct storage of chemicals, appropriate weather conditions during spraying, and management of chemical run-off around drainage lines
Possible spread of weed species and plant pathogens to the site	Limit distribution and numbers of vectors for spread.	No declared or environmental weeds are to be mulched. Declared weed to be disposed of at a licensed waste facility. Weed propagules or weed infested topsoil should not be imported to site. Cleaning of all machinery and equipment prior to site entry and exit in dedicated wash down. Water and waste collected from wash down bays to be disposed of appropriately. Ensure that any plants brought onto the site are free of *Phytophthora* and other plant pathogens.
Feral Animal Management		
Issue	Strategy	Key Actions
Potential increase in feral animal populations or individuals on site	Prevent new feral animal populations or individuals from inhabiting the site	Any new or increased rabbit activity observed on site is to be recorded to enable adaptive management to determine if control measures are necessary. Undertake fox baiting activities if necessary along creeklines but away from public access areas Any works undertaken will need to be arranged in collaboration with National Parks and Wildlife SA.
Revegetation		
Issue	Strategy	Key Actions
Improve biodiversity and habitat value along cliff areas adjacent coast	Restore *Lomandra densiflora* Grassland community	Sensitively revegetate *Lomandra densiflora* Grassland patch with scattered native species (tubestock) suitable to the grassland community
Improve biodiversity of degraded Shrublands	Revegetate shrubland community	Sensitively revegetate with scattered native shrubs and grasses to create open shrubland similar to adjacent shrublands to the north. Any works undertaken will need to be arranged in collaboration with National Parks and Wildlife SA.
Erosion		
Issue	Strategy	Key Actions
Erosion issues	Mitigate against further erosion	Revegetation along watercourse Any works undertaken will need to be arranged in collaboration with National Parks and Wildlife SA.

Summer Flows	Mitigate against further erosion	Ensure that provision is made in future upgrade of Lucretia Dam for low flow releases
Future works		
Issue	Strategy	Key Actions
Clearance of valuable vegetation and potential habitat	Protect existing vegetation from accidental damage	Locate and map significant biodiversity values prior to works being undertaken.

Figure 6.10 Priority Weeds, Management Zone 3

6.5.4 Zone 4 - Pindee Street drain

Condition Rating
High, Moderate & Low

Vegetation Associations

1. Olive / *Pinus* sp. / *Acacia paradoxa* over planted non-local natives
2. Olive Tall Shrubland with scattered Desert Ash over patchy *Austrostipa* sp and *Enneapogon nigricans*
3. *Lomandra densiflora* / exotic grass Grassland
4. *Olearia ramulosa* +/- *Myoporum insulare* Shrubland

General Description
Zone 4 is the northern most zone within the project area, and is located within the Perry Barr Road Catchment. This zone is the only area reported that is entirely within privately owned land. It is bordered by the sea to the west and the corner of Pindee Street and The Cove Road to the east. Marino Conservation Park is situated around 200 m to north-east of this Zone.

Erosion Issues
No significant issues apparent.

Species of significance
A number of regionally threatened species were observed during the field survey, however it was not a comprehensive fauna and flora survey to determine presence of significant or formally threatened species. A previous study of the area (City of Marion Indigenous Vegetation Assessments - Stage Two (J Smith 2008) recorded a total of 17 regionally significance species which have been included in the list below. There is a good level of biodiversity within this zone and a reasonable amount of potential habitat available for fauna and flora species.

- *Acacia cupularis* (Cup Wattle) – rated Rare
- *Acrotriche patula* (Prickly Ground-berry) – rated Rare
- *Alyxia buxifolia* (Sea Box) – rated Rare
- *Aristida behriana* (Brush Wire-grass) – rated Uncommon
- *Calandrinia volubilis* (Twining Purslane) - rated Threatened
- *Dissocarpus biflorus var. biflorus* (Two-horn Saltbush) - rated Vulnerable
- *Eucalyptus porosa* (Mallee Box) – rated Uncommon
- *Goodenia amplexans* (Clasping Goodenia) – rated Uncommon
- *Lomandra effusa* Scented Mat-rush – rated Rare
- *Malva behriana* (Australian Hollyhock) – rated Uncommon
- *Melaleuca lanceolata* (Dryland Tea-tree) – rated Uncommon
- *Myoporum parvifolium* (Creeping Boobialla) - rated Rare for SA and Vulnerable for MLR
- *Myoporum sp. petiolatum (R.Taylor 484)* (Sticky Boobialla) – rated Uncommon
- *Myoporum viscosum* (Sticky Boobialla) – rated Uncommon
- *Pimelea curviflora* (Curved Riceflower) – rated Rare
- *Pittosporum angustifolium* (Native Apricot) – rated Rare
- *Plantago gaudichaudii* (Narrow-leaf Plantain) – rated Uncommon
- *Pleurosorus rutifolius* (Blanket Fern) – rated Uncommon
- *Ptilotus nobilis var. nobilis* (Yellow-tails) - rated Vulnerable
- *Scaevola crassifolia* (Cushion Fanflower) – rated Rare
- *Scleranthus pungens* (Prickly Knawel) – rated Rare
- *Sida petrophila* (Rock Sida) – rated Unknown
- *Vittadinia blackii* (Narrow-leaf New Holland Daisy) – rated Rare

Potential suitable habitat is available for fauna species, particularly birds, and potentially feeding habitat for Yellow-tailed Black Cockatoos. Other species such as the Black-chinned Honeyeater and Crested Shrike-tit are likely to utilise the site (Smith pers. Comm., 2012).

Biodiversity Values

- Proximity – Approx 1 km north of Hallett Cove Conservation Park and 200m south of Marino CP.
- *Lomandra* sp. shrubland patch along the coast. This area should be considered as an opportunity for biodiversity conservation through restorative activities.
- High number of regionally threatened plant species throughout.

Threatening Processes

- Feral animals – likely cats, foxes and rats
- Weed issues – Mainly Olive (see Table 6.10, Figure 6.11)
- Private land encroaching on public land

Restoration Opportunities

- In the short term there is potential for restorative activities to be undertaken within the 'High Value' *Lomandra densiflora* Grassland patch along the coast. This area incorporates the Hallett Cove Boardwalk and has been degraded over time through human impacts, weeds and erosion. Consider increasing the size of the *Lomandra densiflora* Grassland patch (if appropriate) through revegetation to enhance biodiversity and aesthetic values and stabilise soils along cliff face.
- Over a longer term, some restorative activities can be employed within the 'low/moderate value areas along the creekline. This can include removal of woody exotics and revegetation of *Acacia cupularis/Myoporum insulare* Tall Shrubland.
- Some of the scattered Declared weeds (Boxthorn and Prickly Pear) can be removed along the gully faces immediately to halt further spread.

Table 6.10 Priority Weeds, Management Zone 4

Priority	Species	Common name	Infestation description
Very High	*Lycium ferocissimum*	African Boxthorn	Scattered individuals along gully faces
Very High	*Olea europaea ssp. europaea*	Olive	Dense Patches along gully faces
Very High	*Opuntia spp.*	Prickly Pear	Scattered individuals along gully faces
High	*Fraxinus angustifolia ssp. angustifolia*	Desert Ash	Scattered along majority or creek corridor
Medium	*Agave americana*	Century Plant	Scattered individuals along gully faces
Low	*Pinus halepensis*	Aleppo Pine	Scattered individuals along gully faces

Table 6.11 Management Priorities, Management Zone 4

Weed Management		
Issue	Strategy	Key Actions

Occurrence of Declared & Environmental weed species on site	Eradicate or control existing weed species on-site Employ sensitive methods of weed control	Weeds have been categorized according to management priority with higher priority given to Declared and Environmental weeds that are known to have high levels of invasiveness. Contractors should be employed to implement best practice weed control techniques and the Principles of Weed Management to eradicate identified weeds. The method of control will vary according to the species and degree of infestation. Follow up weed control activities should be planned to prevent any re-establishment of weed species. Appropriately experienced and licensed contractors should be employed to implement all weed control activities and follow up activities. Best practice weed control methods and the use of Principles of Weed Management should be employed to prevent any off-target effects. This includes the correct storage of chemicals, appropriate weather conditions during spraying, and management of chemical run-off around drainage lines
Possible spread of weed species and plant pathogens to the site	Limit distribution and numbers of vectors for spread.	No declared or environmental weeds are to be mulched. Declared weed to be disposed of at a licensed waste facility. Weed propagules or weed infested topsoil should not be imported to site. Cleaning of all machinery and equipment prior to site entry and exit in dedicated wash down. Water and waste collected from wash down bays to be disposed of appropriately. Ensure that any plants brought onto the site are free of *Phytophthora* and other plant pathogens.
Feral Animal Management		
Issue	Strategy	Key Actions
Potential increase in feral animal populations or individuals on site	Prevent new feral animal populations or individuals from inhabiting the site	Any new or increased rabbit activity observed on site is to be recorded to enable adaptive management to determine if control measures are necessary. Undertake fox baiting activities if necessary along creeklines but away from public access areas
Revegetation		
Issue	Strategy	Key Actions
Improve biodiversity and habitat value along cliff areas adjacent coast Improve biodiversity of degraded Shrublands in poor/moderate	Restore *Lomandra densiflora* Grassland community Revegetate Shrubland	Sensitively revegetate *Lomandra densiflora* Grassland patch with scattered native species (tubestock) suitable to the grassland community Revegetate shrubland community to create *Acacia cupularis / Myoporum insulare* Tall Shrubland. Potential for direct seeding here.

value area		

Future works

Issue	Strategy	Key Actions
Clearance of valuable vegetation and potential habitat	Protect existing vegetation from accidental damage	Locate and map significant biodiversity values prior to works being undertaken.

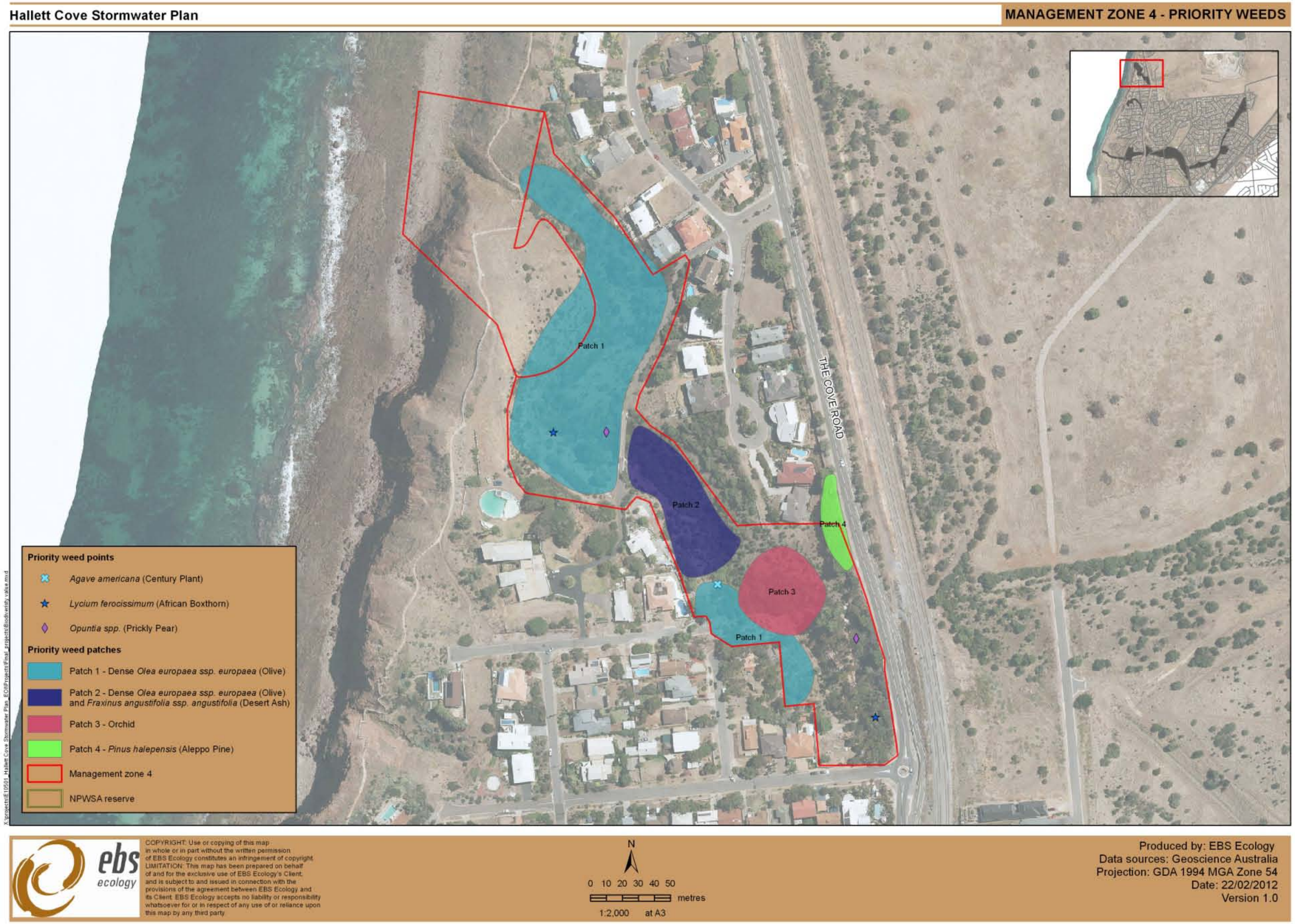


Figure 6.11 Priority Weeds, Management Zone 4

6.5.5 Zone 5 - Narang Street drain

Condition Rating
High, Moderate & Low sections

Vegetation Associations

1. Exotic dominated creekline
2. *Sida petrophila* / *Leguminosae* sp. Low Shrubland

General Description
Zone 5 is located within The Esplanade Catchment. It is bordered by the Esplanade to the west and Narang Street to the south-east.

Erosion Issues
Some erosion of step gully faces from street level stormwater discharge.

Species of significance
A number of regionally threatened species were observed during the field survey, however it was not a comprehensive fauna and flora survey to determine presence of significant or formally threatened species. A previous assessment of the Esplanade Reserve (Smith, 2008) recorded 18 regionally threatened species and one state rare, some of which have been planted and others which were regarded as remnant. These have been added to the list below.

- *Acacia cupularis* (Cup Wattle) – rated Rare
- *Acrotriche patula* (Prickly Ground-berry) – rated Rare
- *Alyxia buxifolia* (Sea Box) – rated Rare
- *Aristida behriana* (Brush Wire-grass) – rated Unknown
- *Dissocarpus biflorus var. biflorus* (Two-horn Saltbush) - rated Vulnerable
- *Eucalyptus porosa* (Mallee Box) – rated Uncommon
- *Exocarpos aphyllus* (Leafless Cherry)- rated Vulnerable
- *Gahnia lanigera* (Black Grass Sawsedge) – rated Rare
- *Goodenia amplexans* (Clasping Goodenia) – rated Uncommon
- *Goodenia varia* (Sticky Goodenia) – rated Unknown
- *Lomandra effusa* (Scented Mat-rush) – rated Rare
- *Lotus australis* (Austral Trefoil) – rated Uncommon
- *Lycium australe* (Australian Boxthorn) – rated Endangered
- *Maireana rohrlachii* (Rohrlach's Bluebush) – rated Rare in SA and Vulnerable
- *Melaleuca lanceolata* (Dryland Tea-tree) – rated Uncommon
- *Myoporum parvifolium* (Creeping Boobialla) - rated Rare in SA and Vulnerable for Southern Lofty Ranges
- *Myoporum sp. petiolatum (R.Taylor 484)* (Sticky Boobialla) – rated Uncommon
- *Pomaderris paniculosa ssp. paniculosa* (Mallee Pomaderris) – rated Uncommon
- *Scaevola crassifolia* (Cushion Fanflower) – rated Rare
- *Sida petrophila* (Rock Sida) – rated Unknown
- *Vittadinia blackii* (Narrow-leaf New Holland Daisy) – rated Rare
- *Zygophyllum confluens* (Forked Twinleaf) – rated Rare

Potential suitable habitat is available for fauna species, particularly birds, and potentially feeding habitat for Yellow-tailed Black Cockatoos. Other species such as the Black-chinned Honeyeater and Crested Shrike-tit are likely to utilise the site (Smith pers. Comm., 2012).

