Objective	Achieved	Priority	Discussion
Objective 1.3	Partial (1% AEP trunk drainage standard achieved in some areas)	F1, F2, F5, F14	The SMP addresses the most pronounced areas of flooding along open channels. Achieving a 1% AEP standard of protection for all open channels is an aspirational target that could be worked towards over a long timeframe. Significant structural upgrades of trunk drainage infrastructure would be required to achieve this target. This would not be economically viable for Council across the 10-year planning horizon; however, works to provide a 1% AEP trunk drainage standard should be identified beyond the 10-year timeframe. Flood mitigation of the North and South Para Rivers and Gawler River not within the scope of the SMP.
Objective 1.4	Yes	F3, F10	Planning updates and use of the flood mapping can be used to ensure a 1% AEP standard of protection.
Objective 1.5	Yes	F4, F13	The education campaign will increase the public awareness of flood risk, allowing a better response to flood events to be achieved.
Objective 1.6	Yes	F9	The 1% AEP 2050 climate change flood map will allow for consideration of possible future climates in future works.
Water quality improvement			
Objective 2.1	Partial	Q3, Q4	Additional GPTs, beyond the priority GPTs identified in the SMP, will be required to achieve the gross pollutant removal target. Significant economic expenditure (not feasible for Council in the short term) is needed to facilitate this. Partial achievement is due to what can be practically achieved over the next 10-year period based on economic and physical constraints, however it is expected the objective can be achieved in the long term; additional GPT locations should be identified after the 10-year horizon.
Objective 2.2	Partial	F1, Q1, Q2, Q4	Significant coverage of retrofitted WSUD measures across the council areas would be required to achieve the target reduction in TSS of 80% (modelled improvement shows 43% reduction). Significant economic expenditure (not feasible for Council in the short term) is needed to facilitate this. Partial achievement is due to what can be practically achieved over the next 10-year period based on economic and physical constraints, however it is expected the objective can be achieved in the long term; additional WSUD measures should be identified after the 10-year horizon.

Objective	Achieved	Priority	Discussion
Objective 2.3	Partial	F1, Q1, Q2, Q4	Significant coverage of retrofitted WSUD measures across the council areas would be required to achieve the target reduction in TP of 60% (modelled improvement shows 31% reduction). Significant economic expenditure (not feasible for Council in the short term) is needed to facilitate this. Partial achievement is due to what can be practically achieved over the next 10-year period based on economic and physical constraints, however it is expected the objective can be achieved in the long term; additional WSUD measures should be identified after the 10-year horizon.
Objective 2.4	Partial	F1, Q1, Q2, Q4	Significant coverage of retrofitted WSUD measures across the council areas would be required to achieve the target reduction in TN of 45% (modelled improvement shows 14% reduction). Significant economic expenditure (not feasible for Council in the short term) is needed to facilitate this. Partial achievement is due to what can be practically achieved over the next 10-year period based on economic and physical constraints, however it is expected the objective can be achieved in the long term; additional WSUD measures should be identified after the 10-year horizon.
Objective 2.5	Yes	F10, R1, R2	Planning updates and reuse priorities will allow the increase in average annual runoff from areas of redevelopment to be minimised.
Water reuse			
Objective 3.1	Yes	R2, Q4, F10	On-site stormwater reuse strategies identified.
Objective 3.2	Yes	R2, Q4, F10	On-site stormwater reuse strategies identified.
Environmental protection and enhancement			
Objective 4.1	Yes	F1, F5, F7	New stormwater management facilities constructed within existing open space will maximise community use and benefit as well as providing water quality improvements.
Objective 4.2	Yes	E1	The restoration of creek lines through weed removal and introduction of native species will provide for additional native habitat and provide an environment that is not as susceptible to erosion.
Objective 4.3	Yes	F10, E1	Works will be undertaken to restore creek lines to natural conditions; flows from new developments will be limited to better mimic the pre-development hydrological regime.
Asset management			

Objective	Achieved	Priority	Discussion
Objective 5.1	Yes	A1	The asset inspection program will ensure drainage infrastructure data is current.
Objective 5.2	Yes	A1	Maintenance strategies are focused towards ensuring early identification of deteriorated assets to enable proper planning of their replacement.
Objective 5.3	Yes	A1	Maintenance management plans are to be developed, with appropriate funding set aside to assist with long-term management.

Objective 1.3 (trunk drainage system with a minimum capacity sufficient to carry a 1% AEP flow) is the only objective not specifically targeted by the measures listed within this SMP. However, the SMP has produced the tools that can be used to identify flow rates, allowing works along the trunk drainage system to be modelled so that they can attempt to achieve this objective.