Biodiversity Values

- Proximity – Approx 500m north of Hallett Cove CP and 700m south of Marino Conservation Park.

- Patch of degraded *Lomandra densiflora* Grassland

Threatening Processes

- Erosion – very steep in sections
- Feral animals – likely cats, foxes and rats
- Weed issues – Many weeds, however they are currently stabilising the banks (refer Table 6.12, Figure 6.12)

Restoration Opportunities

- In the short term there is potential for restorative activities to be undertaken within the 'High Value' *Lomandra densiflora* Grassland patch along the coast. This area incorporates the Hallett Cove Boardwalk and has been degraded over time through human impacts, weeds and erosion. Consider increasing the size of the *Lomandra densiflora* Grassland patch (if appropriate) through revegetation to enhance biodiversity and aesthetic values and stabilise soils along cliff face.
- Over a longer term, some restorative activities can be employed within the 'poor/moderate value areas along the creekline (see Figure 3). This can include the gradual removal of woody exotics and replacement with local native revegetation to assist with bank stabilisation.
- Some of the scattered Declared weeds (Boxthorn) can be removed along the gully faces immediately to halt further spread.

Table 6.12 Priority Weeds, Management Zone 5

Priority	Species	Common name	Infestation description
Very High	*Lycium ferocissimum*	African Boxthorn	Scattered individuals along gully faces
Very High	*Olea europaea ssp. europaea*	Olive	Dense Patches along gully faces
High	*Acacia saligna*	Golden Wreath Wattle	Scattered individuals along gully faces
High	*Cynara cardunculus ssp. flavescens*	Artichoke Thistle	Scattered individuals, small - large patches
High	*Opuntia spp.*	Prickly Pear	Scattered individuals along gully faces
High	*Euphorbia terracina*	False Caper	Scattered individuals
High	*Foeniculum vulgare*	Fennel	Small patches
High	*Fraxinus angustifolia ssp. angustifolia*	Desert Ash	Scattered along majority or creek corridor
High	*Ricinus communis*	Castor Oil	Scattered within creekline
Medium	*Agave americana*	Century Plant	Scattered individuals along gully faces
Medium	*Chrysanthemoides monilifera ssp. monilifera*	Boneseed	Very scattered individuals
Medium	*Pennisetum* sp.	Feather Grass	Dense patches
Medium	*Piptatherum miliaceum*	Rice Millet	Scattered individuals
Medium	*Galenia sp.*	Galenia	Scattered individuals
Low	*Pennisetum clandestinum*	Kikuyu	Dense within creekline

Priority	Species	Common name	Infestation description
Low	*Pinus halepensis*	Aleppo Pine	Scattered individuals along gully faces

Table 6.13 Management Priorities, Management Zone 5

Weed Management		
Issue	Strategy	Key Actions
Occurrence of Declared & Environmental weed species on site	Eradicate or control existing weed species on-site	Weeds have been categorized according to management priority with higher priority given to Declared and Environmental weeds that are known to have high levels of invasiveness. Contractors should be employed to implement best practice weed control techniques and the Principles of Weed Management to eradicate identified weeds. The method of control will vary according to the species and degree of infestation. Follow up weed control activities should be planned to prevent any re-establishment of weed species. Appropriately experienced and licensed contractors should be employed to implement all weed control activities and follow up activities.
	Employ sensitive methods of weed control	Best practice weed control methods and the use of Principles of Weed Management should be employed to prevent any off-target effects. This includes the correct storage of chemicals, appropriate weather conditions during spraying, and management of chemical run-off around drainage lines
Possible spread of weed species and plant pathogens to the site	Limit distribution and numbers of vectors for spread.	No declared or environmental weeds are to be mulched. Declared weed to be disposed of at a licensed waste facility. Weed propagules or weed infested topsoil should not be imported to site. Cleaning of all machinery and equipment prior to site entry and exit in dedicated wash down. Water and waste collected from wash down bays to be disposed of appropriately. Ensure that any plants brought onto the site are free of *Phytophthora* and other plant pathogens.
Feral Animal Management		
Issue	Strategy	Key Actions
Potential increase in feral animal populations or individuals on site	Prevent new feral animal populations or individuals from inhabiting the site	Any new or increased rabbit activity observed on site is to be recorded to enable adaptive management to determine if control measures are necessary. Undertake fox baiting activities if necessary along creeklines but away from public access areas
Revegetation		
Issue	Strategy	Key Actions
Improve biodiversity and habitat value along	Restore *Lomandra densiflora* Grassland community	Sensitively revegetate *Lomandra densiflora* Grassland patch with scattered native species (tubestock) suitable to the grassland community

cliff areas adjacent coast		
Improve biodiversity of degraded gully banks in poor/moderate value area	Revegetate Shrubland	Revegetate creek banks with a native shrubland community (ie. *Acacia cupularis / Myoporum insulare* Tall Shrubland).
Erosion		
Issue	Strategy	Key Actions
Erosion issues	Mitigate against further erosion	Erosion control and bank stabilisation activities may be necessary
Future works		
Issue	Strategy	Key Actions
Clearance of valuable vegetation and potential habitat	Protect existing vegetation from accidental damage	Locate and map significant biodiversity values prior to works being undertaken.

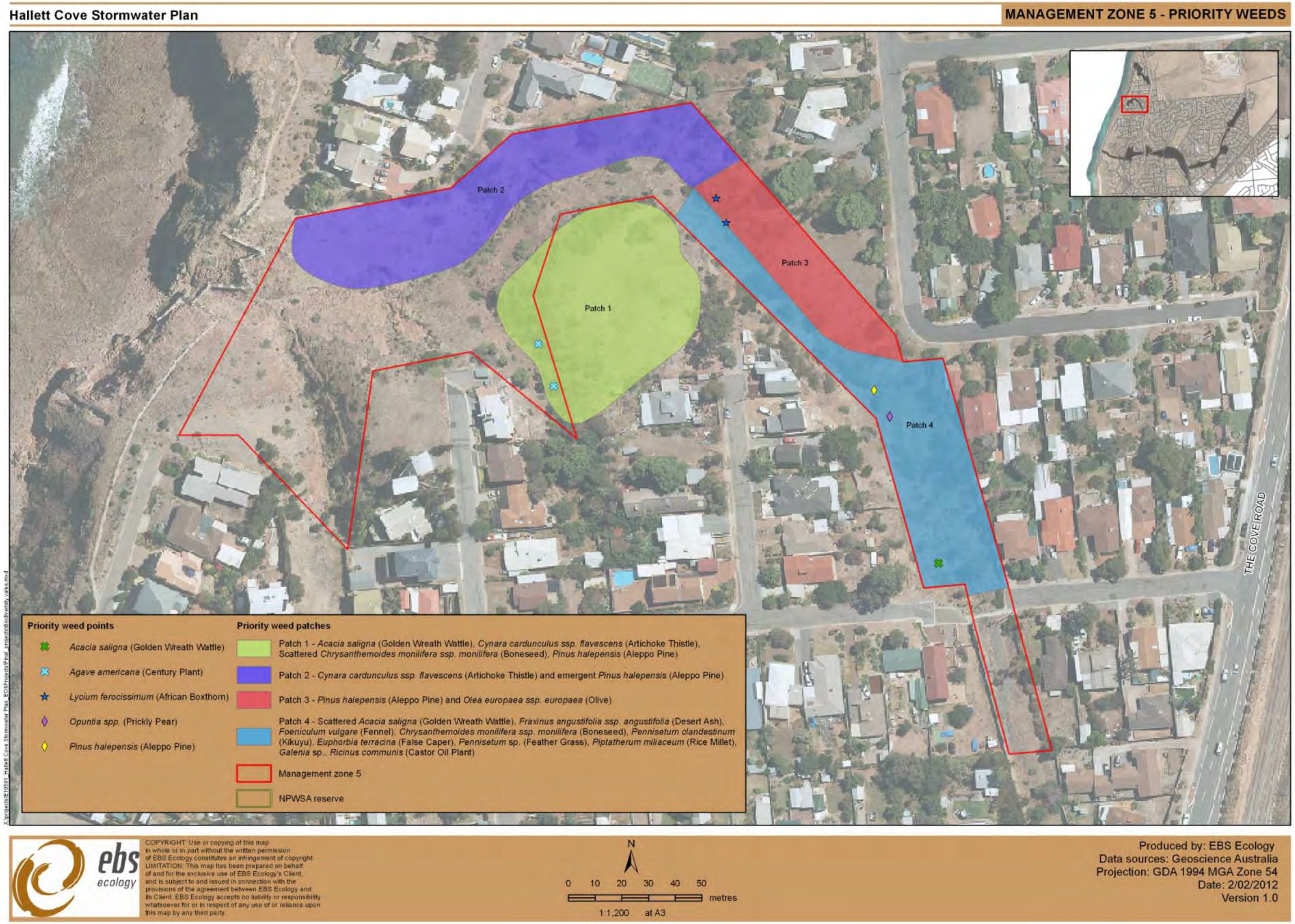


Figure 6.12 Priority Weeds, Management Zone 5

6.6 Action Summary

Table 6.14 Summary of Broad Actions across Zones

Weed Management				
Issue	Strategy	Key Actions	Management Zones	Timing*
Occurrence of Declared & Environmental weed species on site	Eradicate or control existing weed species on-site	Weeds have been categorized according to management priority with higher priority given to Declared weeds and lower priority to Environmental Weeds		
		Manage Very High priority weeds	All Zones	Immediately
		Manage High priority weeds	Zone 1	Medium term
			Zone 2	Medium term
			Zone 5	Medium term
		Manage Medium priority weeds	Zone 1	Medium term
			Zone 2	Medium term
			Zone 4	Medium term
		Manage Low priority weeds	Zone 1	Long term
			Zone 2	Long term
			Zone 4	Long term
			Zone 5	Long term
		Contractors should be employed to implement best practice weed control techniques and the Principles of Weed Management to eradicate identified weeds. The method of control will vary according to the species and degree of infestation.	All Zones	Ongoing
		Follow up weed control activities should be planned to prevent any re-establishment of weed species.		
	Employ sensitive methods of weed control	Appropriately experienced and licensed contractors should be employed to implement all weed control activities and follow up activities.	All Zones	Ongoing
		Best practice weed control methods and the use of Principles of Weed Management should be employed to prevent any off-target effects. This includes the correct storage of chemicals, appropriate weather conditions during spraying, and		

		management of chemical run-off around drainage lines		
Possible spread of weed species and plant pathogens to the site	Limit distribution and numbers of vectors for spread.	No declared or environmental weeds are to be mulched. Declared and environmental weeds to be disposed of at a licensed waste facility. Weed propagules or weed infested topsoil should not be imported to site. Cleaning of all machinery and equipment prior to site entry and exit in dedicated wash down. Water and waste collected from wash down bays to be disposed of appropriately. Ensure that any plants brought onto the site are free of *Phytophthora* and other plant pathogens.	All Zones	Ongoing
Feral Animal Management				
Issue	Strategy	Key Actions		
Potential increase in feral animal populations or individuals on site	Prevent new feral animal populations or individuals from inhabiting the site	Any new or increased rabbit activity observed on site is to be recorded to enable adaptive management to determine if control measures are necessary Undertake fox baiting activities if necessary along creeklines but away from public access areas	All Zones	Immediately
Revegetation				
Issue	Strategy	Key Actions		
Improve biodiversity and habitat value	Protect Native Grasses Revegetation of upper and understorey	Undertake slash and mowing regime to help retain native grasses and promote seed set. Replacement of local overstorey species with native tree species complimented with clumps of local native understorey	Zone 1	Medium term Long term

		species - Long term strategy. Revegetate small areas at end of Madison Square Court		Medium term
Improve biodiversity and habitat value in steep inaccessible areas along Glade Crescent Improve biodiversity, habitat and aesthetic value around dam	Enhance existing revegetation activities	Undertake infill planting to compliment exiting revegetation attempts within Moderate value areas. Restore appropriate structure to the vegetation communities (ie. overstorey, mid and understorey)	Zone 2	Medium term Medium term
Improve biodiversity and habitat value along cliff areas adjacent coast Improve biodiversity of degraded Shrublands	Restore *Lomandra densiflora* Grassland community Revegetate shrubland community	Sensitively revegetate *Lomandra densiflora* Grassland patch with scattered native species (tubestock) suitable to the grassland community Sensitively revegetate with scattered native shrubs and grasses to create open shrubland similar to adjacent shrublands to the north. Any works undertaken will need to be arranged in collaboration with National Parks and Wildlife SA.	Zone 3, 4, 5	Immediate Immediate
Improve biodiversity of degraded Shrublands in Poor/moderate value area	Revegetate Shrubland	Revegetate shrubland community to create *Acacia cupularis / Myoporum insulare* Tall Shrubland. Potential for direct seeding here.	Zone 4	Long term
Improve biodiversity of degraded gully banks in poor/moderate value area	Revegetate Shrubland	Revegetate creek banks with a native shrubland community (ie. *Acacia cupularis / Myoporum insulare* Tall Shrubland).	Zone 5	Medium term

Erosion				
Issue	Strategy	Key Actions		
Low biodiversity within creekline	Promote natural regeneration	Manage weeds	Zone 1	Medium term
Erosion issues	Mitigate against further erosion	Develop concept design for detention storages and watercourse restoration works Care must be taken to remove woody weeds gradually to reduce the impacts of destabilisation to banks (eg. willows). Revegetation activities associated with the Glade Crescent Wetland proposal Revegetation along watercourse. Any works undertaken will need to be arranged in collaboration with National Parks and Wildlife SA.	Zone 1 Zone 2 Zone 3	Immediate
Destabilisation of creek banks	Promote natural regeneration and revegetate	Manage weeds Revegetate with infill planting	Zone 2	Immediate
Future works				
Issue	Strategy	Key Actions		
Clearance of valuable vegetation and potential habitat	Protect existing vegetation from accidental damage	Locate and map significant biodiversity values prior to works being undertaken.	Zones 1-5	Ongoing

* Timeline of proposed events: Immediate = Implement within 12 months, Medium term = 5 – 10years, Long term = >10years

Table 6.15 Watercourse Corridor Actions Indicative Costs

Activity	Zone	Actions	Rates	Area (ha)	Cost estimate ($)
Watercourse Restoration	1	Aroona Road detention storage Barramundi Drive detention storage Quailo Ave detention	-	-	$70,000 $70,000 $30,000

Activity	Zone	Actions	Rates	Area (ha)	Cost estimate ($)
		storage Watercourse restoration (Stage 1 – Quailo Ave to Vennachar Drive) Watercourse restoration (Stage 2 – Vennachar Drv to Arachne Drive)			$550,000 $250,000
Revegetation - Riparian Zone	1	Replanting with tubestock and cells at approximately 2 plants per square metre within an approximate 5m wide riparian corridor. Low growing shrubs and sedges.	Approx $2 per cell	0.79	$30,000
	2			0.75	$30,000
	3			0.21	$10,000
	4			0.23	$10,000
	5			0.26	$10,000
Revegetation - Woodland Zone	1	Replanting with tubestock for Woodland community (approx 100 trees/ ha, 200 shrubs / ha, 10,000 grasses, low ground covers / ha) or Direct seeding of grasses at 10kg seed*** per hectare, 5 hours per hectare labour	Approx $4-6 per tube stock* $41, 200 – 61,800 / ha) $150 /kg seed $150 per hour labour	13.71**	$560,000 – $850,000 or $30,000 (grasses) + $15,000– $25,000 (trees & shrubs) = $45,000 – $55,000
	2	Replanting with tubestock for Woodland community (approx 100 trees/ ha, 200 shrubs / ha, 10,000 grasses, low ground covers / ha) or Direct seeding of grasses at 10kg seed*** per hectare, 5 hours per hectare labour	Approx $4-6 per tube stock* $41, 200 – 61,800 / ha) $150 /kg seed $150 per hour labour	18.85**	$780,000 – $1,200,000 or $40,000 (grasses) + $25,000 – $35,000 (trees & shrubs) = $65,000 - $75,000
	3	Replanting with tubestock for Shrubland community (approx 200 shrubs / ha, 10,000 grasses, low ground covers / ha) or Direct seeding of grasses at 10kg seed*** per hectare, 5 hours per hectare labour	Approx $4-6 per tube stock* $40, 800 – 61,200 / ha) $150 /kg seed $150 per hour labour	1.58**	$65,000 – $100,000 or $4,000 (grasses) + $1,500 – $2,000 (shrubs) = $5,500 - $6,000

Activity	Zone	Actions	Rates	Area (ha)	Cost estimate ($)
	4	Replanting with tubestock for Shrubland community (approx 200 shrubs / ha, 10,000 grasses, low ground covers / ha) or Direct seeding of grasses at 10kg seed*** per hectare, 5 hours per hectare labour	Approx $4-6 per tube stock* $40, 800 – 61,200 / ha) $150 /kg seed $150 per hour labour	3.77**	$150,000 – $230,000 or $10,000 (grasses) + $3,000 – $5,000 (shrubs) = $13,000 - $15,000
	5	Replanting with tubestock for Shrubland community (approx 200 shrubs / ha, 10,000 grasses, low ground covers / ha) or Direct seeding of grasses at 10kg seed*** per hectare, 5 hours per hectare labour	Approx $4-6 per tube stock* $40, 800 – 61,200 / ha) $150 /kg seed $150 per hour labour	2.14**	$90,000 - $130,000 or $5,000 (grasses) + $2,000 – 2,500 (shrubs) = $7,000 - $7,500
Weed control	All Zones	Removal of woody weeds, herbaceous and grassy exotics	$55 / hr		

*includes product, tree guard, installation and maintenance

** This assumes total area for revegetation. Once revegetation plan is developed, rates can be applied to individual areas.

***mulched plant material with seed

7 Water Sensitive Urban Design

7.1 Stormwater Impacts

The draft Adelaide Coastal Water Quality Improvement Plan EPA, 2011) nominates marine ecosystems and recreational amenity as the two main aspects of coastal water quality that are impacted by pollutants in Adelaide's stormwater.

Pollutions sources within stormwater that impact on the receiving marine environment include:

- Gross pollutants (larger objects, floating litter and 'green' waste)
- Sediment
- Dissolved pollutants (nutrients, hydrocarbons and coloured dissolved organic matter)
- Pathogens

The impacts of these pollutant groups are detailed in Section 2.9.4. This Section estimates the existing pollutant loads generated by the Hallett Cove Creeks catchments and presents strategies by which these loads can be reduced.

7.2 Water Quality Modelling Approach

An assessment of the pollutant loads within stormwater discharges to the receiving waters is outlined in this section.

The MUSIC (Model for Urban Stormwater Improvement Conceptualisation) computer software package developed by the Cooperative Research Centre for Catchment Hydrology has been used for this purpose.

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

7.2.1 Meteorological Data

The meteorological data templates used for this project were compiled using average monthly potential evapo-transpiration (PET) values for Adelaide, and 6 minute rainfall data from a gauge at the Adelaide Airport for the years 1970-2005. The average annual rainfall for this period was 438mm.

6 minute rainfall data is also available at other nearby sites, but were not selected for use for the following reasons:

- Noarlunga – Limited record duration available (10 years, 431 mm/yr), which was considered to be too short for stormwater harvesting modelling
- Happy Valley reservoir – Higher rainfall average (633 mm/yr) considered to be unrepresentative of rainfall on the coast

7.2.2 Catchment Area and 'Effective Impervious' Fraction

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

The typical 'effective impervious' fraction, for the purposes of MUSIC modelling, for residential development in Hallett Cove was estimated to be 0.38. This value was adjusted for individual subcatchments based on the relative proportions of urban development and open space within the subcatchment area; hence the 'effective impervious' fractions for the MUSIC subcatchments varied from 0.20 to 0.38.

7.2.3 Rainfall-runoff Parameters

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

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

7.2.4 Pollutant Load Parameters

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

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

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

7.3 Existing Pollutant Loads

7.3.1 Water Quality Improvement Measures

No existing water quality improvement measures have been included in the 'existing scenario' model. This decision has been made to allow for a baseline to be established of an 'untreated' catchment, against which the effectiveness of a suite of treatment measures can be evaluated in accordance with water quality objective framework.

Notwithstanding, it is clear that existing treatment measures are extremely limited. Of the two gross pollutant traps within the catchment, the Heron Way trap has been out of service for a number of years following a structural failure of the diversion weir, and the Douglas Court trap is a relatively small measure, receiving runoff from a 14 lot land division.

The Lucretia Dam currently provides a water quality improvement role in a similar manner to a sedimentation pond, however this is expected to be limited to settlement of coarse sediments. The waterbody has consistently been observed to have a cloudy appearance, and is reported to have an abundance of carp, which suggests that its water quality improvement performance is likely to be limited.

7.3.2 Water Harvesting Schemes

Other than small-scale on-site practices, there are no existing stormwater harvesting and reuse schemes within the catchment.

It is understood that the McDonalds restaurant (located within the Hallett Cove Shopping Centre) was established with a Rocla ecoRain rainwater utilisation system (20kL capacity), used for toilet flushing and irrigation.

7.3.3 Assessed Performance

A MUSIC model was compiled for the existing Hallett Cove Creeks catchment using the input parameters described above. Individual pit level subcatchments from the DRAINS model were aggregated to form the MUSIC subcatchments. This approach enables the user to obtain estimates of the quantity and quality of runoff at specific points of interest in the drainage system (eg. coastal outfalls, the Glade Crescent Wetland site etc). A plan of the MUSIC model layout is shown in Figure 7.1.

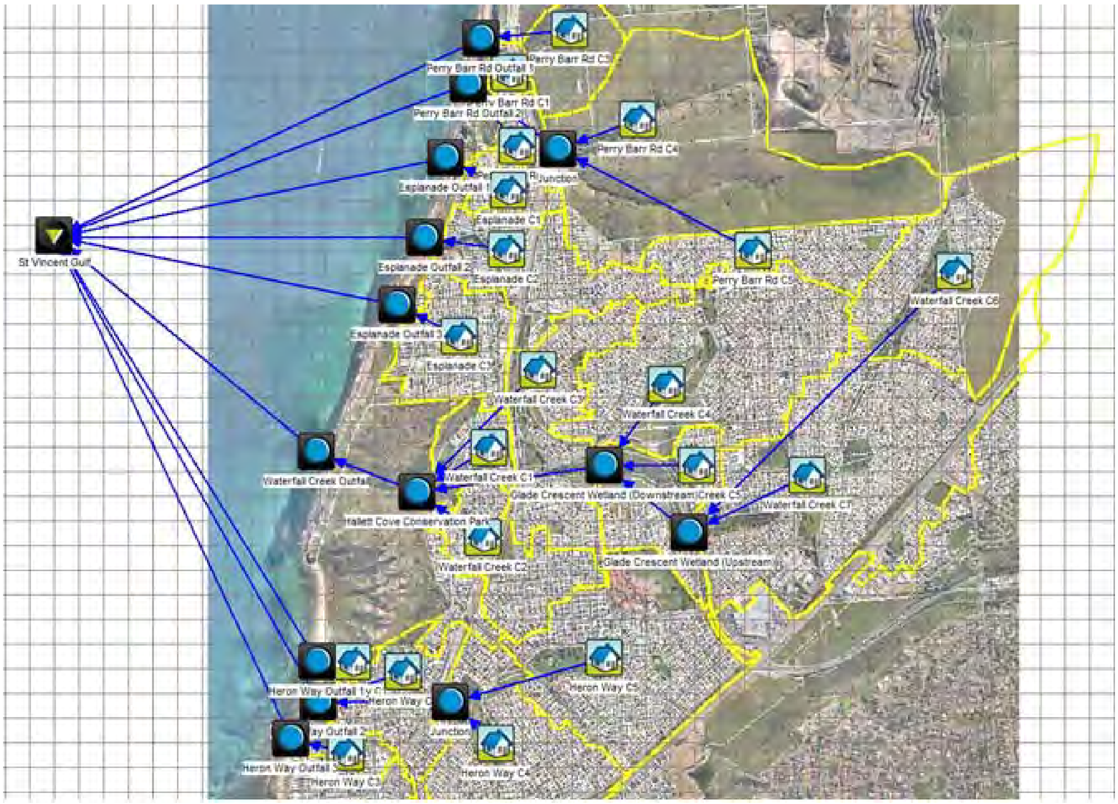


Figure 7.1 Existing Scenario MUSIC Model Layout

The results of the existing scenario MUSIC model for discharge to Gulf St Vincent during the years 2001-2005 are as summarised in Table 7.1 below.

Table 7.1 Existing Scenario MUSIC Model Results (2001-2005)

Loads	Units	Model Result
Catchment Area	km^2	6.78
Runoff Volume	ML/yr	1020
Yield	mm/yr	150
TSS	t/yr	177

TN	t/yr	2.85
TP	t/yr	0.38
GP	t/yr	33.8

7.4 Proposed WSUD Elements

New WSUD measures are proposed to be constructed in a number of locations to improve stormwater quality and enable stormwater harvesting and reuse. These proposed upgrades have been modelled within the MUSIC model (refer Section 7.5) to allow for preliminary sizing of elements and budget cost estimation.

In addition to the measures identified, it is expected that further WSUD opportunities will be achieved over time, particularly through road reconstruction activities, and individual site redevelopments.

7.4.1 Perry Barr Road Catchment

No additional measures are proposed to complement the existing gross pollutant trap at Douglas Court.

7.4.2 Esplanade Catchment

Gross pollutant traps are proposed to provide primary treatment prior to marine discharge for these stormwater drainage systems:

- Barndoo Street
- Fryer Street / Kurnabinna Terrace (as per outstanding 'Coastal Outlet' action described in Section 4.3)

Further, it is recommended that a bioretention swale / basin be established within the Fryer Street Reserve. Figure 7.2 below shows an indicative layout for this site as well as the main components of the system. It should be noted that this layout is indicative only and that concept development and master planning for the reserve would be required to confirm the proposal. In this concept, a bioretention swale is shown to be aligned along the prevailing contours of the site, prior to discharge to the existing channel.

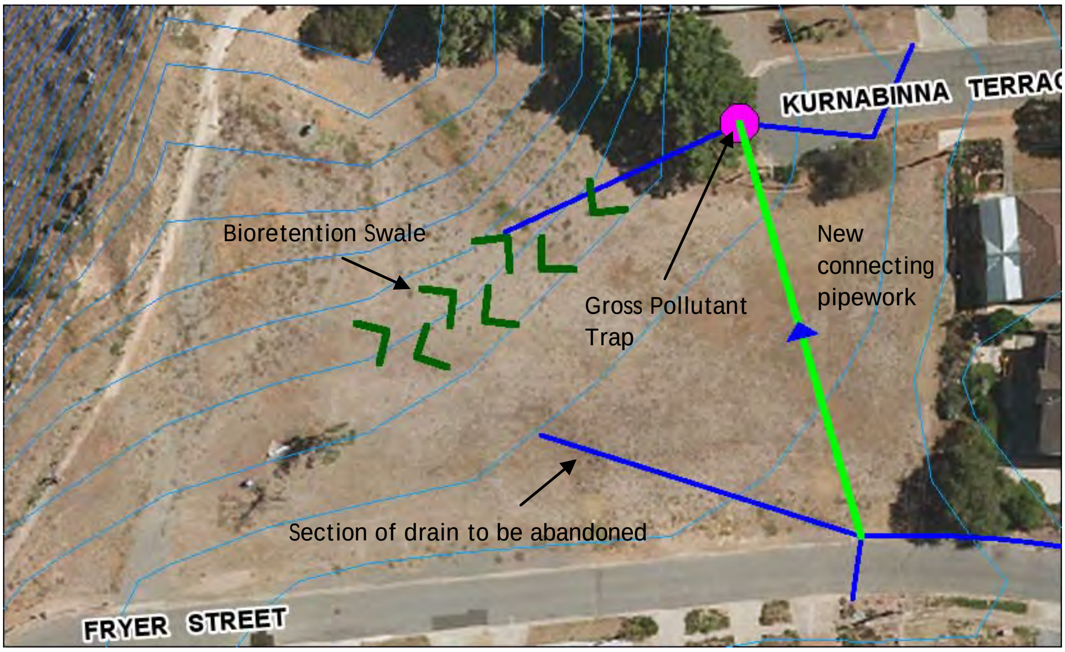


Figure 7.2 Fryer Reserve WSUD Concept

7.4.3 Waterfall Creek Catchment

Lonsdale Highway Swales

Lonsdale Highway is a major arterial road with a two-way traffic count in excess of 30,000 movements per day. Roads of this nature are generally associated with generating highly polluted stormwater runoff.

Within the roadside verge, there is the opportunity to establish vegetated swales that would provide an important role in capturing grits and sediments, while also allowing for some oil and grease removal. Figure 7.3 below illustrates a location where this application is proposed.

Figure 7.3 Lonsdale Highway WSUD Concept

Waterfall Creek Restoration

The proposal to rehabilitate sections of Waterfall Creek where significant erosion and is occurring is outlined in Section 6.4.3. These works are also considered to have a positive water quality improvement role, through:

- Sedimentation associated with each of the small in-line detention storages
- Treatment associated with flow through revegetated sections of the channel
- Avoidance of export of eroded sediments

These aspects have been taken into account in the performance assessment presented in Section 7.5.

Glade Crescent Wetland and Recreational Reserve Development

The Glade Crescent Reserve, bounded by Glade Crescent, Capella Drive, the Coast to Vines trail and the Sandison Road road reserve, is classified as a Precinct level reserve. Waterfall Creek flows through the reserve, with an upstream catchment area of 255 ha. The reserve is underutilised, and key issues previously identified at this site include the extremely steep terrain creating difficulty for Council maintenance activities and vegetation that is highly degraded and dominated by weeds (EBS, 2008), although does contain areas of underlying biodiversity value (pers comm., J Smith). A northern portion of the reserve contains two 'Bush for Life' sites.

Figure 7.4 Glade Crescent Reserve

Development of the reserve has been the subject of previous investigation and consultation. The opportunity to upgrade this open space (and incorporate wetlands) had been identified as a strategy that would:

- Enhance the biodiversity and amenity of the area
- Provide new recreational opportunities for the community
- Improve water quality
- Make use of surplus soil generated by other (off-site) Council activities, which would be required to create a landform within the gully suitable for the integration of surrounding areas. It has been identified that any fill brought to the site would need to be assessed for its intended use and be physically compliant with the clean fill criteria and that all contaminants of concern be below the NEPM criteria for recreational land use (PB, 2011).

A functional design for the development of a series of wetland ponds within the Glade Crescent Reserve was undertaken during the development of this Stormwater Management Plan. This was undertaken to provide clarity in relation to the likely scope and cost of these works, for a scheme that through integration with other works upstream and downstream of Glade Crescent Reserve, meets the objectives of this Stormwater Management Plan. The sketch plans associated with the Glade Crescent wetlands functional design are presented in Appendix B.

The design intent associated with these wetlands is described below.