9.9 Consultation

Consultation in relation to the SMP has been thorough. It has included the following:

- Communication with key stakeholders, with stakeholder workshops held on 8/12/15 and 7/12/18. Stakeholders include the Gawler Urban Rivers Biodiversity Working Group, EPA, Gawler Community Services Forum, Gawler Regional Natural Resource Centre, Gawler River Floodplain Management Authority, SES, Food Forest, Trinity College, SA Police & DIT.
- Communication with and feedback from the Project Steering Group (representatives from Town of Gawler, Light Regional Council, Barossa Council, Stormwater Management Authority, and the former Adelaide and Mt Lofty Ranges Natural Resources Management Board).
- Communication with elected members from the Town of Gawler, Light Regional Council and Barossa Council.

A final round of consultation is still to be undertaken on this final draft SMP prior to endorsement by the SMA.

Additional detail of the consultation undertaken to date is contained within Appendix H.

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Appendix A – Habitat and erosion potential of selected tributaries to the North Para and South Para rivers

GAWLER RIVER FLOODPLAIN MANAGEMENT STRATEGY

Condition and Erosion Potential of Selected Tributaries to the North and South Para Rivers

Prep. By

Eco Management Services Pty Ltd

For

Tonkin

October 2020

Our Ref 540/15

Contents

Contents		Page No
1.0	Introduction	1
1.1	Scope	1
1.2	Additional more Recent Information	1
2.0	Overview of Habitat Quality	1
2.1	General Description of Tributaries within Study Area	1
2.2	Assessing Watercourse Condition	3
2.3	Potential Presence of threatened fauna and flora species	4
3.0	Soil Erosion Risk	24
References		30

List of Figures

- **Figure 1** Tributaries
- **Figure 2** Soil Land Systems
- **Figure 3** Soil Erosion Risk Matrix
- **Figure 4** Soil Erosion Risk Classes within Soil Land Systems
- **Figure 5** Soil Erosion Risk

List of Tables

- **Table 1** Condition Overview of Main Tributaries within Study Area

Attachments

- **Attachment 1** Threatened species and migratory birds listed as potentially occurring in the Gawler area
- **Attachment 2**
  - Land System Reports Maschmedt, D J (2002) – Kalbeeba, Yattalunga, Smithfield, Tenafeate.
  - Pages 79-81 from Maschmedt (2002).

GAWLER RIVER FLOODPLAIN MANAGEMENT STRATEGY

Existing Condition and Erosion Potential of Tributaries to the North and South Para Rivers, within the 30 Year Plan Boundary

1.0 Introduction

1.1 Scope

As part of the Gawler River Floodplain Management Strategy, a high level assessment has been made of the tributary watercourses of the North and South Para Rivers, which are within the Gawler 30 urban development zone, identified in the Adelaide Metropolitan 30 Development Plan, shown on Figure 1. As required in the study brief the scope of work was as follows:

> *The successful tenderer will be required to undertake a high-level assessment of the existing condition of the watercourses within the study area. The high-level assessment will include a walk over of the watercourses, noting:*
> - *Existing erosion of the bed and/or banks.*
> - *Stock crossing points.*
> - *Areas of woody weeds or weed species of national significance. Any obstructions to flow.*
> - *Areas of remnant or significant indigenous vegetation to be protected.*
>
> *Information will be input into GIS noting the location and approximate extent. The aim will be to rate each watercourse or sections within a watercourse with a high, medium or low risk of further deterioration or threat, assuming existing and unmitigated long-term scenario (refer to Task 9 of the brief) levels of development. Other factors, including the longitudinal slope of the watercourse will also be used to assess each watercourse or sections within a watercourse.*

The required work on weeds and remnant or significant indigenous vegetation in the watercourses was undertaken in 2015, in which overall habitat condition was described. Following a review of a draft report by Council and relevant Government Agencies, the work on habitat condition was accepted, but it was determined that in addition to noting the occurrence of erosion in the watercourses observed during the brief walk overs, a high level soil erosion risk assessment was to be undertaken for Tributaries 1, and 4 to 11.

This was later included in the final EMS (2017) report. No changes were made to the section on habitat. For the habitat condition of the watercourses, the limitations on the study only allowed for an assessment based on, a review of aerial photography to determine watercourse type, vegetation cover and other visible issues, a single walk over for each watercourse at selected locations, and a search of readily available databases on the potential presence of endangered or threatened flora species. An assessment of native fauna presence was not required for this study, but for completeness fauna were also included in the search. To provide structure in the assessment, use was made of the Bush Condition Monitoring Manual – Southern Mount Lofty Ranges. The soil risk assessment was undertaken using the method outlined in 'Assessing Agricultural Lands, Agricultural Land Classification Standards used in South Australia's Land Resource Mapping Program' DWLBC (2002).