<u>Pond 1</u>

- Sediment trap and trash rack structure located immediately downstream of the existing creek culvert outlet
- Filling of surrounding areas (over areas assessed as having no desirable biodiversity value) to achieve gentler batter slopes and improved integration with adjoining boundaries, paths, roads and access tracks
- To be configured with 3 cascading pools (2m elevation difference between each pool), with the discharge from each pool controlled by a

broad-crested weir, inset with a low flow weir regulating flows up to a 1 year ARI, discharging into the receiving pool via a rock chute

Pond 2

- Single water body, with the discharge controlled by a broad-crested weir, inset with a low flow weir regulating flows up to a 1 year ARI, discharging into the receiving creek reach via a cascading gabion wall
- Removal of adjacent fill mound

Pond 3

- Single water body, with the discharge controlled by a 'field gully' style flow control structure, inset with a low flow outlet regulating flows up to a 1 year ARI, discharging into the receiving creek reach via the existing culvert under the road reserve embankment
- Existing embankment to be raised, with the potential for this to be integrated with the location of the interpretative centre, and maintenance / visitor access
- Subject to geotechnical assessment determining permeability rates, utilisation of the existing pond area base rather than the construction of a pond liner across the pond base, to reduce impact on existing biodiversity
- Provision for a 0.3m deep 'active' storage depth for stormwater harvesting (described further below)

Preliminary modelling indicates that provided sufficient tank storage could be provided, it would be possible to achieve 10 ML/yr of reuse (76% of the estimated combined demand for irrigation water at Capella Drive Reserve and Hallett Cove School).

General

- Provision for environmental flow

The presence of a small perennial spring in the upper reach of Waterfall Creek has previously been identified (Cooper, 1970 and AWE, 2007). While the flow from this spring is reported to be highly variable, the *Hallett Cove and Marino Conservation Parks Management Plan* (DEH, 2010) identifies that the restriction of this flow has a negative impact on the riparian vegetation within the Park and contains objectives and strategies associated with influencing Council's management of hydrological regimes to ensure the maximum benefit to Hallett Cove Conservation Park.

It is recommended that the Glade Crescent wetland ponds make provision for this natural spring flow via a low flow diversion around the water body(s).

- Low ARI flow detention

As described in Section 6.4.3, detention of low flows is recommended to be incorporated into each of the 3 pond areas, in order to reduce the risk of erosion in downstream natural channel sections, and to assist with increasing the hydraulic residence time within each of the ponds.

- Stormwater harvesting and reuse

It is recommended that the design of Pond 3 incorporate the functionality to support a local-scale harvesting scheme, that would service local irrigation demand associated with the adjacent Capella Drive Oval reserve area. This scheme could be configured with the following key elements:

- A 0.3m deep 'active' storage within the Lower Pond, above the permanent water level, from which treated stormwater would be extract via a pump.
- A large (500 kL) above ground or semi-bunkered storage tank located within the Capella Drive Reserve
- A new sub-surface irrigation system within the Capella Drive Reserve

This type of stormwater harvesting and reuse scheme would not need to achieve a water quality improvement performance similar to an Aquifer Storage and Recovery scheme, as the stringent water quality requirements for aquifer injection would not be applicable. Due to the lower quality of this harvested water, it is anticipated that all reuse would be achieved through sub-surface irrigation systems, thereby avoid health issues that might arise through direct contact.

There is the opportunity for this scheme to be expanded to service the irrigation demand within the nearby Hallett Cove R-12 School, however it is noted that the introduction of a non-Council 'customer' to the scheme would need to be address issues including performance expectations (quality, reliability) and cost recovery.

Lucretia Dam

The Lucretia Dam, located on Waterfall Creek within the Lucretia Way Reserve, is an earth dam immediately upstream of the Hallett Cove Conservation Park. A concrete spillway releases overflows from the dam into the downstream creek channel section. The general background, along with the design standards, materials and construction practices used to create the dam are not known.

The dam provides an aesthetically pleasing amenity for visitors to the reserve, and to the residential properties that overlook the reserve. The dam provides an unintended benefit in capturing coarse sediments and a small mitigating effect on peak flows.

It is recommended that the dam be reconstructed to provide a broader range of benefits that is integrated with other measures proposed upstream, while maintaining the amenity of a permanent waterbody. The site (downstream of all Waterfall Creek catchment urban inflows) is in an ideal location for the final treatment of stormwater flows prior to discharge to the Gulf. A functional design for this concept has been prepared, the key features of which are:

- Wetland to be a 'high performance' wetland with low flows to be directed into the wetland system for treatment
- Provision of 1 year ARI detention storage (depth of 1.5m above the wetland surface)
- Release of wetland overflow up to the 1 year ARI mitigated flow rate to the bypass channel / downstream creek reach
- Provision of a high flow bypass channel such that high flows can bypass the wetland once the wetland / detention storage is full
- Provision for upstream natural spring flows to bypass the wetland via a base flow diversion around the water body.
- Gross Pollutant Trap to treat flows arriving via the stormwater drain to the south east

-	Provision within the wetland outlet structure for the ability for controlled (very low flow) release of stored water for the purpose of supplying an environmental flow to support riparian vegetation in the downstream reach through the Conservation Park
-	Undertake a geotechnical assessment of the existing embankment to determine whether the existing dam wall can be retained or needs to be replaced as a part of these works

A sketch plan for this concept is presented in Appendix B.

7.4.4 Heron Way Catchment

Lonsdale Highway Swales

Lonsdale Highway is a major arterial road with a two-way traffic count in excess of 30,000 movements per day. Roads of this nature are generally associated with generating highly polluted stormwater runoff.

Within the roadside verge, there is the opportunity to establish vegetated swales that would provide an important role in capturing grits and sediments, while also allowing for some oil and grease removal. Figure 7.3 below illustrates a location where this 2 swales are proposed.

Figure 7.5 Lonsdale Highway WSUD Concept

Shamrock Road Reserve

The opportunity is available to utilise a portion of this reserve to both improve stormwater quality and harvest from the Heron Way main drain that passes beneath the reserve in a deep main drain.

Figure 7.6 below shows an indicative layout for this site as well as the main components of the system. It should be noted that this layout is indicative only and that concept development and master planning for the reserve would be required to confirm the proposal. The intent associated with this concept is as follows:

- Construction of pump station (diverting flows up to the 3 month ARI peak flow) from the deep main drain
- Initial treatment of pumped flows through a gross pollutant trap
- Discharge of flows into bioretention cell(s) within Shamrock Road Reserve
- Capture and transfer of treated flows to an above ground tank storage
- Reuse of harvested stormwater to irrigate surrounding reserves (and potentially Hallett Cove South Primary School oval)

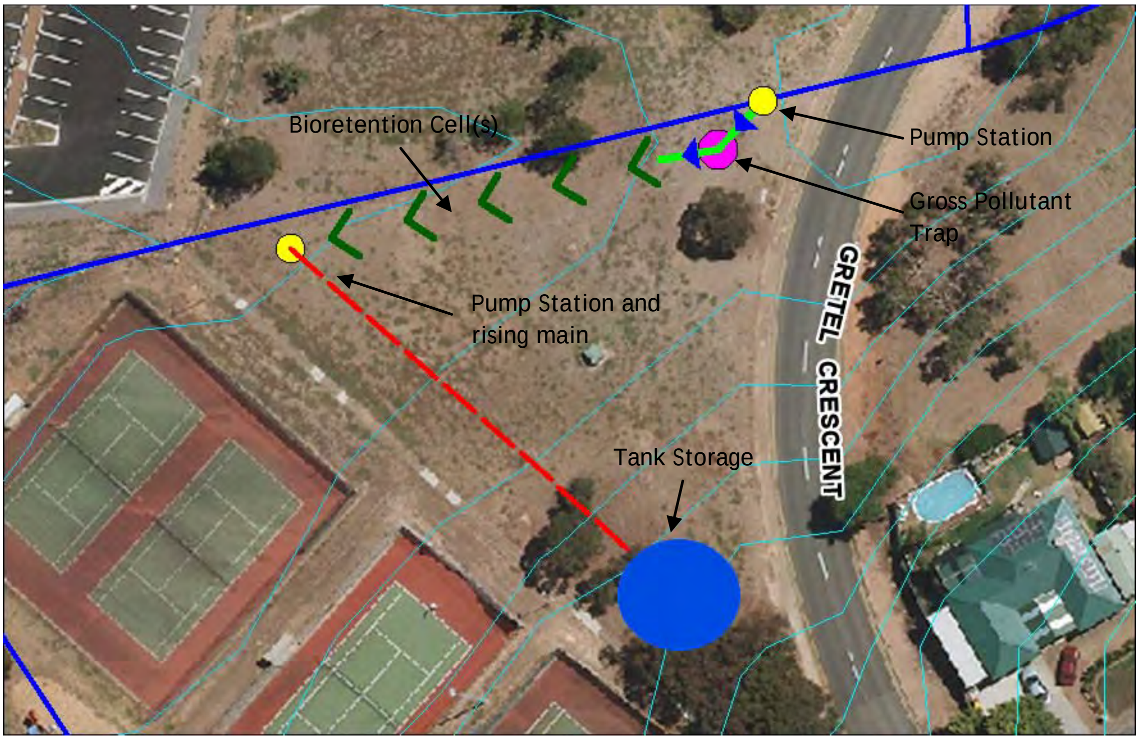


Figure 7.6 Shamrock Road Reserve WSUD Concept

Preliminary modelling indicates that a scheme utilising a 400kL tank storage could achieve 3.1 ML/yr of reuse (86% of the estimated demand for irrigation water at the Hallett Cove South Primary School). In the longer term, this approach could be duplicated / expanded to meet the irrigation demand of other adjacent reserves.

Heron Way Reserve

Gross pollutant traps are proposed to provide primary treatment prior to marine discharge for these stormwater drainage systems:

- Heron Way main drain (to replace the failed unit)
- Grand Central Avenue drain (as per outstanding 'Coastal Outlet' action described in Section 4.3)

Further, it is recommended that a bioretention swales / basins be established within the Heron Way Reserve to cater for locally generated runoff, such as from the Surf Club carpark or adjacent roadways. A Masterplan is currently being prepared for this reserve, which may identify how these opportunities could be incorporated into the area.

Opportunities to harvest stormwater from the Heron Way main drain for reuse in irrigating the reserve have been discounted at this time. Key challenges to be overcome in the future consideration of such a scheme include locating bioretention cells, tank storage and other infrastructure in a manner that does not detract from the visual amenity of the reserve.

7.4.5 Residential Rainwater Tanks

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

The opportunity is available for Council to increase the minimum rainwater tank storage capacity. This is considered appropriate, given that:

- Capture of stormwater would reduce the pollutant load discharged to the local marine environment
- Capture of stormwater would reduce the severity of erosion in local watercourses caused by regular short duration rainfall events
- Greater storage capacities would achieve a greater reduction in residential mains water usage
- Rainwater tank prices have become more competitive in recent years, and hence the payback period of providing a greater storage capacity has been reduced

For the purposes of the MUSIC modelling report in Section 7.5, the following scenario has been adopted:

- 2kL rainwater tank implemented across 50% of all residential properties, no rainwater tank in the remaining 50% of residential properties
- Each rainwater tank connected to a daily demand of 300 L/day

7.5 Assessed Performance

A preliminary MUSIC model was compiled for the Hallett Cove Creeks catchment incorporating various Water Sensitive Urban Design (WSUD) features. A plan of the MUSIC model layout is shown in Figure 7.7.

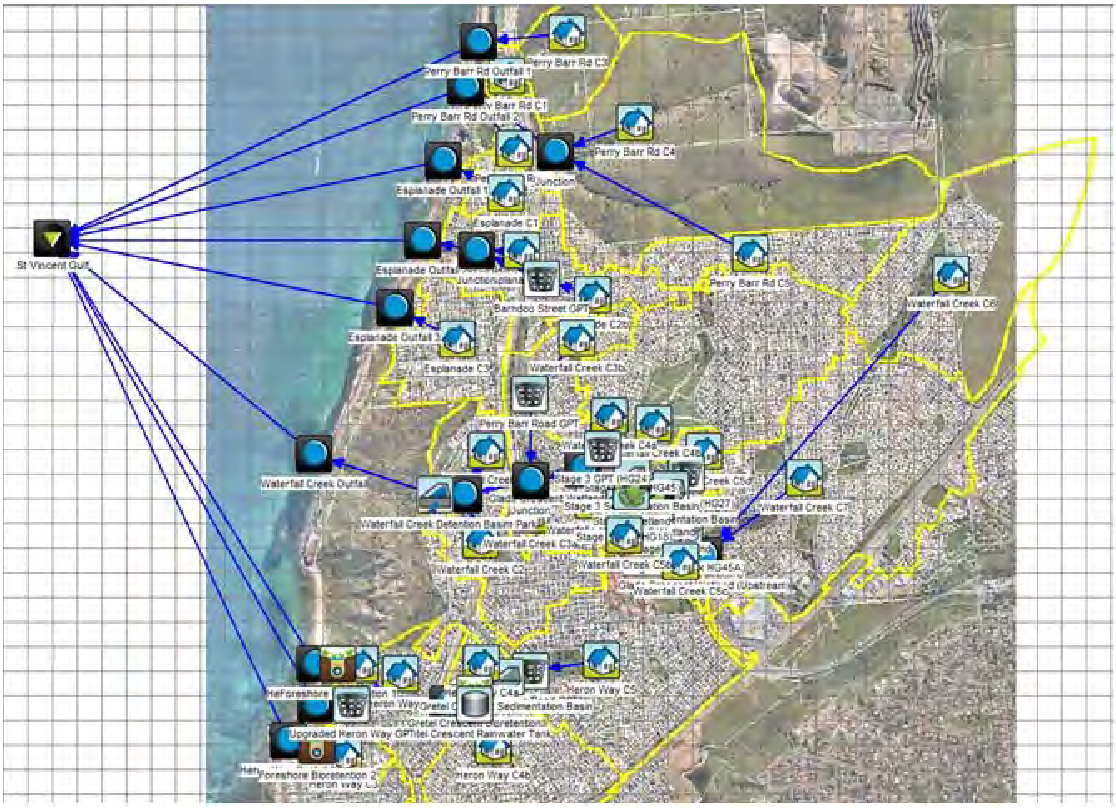


Figure 7.7 Proposed Scenario MUSIC Model Layout

The results of the proposed scenario MUSIC model for discharge to Gulf St Vincent during the years 2001-2005 are as summarised in Table 7.2 below.

Table 7.2 Proposed Scenario MUSIC Model Results (2001-2005)

Parameter	Annual Load[1]	% Reduction[1]	% Reduction[2]	Target[3]
Runoff Volume, ML/yr	962	6	16	-
Yield, mm/yr	142	6	16	-
TSS, t/yr	79	55	62	80
TN, t/yr	2.22	22	31	45
TP, t/yr	0.23	41	48	60
GP, t/yr	5.3	84	89	90

1 Reductions achieved without rainwater tank scenario

2 Reductions achieved with rainwater tank scenario described in Section 7.4.5

3 Performance targets adopted from *Water Sensitive Urban Design – Consultation Statement* (Department for Water, 2011)

The modelling indicates that while the works identified in this Plan would contribute significantly towards the improvement in stormwater quality discharged to the Gulf, that further measures would need to be implemented in order to ultimately achieve the targets.

The opportunity for these measures exists at the street level (such as WSUD measures incorporated into road reconstructions) and at the site level (such as rainwater tanks and other site-based measures incorporated into new developments).

The modelling also indicates that an increased rainwater tank requirement would achieve significant catchment-scale water quality improvements, while also diverting 101 ML/yr of stormwater (10% of the volume currently estimated to discharge to the Gulf) to residential reuse.

7.6 Action Summary

The proposed works are summarised in Table 7.3.

Table 7.3 Proposed WSUD Upgrades Summary

Location	Comments	Budget Estimate
Perry Barr Rd Catchment		
	No works proposed	
Esplanade Catchment		
Barndoo Street	Gross Pollutant Trap	$100,000
Fryer Street Reserve	Gross Pollutant Trap, Bioretention	$180,000
Waterfall Creek Catchment		
Glade Crescent Reserve	Trash Rack and sediment trap, wetlands, detention, stormwater harvesting and reuse	$2,600,000[1]
Lucretia Dam	Gross Pollutant Trap, Detention, stormwater harvesting and reuse	$1,100,000[1]
Lonsdale Hwy	Vegetated Swales	$80,000
Heron Way Catchment		
Heron Way Reserve	Gross Pollutant Trap, Bioretention	$250,000[1]
Shamrock Road Reserve	Gross Pollutant Trap, Bioretention, stormwater harvesting and reuse	$710,000[1]
Lonsdale Hwy	Vegetated Swales	$160,000

[1] Project eligible for Stormwater Management Authority funding, based on the 40ha contributing area criteria

8 Stormwater Management Plan

8.1 Strategy Action Costs, Benefits and Priority Summary

The actions outlined in Section 4, 5, 6 and 7 are presented in Summary form in Table 8.1, together with a brief description of the benefits realised through implementation of each action.

8.2 Prioritisation and Timeframe

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

Each of the actions within the plan has been assigned one of three priority levels, as follows:

- Short Term (0 - 2 years)
- Medium Term (2 - 5 years)
- Long Term (5 – 10+ years)

The prioritisation of each action has recognised greater urgency where:

- There is property (above floor-level) flood risk
- Related projects are underway
- Existing asset condition is poor

The priority rating of actions is flexible and subject to change over time, and that some actions will be 'brought forward', particularly when opportunities for grant funding arise.

8.3 Supporting Activities

The following activities have also been identified to support the implementation of this Plan.

- Condition Assessment of deep drains

A number of main drain reaches (particularly in the Heron Way drainage system) were installed within the base of the pre-existing watercourse, with the gully and creekline subsequently filled over to create developable land. The depth of the major underground drains is up to 10 metres deep (under Dutchman Drive) which could provide Council with a major difficulty in future maintenance and replacement of this asset. It is recommended that these sections of drain be identified for more regular and routine inspection and condition assessment, such that any structural defects can be identified as early as possible, and opportunities for rectification are maximised.

- Periodic Assessment of development trends

This Stormwater Management Plan has been informed by a development trend assessment that indicates that the catchment area is unlikely to the subject of significant development (unlike other parts of the City of Marion) of a nature that would affect the current hydrological regime. To confirm this assumption, it is recommended that a periodic assessment (every 5 years on average) of development trends be undertaken through discussion with Council planning staff and inspection of aerial photography.

- Concept / Detailed Design of key Waterfall Creek works

The majority of the high value actions identified in this Plan are associated with creek restoration and wetland development. In order to improve the confidence of budget estimates, and to facilitate a truly integrated design that delivers substantial biodiversity enhancements, it is recommended that the process of concept design / detailed design development be undertaken to enable Council to be appropriately informed and 'spade-ready' for when funding opportunities arise.

- Review Rainwater Tank Requirements

This Stormwater Management Plan has identified and broadly scoped the benefits associated with increased adoption of rainwater tanks, with increased storage capacity, plumbed to in-house non-potable demand nodes. It is recommended that further work be undertaken to review Council's city-wide rainwater tank requirements, and in tandem with rainwater tank requirements / recommendations that may emerge from other Stormwater Management Plans that affect the Council area, identify the appropriate approach by which changes in development requirements can be achieved. Further, it is recommended that initiatives be developed to encourage existing development to retrofit compliant tanks.

- Management of watercourses through privately owned land

The Perry Barr Road catchment drains via a watercourse that is aligned within privately owned land. While this ownership clearly defines that associated watercourse maintenance responsibilities reside with the respective private property owners, it is recommended that that the City of Marion and the Adelaide & Mt Lofty Ranges NRM Board provide planning support and advice where appropriate to facilitate appropriate privately initiated watercourse management works, which may include:

  - native habitat restoration
  - pest animal and plant management
  - stabilisation and revegetation of degraded riparian areas
  - stream bank stabilisation
  - erosion control
  - control and management of access to riparian zones
  - fencing

Included within this Stormwater Management Plan (in Section 6.5.4) are recommended actions that would address some of these issues. Further, while no further development is anticipated at this time within this catchment, it is recommended that Council ensure that should any further land development occur within this catchment that strict discharge control limits / onsite retention be enforced to mitigate against potential erosion impacts to downstream watercourse reaches.

- Integration with Open Space Master Planning

In addition to works along the Waterfall Creek corridor, this Stormwater Management Plan has identified opportunities for works within:

  - Fryer Street Reserve
  - Shamrock Road Reserve
  - Capella Drive Reserve
  - Heron Way Reserve

It is anticipated that these opportunities will need to be filtered through a master planning and consultation process, specific to each area of open space.

8.4 Responsibilities for Implementation

The lead agency for all actions within this Stormwater Management Plan is the City of Marion. None of the stormwater drainage infrastructure or flood protection actions recommended in the Plan are of a sufficient size (ie. serve catchments greater than 40ha) in order to qualify for funding from the Stormwater Management Authority.

Council may be able to secure funding for components of the watercourse restoration and stormwater harvesting actions, on an opportunistic basis (such as from Commonwealth grant schemes), however it should be noted that Commonwealth / State based grant schemes generally rely on matching contributions from Local Government.

The Adelaide & Mt Lofty Ranges NRM Board may provide support for projects that improve the quality of water discharged to the marine environment, such as restoration of Waterfall Creek, construction of wetlands and other WSUD initiatives.

No works are specifically identified within the Hallett Cove Conservation Park, where recent remedial works were undertaken to a section of Waterfall Creek. It is expected that any future works would be led by DEWNR, in collaboration with the City of Marion and Adelaide & Mt Lofty Ranges NRM Board.

No works are specifically identified to creek channels and gullies within the Perry Barr Road catchment. The creekline in this catchment is generally aligned within private land and hence responsibility for any maintenance works resides with the respective property owners.

8.5 Implications for Adjoining Catchments

The Hallett Cove Creeks Catchment adjoins the Holdfast Bay - Marion Stormwater Management Plan area to the north, and the Field River catchment area to the east and south.

There are no known boundary interface issues, in relation to exchange of stormwater or floodwaters, or distribution of harvested stormwater.

Table 8.1 Stormwater Management Plan Works Summary

Priority	Project / Activity	Capital Cost ($)	Recurrent Cost ($/yr)	Flood Mitigation Benefit	Water Harvesting Benefit	Water Quality Benefit	Other Benefits
High	Aroona Road detention	70,000	3,000[1]	-	-	Medium -Reduces downstream erosion	-
High	Barramundi Drive detention	70,000	3,000[1]	-	-	Medium -Reduces downstream erosion	-
High	Quailo Ave detention	30,000	2,000[1]	-	-	Medium -Reduces downstream erosion	-
High	Watercourse restoration (Stage 1 – Quailo Ave to Vennachar Drive)	550,000	25,000[1]	-	-	High – prevents further erosion, provides instream treatment	High - biodiversity enhancement
High	Ramrod Ave Drain	630,000	-	Replaces existing 1 yr ARI standard drain	-	-	Medium – replaces structurally suspect asset, required for new library development
Medium	Glade Crescent Reserve	2,600,000	130,000[1]	-	10 ML/yr	High	High - biodiversity enhancement
Medium	Lucretia Wetland	1,100,000	50,000[1]	-	Minor (< 1 ML/yr)	High	High - biodiversity enhancement
Medium	Watercourse restoration (Stage 2 – Vennachar Drv to Arachne Drive)	250,000	10,000[1]	-	-	High – prevents further erosion, provides instream treatment	High - biodiversity enhancement
Medium	Heron Way Reserve GPT	250,000	10,000	-	-	High	-
Medium	Sandison Rd Drain	60,000	-	4 properties	-	-	-

Priority	Project / Activity	Capital Cost ($)	Recurrent Cost ($/yr)	Flood Mitigation Benefit	Water Harvesting Benefit	Water Quality Benefit	Other Benefits
Medium	Mercedes Ave Drain	340,000	-	8 properties	-	-	-
Medium	First St Drain	110,000	-	-	-	-	Prevent gutter flows spilling into low property
Medium	Second St Reserve Drain	190,000	-	-	-	-	Realign drain in public land
Medium	Fryer St Reserve WSUD	180,000	10,000[1]	-	-	High	-
Low	Shamrock Reserve WSUD	710,000	30,000[1]	-	3 ML/yr	Medium	-
Low	Barndoo St GPT	100,000	5,000	-	-	High	-
Low	Perry Barr Rd / Kanowna St Drain	40,000	-	-	-	-	Improve inlet capacity
Low	Kurnabinna Tce Drain	110,000	-	-	-	-	Reduce excessive gutter flows
Low	Rogana Cres Drain	70,000	-	-	-	-	Reduce excessive gutter flows
Low	Balandra St Drain	80,000	-	-	-	-	Reduce excessive gutter flows
Low	Glade Cres Drain	90,000	-	-	-	-	Reduce excessive gutter flows
Low	Kalmia Ct Drain	80,000	-	-	-	-	Reduce excessive gutter flows
Low	Bounty Rd Drain	90,000	-	-	-	-	Reduce excessive gutter flows
Low	Dutchman Dve Drain	50,000	-	-	-	-	Reduce excessive gutter flows
Low	Gretel Cres Drain	80,000	-	-	-	-	Reduce excessive gutter flows

Priority	Project / Activity	Capital Cost ($)	Recurrent Cost ($/yr)	Flood Mitigation Benefit	Water Harvesting Benefit	Water Quality Benefit	Other Benefits
Low	Grand Central Ave Drain	80,000	-	-	-	-	Reduce excessive gutter flows
Low	Madeleine Cres Drain	80,000	-	-	-	-	Reduce excessive gutter flows
Low	Lonsdale Highway Veg Swales	240,000	10,000[1]	-	-	Medium	-
Total		8,330,000	288,000				

[1] Recurrent cost estimated as 5% of capital cost

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Appendix A
Floodplain Maps

Background
This map has been prepared using the technology currently available to a standard of accuracy sufficient for broad scale flood risk management and planning. The map does not increase the risk or affect the level of flooding over an area or property; It merely seeks to identify the extent of flooding under a given set of conditions. Limitations to the information shown on this map and a brief description of some concepts upon which it is based are set out below.

Annual Recurrence Interval (ARI)
Flood risk can be considered in terms of average recurrence interval (ARI). This is the number of years, on average, within which a given flood will be equalled or exceeded. A 100 year ARI flood will be equalled or exceeded once in 100 years on average. A 20 year ARI flood will be equalled or exceeded once in 20 years on average, and so on.

Due to the random nature of floods, however, a 100 year ARI flood need not occur in every 100 years and conversely several floods which exceed the 100 year ARI flood could occur within any one period of 100 years.

Storm Durations
The flooding response of a catchment is dependent on the duration of any storm event. Generally shorter, more intense storms produce the greatest flows from urban areas. Longer duration, but less intense storms produce the greatest flow from undeveloped hills areas.

As a result of this interaction this map combines the outer envelope or flood extent from the various storm events each of which produce the maximum flood extent in different parts of the catchment. Because of this, the extent of flooding shown may not occur across the entire area at the same time or during any one storm event.

Scope of mapping
The limit of flooding on this map is not a boundary flood prone and flood free land.
Land outside the flood extent shown on this map could be affected by:
Storms with different Average Recurrence Interval.
Flooding from local drainage systems which can occur as a result of localised intense rainfall or drain blockage.

Areas of very shallow flooding
In areas shown as being affected by flood depths of less than 0.1m, fences, walls, landscaping and buildings will affect the flow of floodwaters. Resolution to this level of detail is beyond the capabilities of the modelling process and consequently the level of certainty in relation to flood depths in these areas is reduced.

Areas of very shallow flooding
In areas shown as being affected by flood depths of less than 0.1m, fences, walls, landscaping and buildings will affect the flow of floodwaters. Resolution to this level of detail is beyond the capabilities of the modelling process and consequently the level of certainty in relation to flood depths in these areas is reduced.

Impact on buildings
The flood extents shown are a prediction of land affected for the specific level of risk and do not necessarily indicate a threat to buildings located on that land. Flood assessment for particular sites will require more detailed interpretation, survey and analysis by qualified and experienced persons.

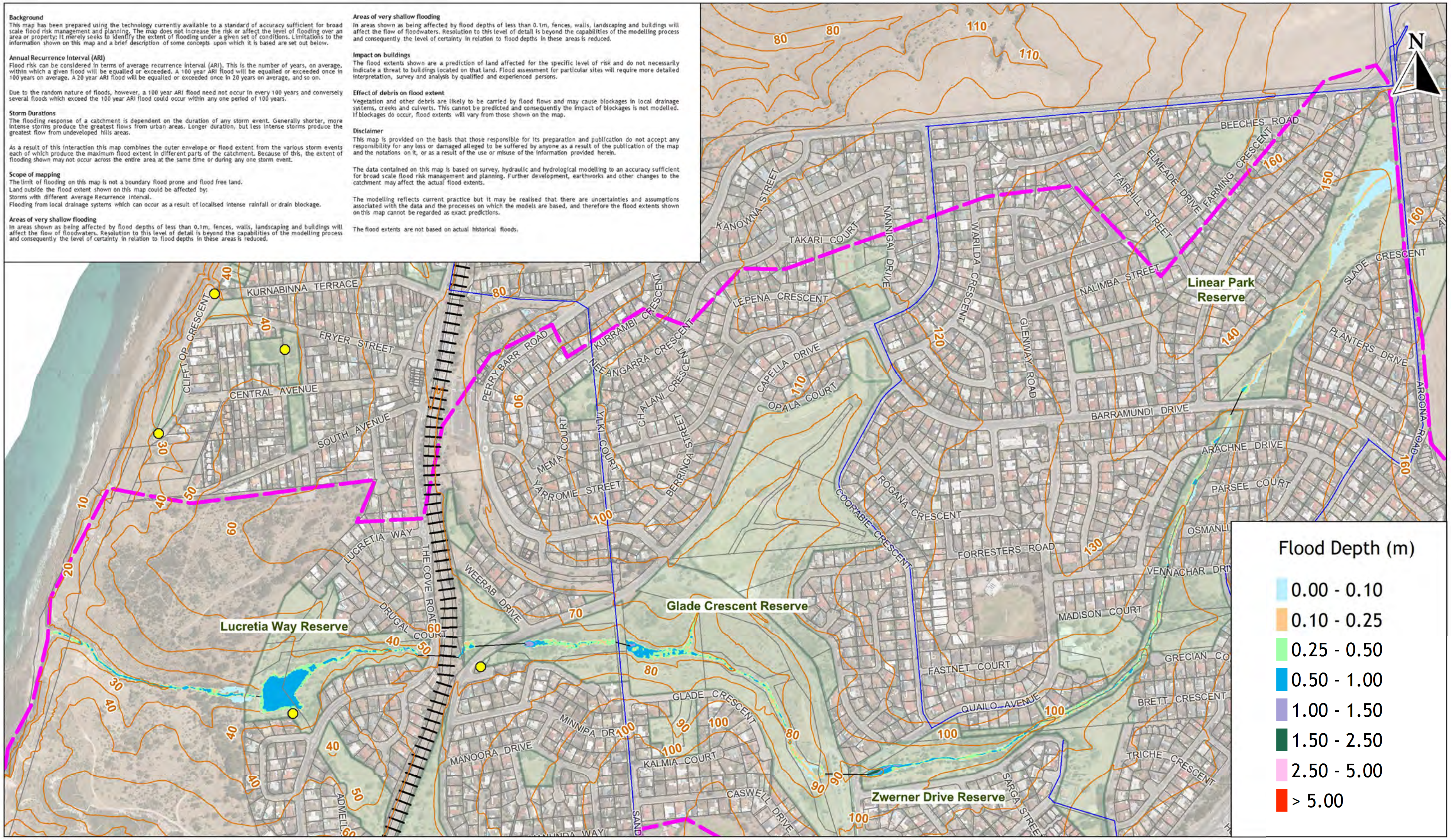
Effect of debris on flood extent
Vegetation and other debris are likely to be carried by flood flows and may cause blockages in local drainage systems, creeks and culverts. This cannot be predicted and consequently the impact of blockages is not modelled. If blockages do occur, flood extents will vary from those shown on the map.

Disclaimer
This map is provided on the basis that those responsible for its preparation and publication do not accept any responsibility for any loss or damaged 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.

The data contained on this map is based on survey, hydraulic and hydrological modelling to an accuracy sufficient for broad scale flood risk management and planning. Further development, earthworks and other changes to the catchment may affect the actual flood extents.

The modelling reflects current practice but it may be realised that there are uncertainties and assumptions associated with the data and the processes on which the models are based, and therefore the flood extents shown on this map cannot be regarded as exact predictions.

The flood extents are not based on actual historical floods.



Data Sources:
City of Marion (Aerial Photograph, Contours, Cadastre, Roads, Drainage)
AMLR NRM Board (Emergency Services, Services Infrastructure)
Southfront (Floodplain Extents)

southfront

0 200 400m
Scale 1:7,500

	Emergency Services
	Sewer Pump Station
	Power Substation
	Water main (300mm dia and above)
	Railway Line
	Council Reserve
	Cadastral Boundary
	Contour (10m interval)
	Flood Plain Model Extents

Hallett Cove Creeks
Stormwater Management Plan

Waterfall Creek

10 Year ARI Flood Inundation Map

Revision A - Issued 27 June 2012

Background

This map has been prepared using the technology currently available to a standard of accuracy sufficient for broad scale flood risk management and planning. The map does not increase the risk or affect the level of flooding over an area or property; It merely seeks to identify the extent of flooding under a given set of conditions. Limitations to the information shown on this map and a brief description of some concepts upon which it is based are set out below.

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Areas of very shallow flooding

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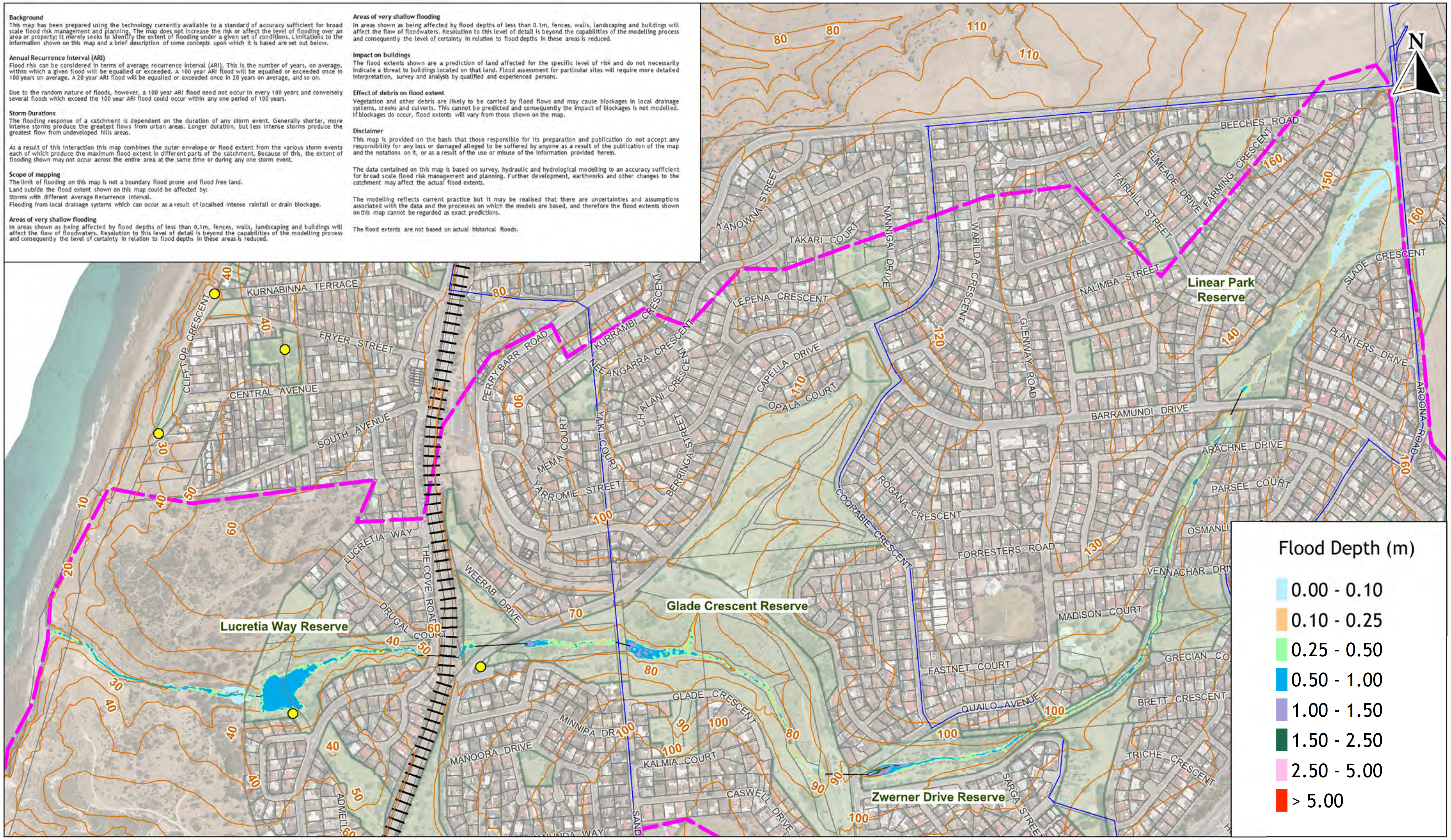
The modelling reflects current practice but it may be realised that there are uncertainties and assumptions associated with the data and the processes on which the models are based, and therefore the flood extents shown on this map cannot be regarded as exact predictions.

The flood extents are not based on actual historical floods.



Data Sources:
City of Marion (Aerial Photograph, Contours, Cadastre, Roads, Drainage)
AMLR NRM Board (Emergency Services, Services Infrastructure)
Southfront (Floodplain Extents)

southfront

0 200 400m

Scale 1:7,500

Emergency Services
Sewer Pump Station
Power Substation
Water main (300mm dia and above)
Railway Line
Council Reserve
Cadastral Boundary
Contour (10m interval)
Flood Plain Model Extents

Hallett Cove Creeks
Stormwater Management Plan

Waterfall Creek

20 Year ARI Flood Inundation Map

Revision A - Issued 27 June 2012

Background
This map has been prepared using the technology currently available to a standard of accuracy sufficient for broad scale flood risk management and planning. The map does not increase the risk or affect the level of flooding over an area or property; It merely seeks to identify the extent of flooding under a given set of conditions. Limitations to the information shown on this map and a brief description of some concepts upon which it is based are set out below.

Annual Recurrence Interval (ARI)
Flood risk can be considered in terms of average recurrence interval (ARI). This is the number of years, on average, within which a given flood will be equalled or exceeded. A 100 year ARI flood will be equalled or exceeded once in 100 years on average. A 20 year ARI flood will be equalled or exceeded once in 20 years on average, and so on.

Due to the random nature of floods, however, a 100 year ARI flood need not occur in every 100 years and conversely several floods which exceed the 100 year ARI flood could occur within any one period of 100 years.

Storm Durations
The flooding response of a catchment is dependent on the duration of any storm event. Generally shorter, more intense storms produce the greatest flows from urban areas. Longer duration, but less intense storms produce the greatest flow from undeveloped hills areas.

As a result of this interaction this map combines the outer envelope or flood extent from the various storm events each of which produce the maximum flood extent in different parts of the catchment. Because of this, the extent of flooding shown may not occur across the entire area at the same time or during any one storm event.

Scope of mapping
The limit of flooding on this map is not a boundary flood prone and flood free land.

Land outside the flood extent shown on this map could be affected by:

Storms with different Average Recurrence Interval.

Flooding from local drainage systems which can occur as a result of localised intense rainfall or drain blockage.

Areas of very shallow flooding
In areas shown as being affected by flood depths of less than 0.1m, fences, walls, landscaping and buildings will affect the flow of floodwaters. Resolution to this level of detail is beyond the capabilities of the modelling process and consequently the level of certainty in relation to flood depths in these areas is reduced.

Areas of very shallow flooding
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Impact on buildings
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Effect of debris on flood extent
Vegetation and other debris are likely to be carried by flood flows and may cause blockages in local drainage systems, creeks and culverts. This cannot be predicted and consequently the impact of blockages is not modelled. If blockages do occur, flood extents will vary from those shown on the map.

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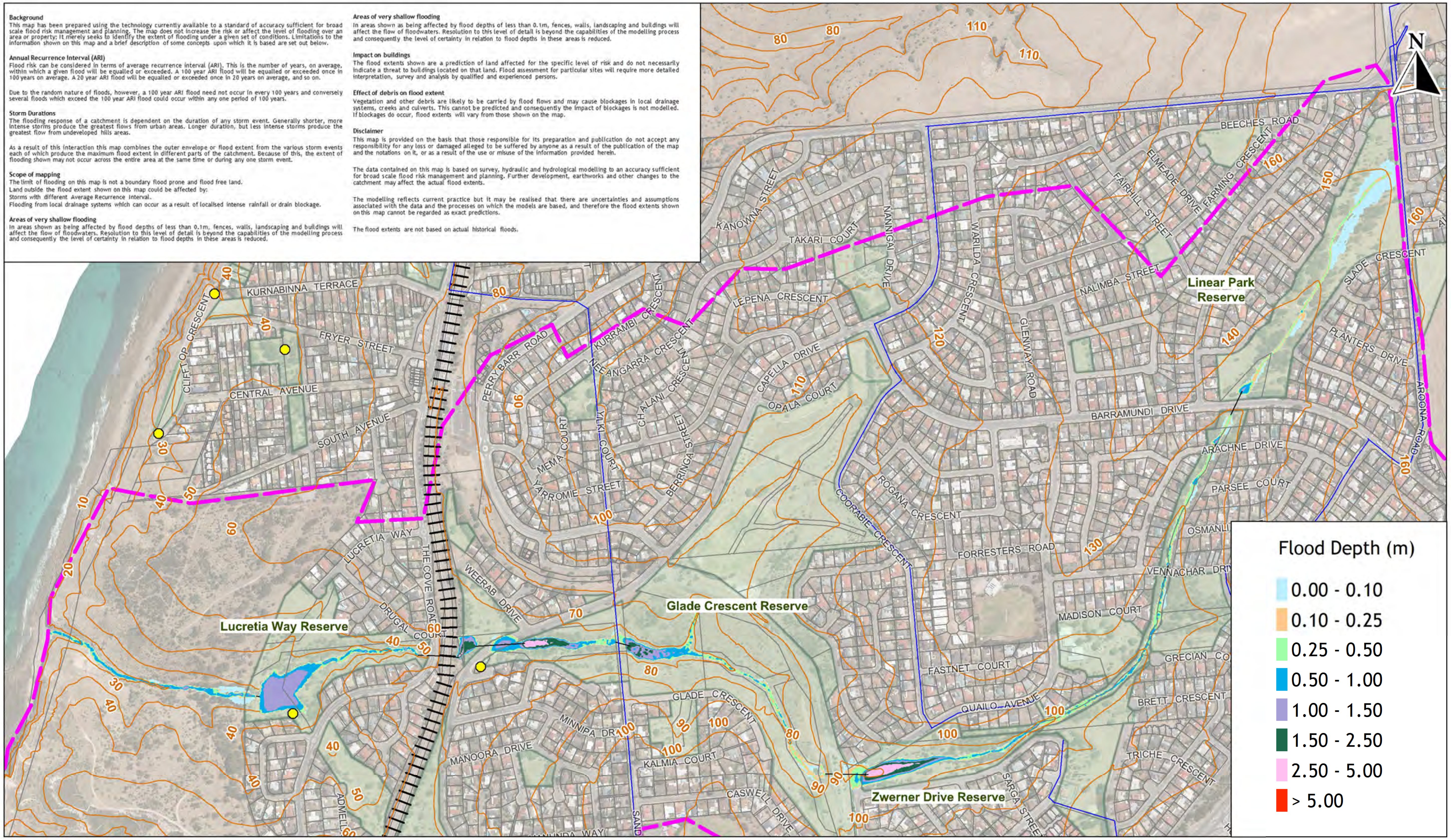

Data Sources:
City of Marion (Aerial Photograph, Contours, Cadastre, Roads, Drainage)
AMLR NRM Board (Emergency Services, Services Infrastructure)
Southfront (Floodplain Extents)

0 200 400m
Scale 1:7,500

- Emergency Services
- Sewer Pump Station
- Power Substation
- Water main (300mm dia and above)
- Railway Line
- Council Reserve
- Cadastral Boundary
- Contour (10m interval)
- Flood Plain Model Extents

southfront

Hallett Cove Creeks
Stormwater Management Plan

Waterfall Creek

100 Year ARI Flood Inundation Map

Revision A - Issued 27 June 2012

Background
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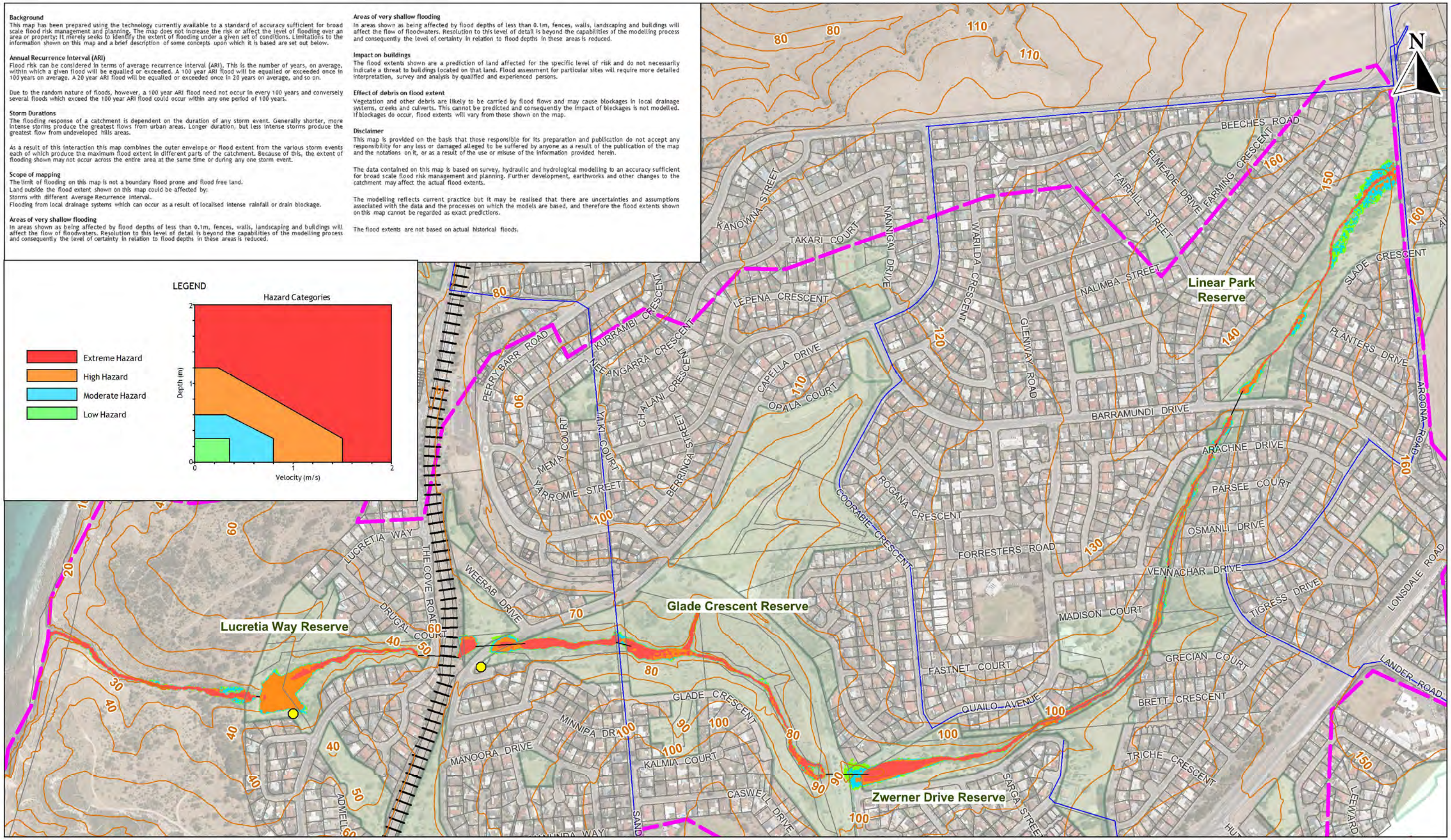
The flood extents are not based on actual historical floods.

LEGEND

- Extreme Hazard
- High Hazard
- Moderate Hazard
- Low Hazard

Hazard Categories
Depth (m)
Velocity (m/s)
0
1
2



Data Sources:
City of Marion (Aerial Photograph, Contours, Cadastre, Roads, Drainage)
AMLR NRM Board (Emergency Services, Services Infrastructure)
Southfront (Floodplain Extents)

southfront

0 200 400m

Scale 1:7,500

- Emergency Services
- Sewer Pump Station
- Power Substation
- Water main (300mm dia and above)
- Railway Line
- Council Reserve
- Cadastral Boundary
- Contour (10m interval)
- Flood Plain Model Extents

Hallett Cove Creeks Stormwater Management Plan

Waterfall Creek

100 Year ARI Flood Hazard Map

Revision A - Issued 27 June 2012

Background

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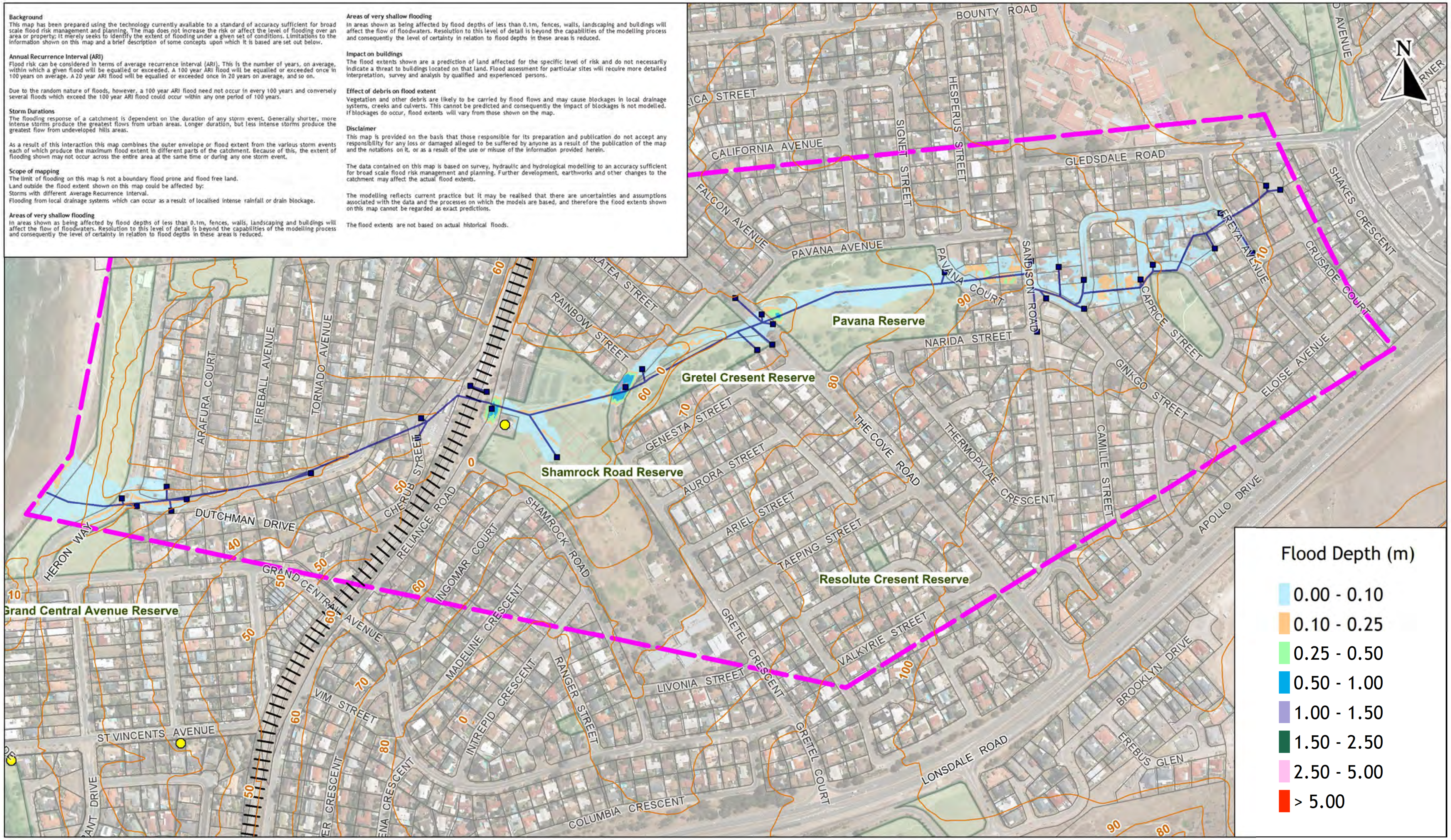
The flood extents are not based on actual historical floods.



Data Sources:
City of Marion (Aerial Photograph, Contours, Cadastre, Roads, Drainage)
AMLR NRM Board (Emergency Services, Services Infrastructure)
Southfront (Floodplain Extents)

southfront

0 200 400m

Scale 1:5,000

- Emergency Services
- Sewer Pump Station
- Power Substation
- Modelled Drain Reach
- Modelled Flow Input
- Railway Line
- Council Reserve
- Cadastral Boundary
- Contour (10m interval)
- Flood Plain Model Extents

Hallett Cove Creeks
Stormwater Management Plan

Heron Way Drain Catchment

10 Year ARI Flood Inundation Map

Revision A - Issued 27 June 2012

Background
This map has been prepared using the technology currently available to a standard of accuracy sufficient for broad scale flood risk management and planning. The map does not increase the risk or affect the level of flooding over an area or property; it merely seeks to identify the extent of flooding under a given set of conditions. Limitations to the information shown on this map and a brief description of some concepts upon which it is based are set out below.

Annual Recurrence Interval (ARI)
Flood risk can be considered in terms of average recurrence interval (ARI). This is the number of years, on average, within which a given flood will be equalled or exceeded. A 100 year ARI flood will be equalled or exceeded once in 100 years on average. A 20 year ARI flood will be equalled or exceeded once in 20 years on average, and so on.

Due to the random nature of floods, however, a 100 year ARI flood need not occur in every 100 years and conversely several floods which exceed the 100 year ARI flood could occur within any one period of 100 years.

Storm Durations
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As a result of this interaction this map combines the outer envelope or flood extent from the various storm events each of which produce the maximum flood extent in different parts of the catchment. Because of this, the extent of flooding shown may not occur across the entire area at the same time or during any one storm event.

Scope of mapping
The limit of flooding on this map is not a boundary flood prone and flood free land.
Land outside the flood extent shown on this map could be affected by:
Storms with different Average Recurrence Interval.
Flooding from local drainage systems which can occur as a result of localised intense rainfall or drain blockage.

Areas of very shallow flooding
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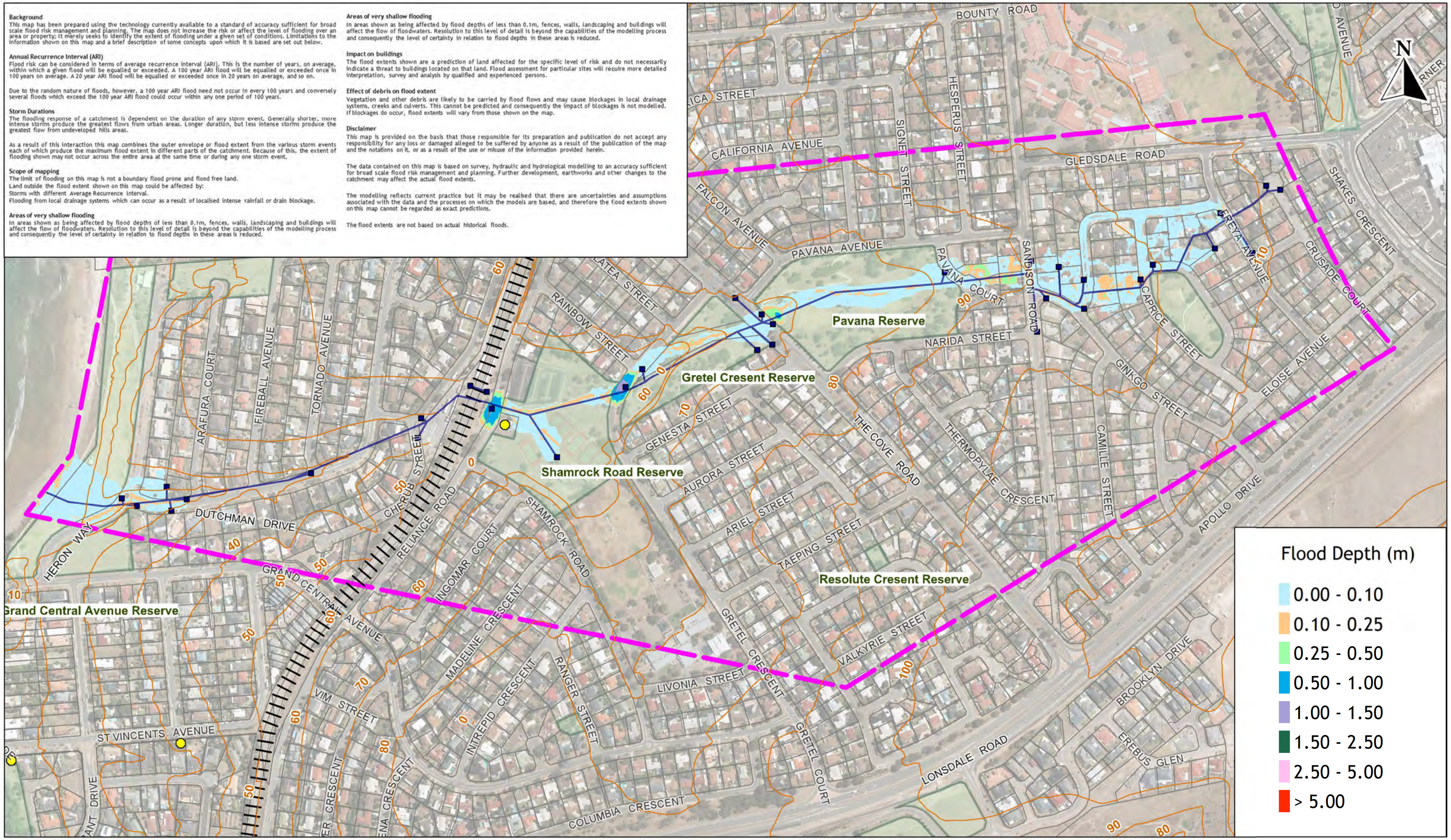
The flood extents are not based on actual historical floods.



Data Sources:
City of Marion (Aerial Photograph, Contours, Cadastre, Roads, Drainage)
AMLR NRM Board (Emergency Services, Services Infrastructure)
Southfront (Floodplain Extents)

0 200 400m
Scale 1:5,000

- Emergency Services
- Sewer Pump Station
- Power Substation
- Modelled Drain Reach
- Modelled Flow Input
- Railway Line
- Council Reserve
- Cadastral Boundary
- Contour (10m interval)
- Flood Plain Model Extents

southfront

Hallett Cove Creeks
Stormwater Management Plan

Heron Way Drain Catchment

20 Year ARI Flood Inundation Map

Revision A - Issued 27 June 2012

Background
This map has been prepared using the technology currently available to a standard of accuracy sufficient for broad scale flood risk management and planning. The map does not increase the risk or affect the level of flooding over an area or property; It merely seeks to identify the extent of flooding under a given set of conditions. Limitations to the information shown on this map and a brief description of some concepts upon which it is based are set out below.

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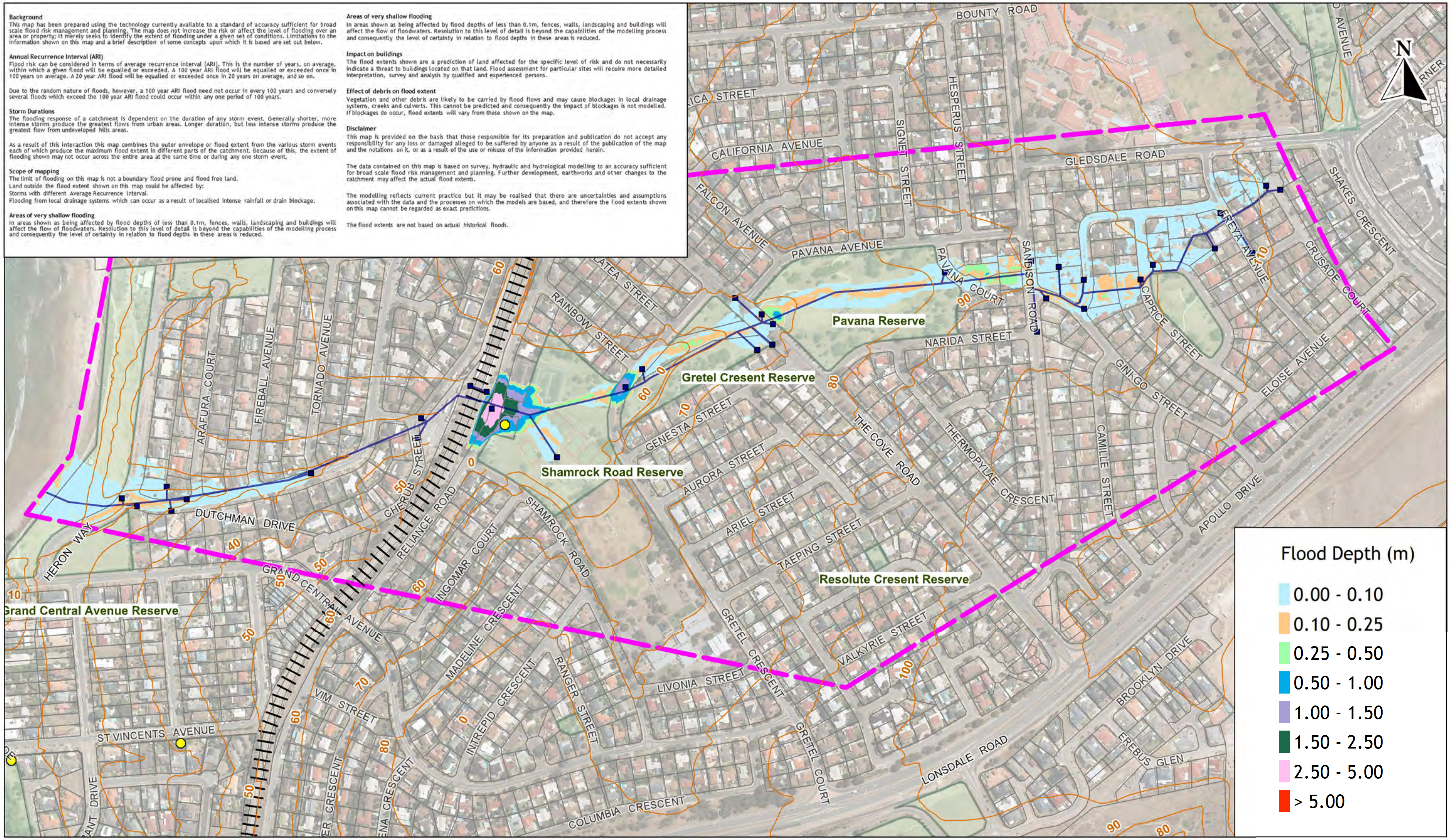

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AMLR NRM Board (Emergency Services, Services Infrastructure)
Southfront (Floodplain Extents)

0 200 400m
Scale 1:5,000

Emergency Services
Sewer Pump Station
Power Substation
Modelled Drain Reach
Modelled Flow Input
Railway Line
Council Reserve
Cadastral Boundary
Contour (10m interval)
Flood Plain Model Extents

southfront

Hallett Cove Creeks
Stormwater Management Plan

Heron Way Drain Catchment

100 Year ARI Flood Inundation Map

Revision A - Issued 27 June 2012

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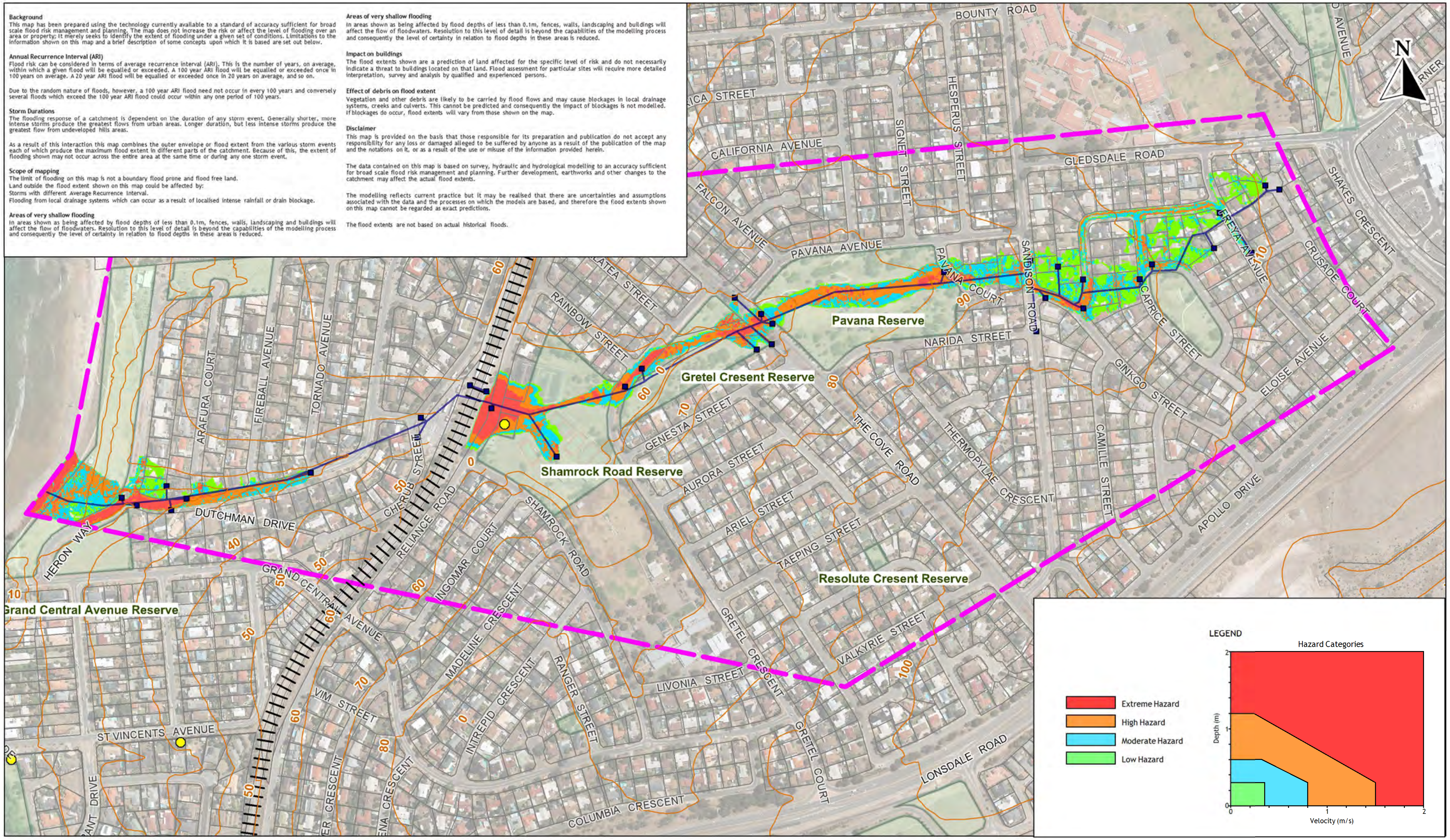

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AMLR NRM Board (Emergency Services, Services Infrastructure)
Southfront (Floodplain Hazard)

southfront

0 200 400m
Scale 1:5,000

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Hallett Cove Creeks Stormwater Management Plan

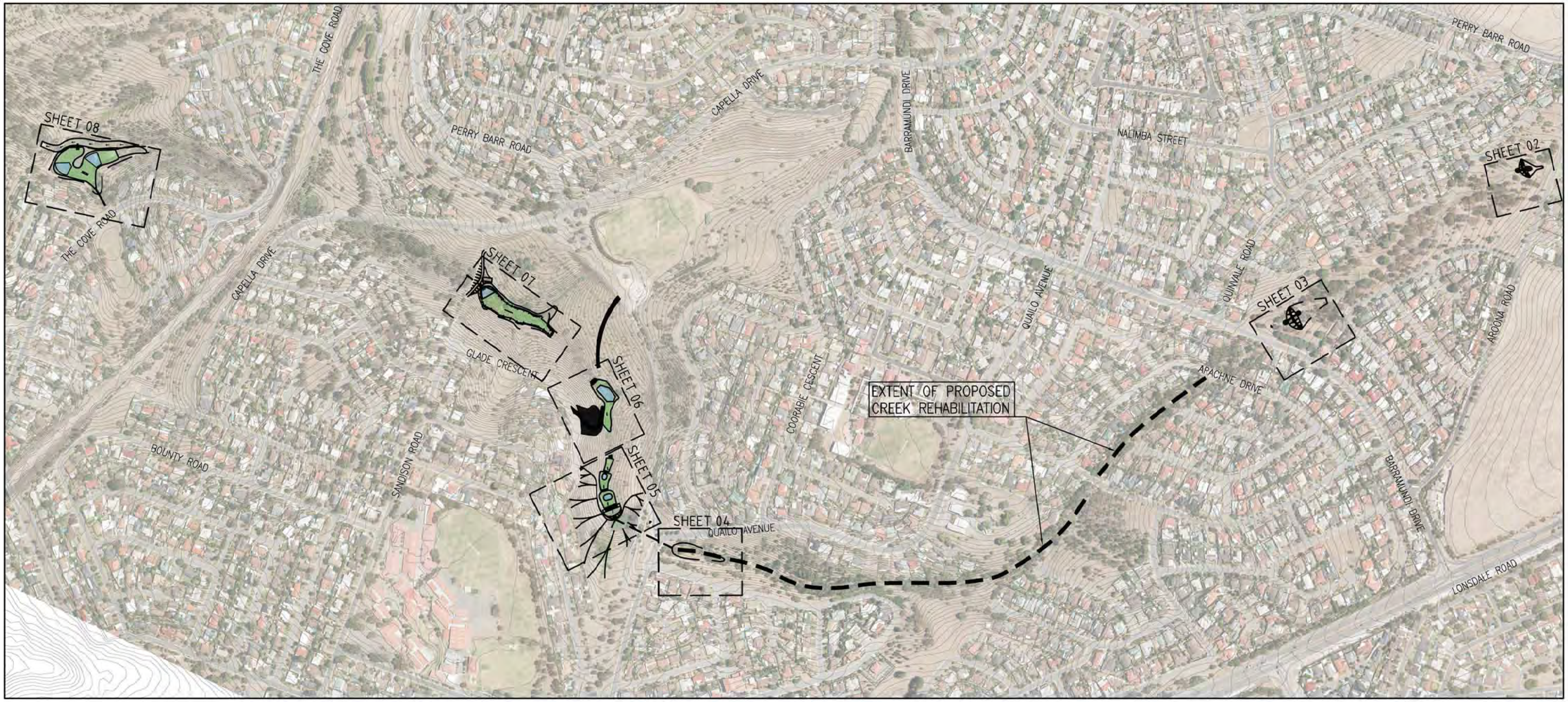
Heron Way Drain Catchment

100 Year ARI Flood Hazard Map

Revision A - Issued 27 June 2012

Appendix B
Waterfall Creek
Functional Design
Sketch Plans

NOT FOR CONSTRUCTION



LOCALITY PLAN
N.T.S.

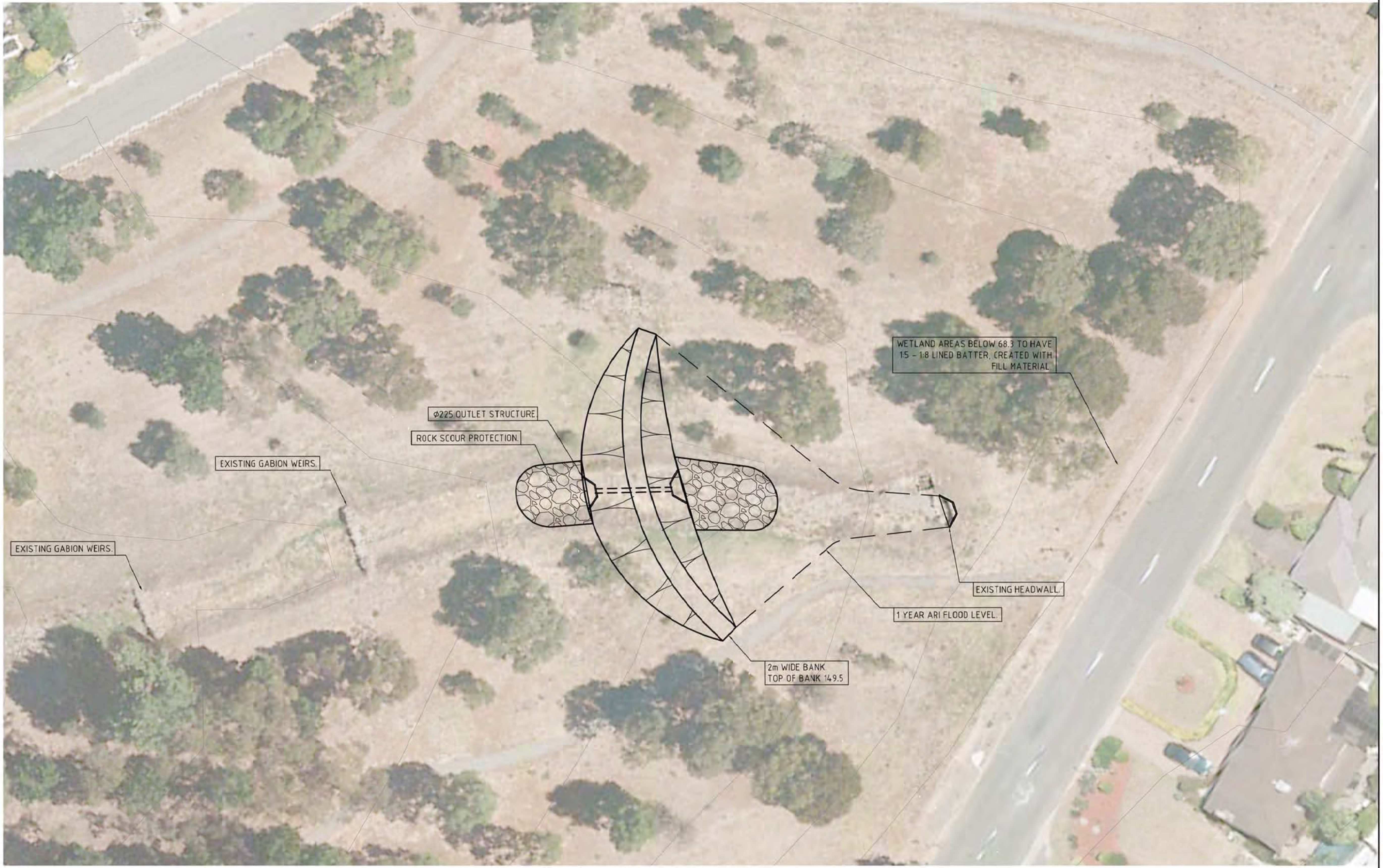
GLADE CRESCENT RESERVE, FUNCTIONAL DESIGN

SHEET No.	DESCRIPTION
01	LOCALITY PLAN
02	AROONA ROAD DETENTION STORAGE
03	BARRAMUNDI DRIVE DETENTION STORAGE
04	QUAILO AVENUE DETENTION STORAGE
05	GLADE CRESCENT RESERVE – POND 1
06	GLADE CRESCENT RESERVE – POND 2
07	GLADE CRESCENT RESERVE – POND 3
08	LUCRETIA WETLAND

southfront
LEVEL 3, 170 GREENHILL ROAD, PARKSIDE
SA 5063
P: (08) 8172 1088
F: (08) 8271 2055
E: enquiry@southfront.com.au
W: www.southfront.com.au

SCALE: N.T.S.	CITY OF MARION
JOB No: 11021	HALLETT COVE CREEKS STORMWATER MANAGEMENT PLAN
SHEET No: 1 OF 8	WATERFALL CREEK FUNCTIONAL DESIGN

NOT FOR CONSTRUCTION



AROONA ROAD DETENTION STORAGE

SCALE 1:200

southfront

LEVEL 3, 170 GREENHILL ROAD, PARKSIDE
SA 5063
P: (08) 8172 1088
F: (08) 8271 2055
E: enquiry@southfront.com.au
W: www.southfront.com.au

SCALE: 1:200	CITY OF MARION
JOB No: 11021	HALLETT COVE CREEKS STORMWATER MANAGEMENT PLAN
SHEET No: 2 OF 8	WATERFALL CREEK
	FUNCTIONAL DESIGN

NOT FOR CONSTRUCTION

BARRMUNDI DRIVE DETENTION STORAGE

SCALE 1:200

southfront

LEVEL 3, 170 GREENHILL ROAD, PARKSIDE
SA 5063
P: (08) 8172 1088
F: (08) 8271 2055
E: enquiry@southfront.com.au
W: www.southfront.com.au

0 2 4 6 8 10m
SCALE 1:200m

SCALE: 1:200	CITY OF MARION
JOB No: 11021	HALLETT COVE CREEKS STORMWATER MANAGEMENT PLAN
SHEET No: 3 OF 8	WATERFALL CREEK FUNCTIONAL DESIGN

NOT FOR CONSTRUCTION

QUAILO AVENUE DETENTION STORAGE

SCALE 1:200

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0 2 4 6 8 10m
SCALE 1:200m

SCALE: 1:200	CITY OF MARION
JOB No: 11021	HALLETT COVE CREEKS STORMWATER MANAGEMENT PLAN
SHEET No: 4 OF 8	WATERFALL CREEK FUNCTIONAL DESIGN

GLADE CRESCENT RESERVE - POND 1

SCALE 1:200

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0 2 4 6 8 10m
SCALE 1:200m

SCALE: 1:200	CITY OF MARION
JOB No: 11021	HALLETT COVE CREEKS STORMWATER MANAGEMENT PLAN
SHEET No: 5 OF 8	WATERFALL CREEK
	FUNCTIONAL DESIGN

GLADE CRESCENT RESERVE POND 2

SCALE 1:200

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SCALE 1:200m

SCALE: 1:200	CITY OF MARION
JOB No: 11021	HALLETT COVE CREEKS STORMWATER MANAGEMENT PLAN
SHEET No: 6 OF 8	WATERFALL CREEK
	FUNCTIONAL DESIGN

GLADE CRESCENT RESERVE - POND 3

SCALE 1:200

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0 2 4 6 8 10m
SCALE 1:200m

SCALE: 1:200	CITY OF MARION
JOB No: 11021	HALLETT COVE CREEKS STORMWATER MANAGEMENT PLAN
SHEET No: 7 OF 8	WATERFALL CREEK
	FUNCTIONAL DESIGN