Overall, the intent of the habitat assessment was to generally provide a snapshot of the condition of the watercourse and available aquatic/riparian habitats. The main issue with any future upstream development is the risk of changed hydrological condition, particularly with increased rates and volumes of urban stormwater runoff. Because of the very limited nature of the field assessment, the report indicated that in the event that any significant hydrological changes occurring in a watercourse, a more detailed survey may be needed.

1.2 Additional More Recent Information

Since the work was undertaken in 2015, important and relevant valuable information on the characteristics of the original flora associations along the creeklines has become available. This was summarised by Mr. A. Shackley in a Public Submission in 2019. He points out that DEW/DIT maps "pre-European" vegetation maps for the Gawler foothills area are mostly wrong in describing the area as Mallee Box woodland, Peppermint Box woodland, Blue Gum woodland and Sheoak Woodland, and these maps are in the process of being revised. In addition, evidence of original plant associations is covered comprehensively in "Concordia Biodiversity Survey and Restoration Report" (2017) Donovans Earth Care, the Council Biodiversity Management Plan, "Biological Survey of Lower North Grasslands (Shackley, Allanson, Kuys 2015). Quite a bit of this data is now available on the Atlas of Living Australia or DEW websites.

Using this information and local sources, Mr. Shackley has provided valuable summary information on flora for the watercourses and this has been incorporated into the report as indicated. It certainly helps provide a more complete picture of the ecological status of the various watercourses.

2.0 Overview of Watercourse Condition

2.1 General Description of Tributaries within Study Area

The study area is in the northern Adelaide Plains, described as a relictual landscape, which is extensively modified with a remaining vegetative cover of <10%. The headwaters of the small tributaries are in the Hills Face Foothills, and are being disproportionally cleared in a fragmented landscape with native vegetation cover below 30% (DEH 2011).

The tributaries in the study area are mostly small first, second or third order streams, and are gullies with rocky headwaters and outcrops and/or drainage lines in grassy woodlands which drain down more gentle slopes (<20°). These tributaries have short term episodic seasonal flows. The occurrence of any habitat for aquatic fauna (macroinvertebrates) or flora (emergent, submergent) depends on whether there are more permanent spring fed flows/soaks, producing waterlogged or swampy conditions, or permanent or ephemeral pools. Generally, however, they are only generally seen as providing marginal aquatic habitat, and very unlikely to be important for native fish species.

Regarding the riparian, all tributaries have been highly modified, with little of the original natural habitat remaining, mainly through vegetation clearance, urban development, and grazing. Although most of the watercourses are pasture areas dominated by introduced understorey species, with scattered tall shrubs and trees, information provided by Shackley, referred to above, indicates there are important remnant vegetation areas which have ecological and conservation significance, particularly for native grasses. There are occasional isolated stands of mallee box (*Eucalyptus porosa)* in gullies, and very occasional large remnant redgums (*E. camaldulensis*) in tributaries close to the North Para River. Much of the remaining vegetation is introduced woody weeds or amenity plantings of native and exotic species. Planted and escaped introduced species, including olive, pepper tree, radiata pine and Aleppo pine also occur as tall shrub storey and overstorey species over pasture. Their value as native fauna habitat (particularly mammals and reptiles) is also reduced by the increased presence of feral species, including domestic cats and dogs, found in adjacent urban areas. However, some of the older trees have hollows that potentially may be used by a variety of native parrots, possums or gliders.

2.2 Assessing Watercourse Condition

The existing condition of the watercourses with regard to remnant vegetation is described by examining the aquatic and riparian zones and the general habitat condition at the selected locations. The **aquatic** zone carries normal stream flow, and includes the in-stream channel, and is permanently or frequently under water or wet. The **riparian** zone comprises the strips of watercourse on either side of the aquatic zone, including the banks, where there is extra moisture associated with the watercourse flow. While the ground is often inundated during flood events, it is not constantly under water.

2.2.2 Criteria used for Assessing Condition

Aquatic Zone

The relative value of the aquatic zone of these tributaries becomes apparent when compared with the main North and South Para River channels, where there are large permanent pools, and swathes of aquatic vegetation and riparian habitat. In comparison the aquatic habitat in the tributaries is minimal. Main characteristics include:

- Presence of pools (permanent, ephemeral), spring fed flows, riffles/cascades
- Presence of aquatic vegetation (amphibious emergent, submerged)
- Continuity, extent of habitat, linkage with North and South Para Rivers

These characteristics were largely absent in the selected locations examined, except on the lower section of Tributary 6 (Figure 1) which was spring fed providing a linear waterlogged area, supporting a dense swathe of species including *Bolboschoenus caldwellii* and *Juncus* sp., and a small pool near the confluence near the South Para River.

Riparian Zone

The qualitative assessment of overall condition undertaken in 2015 was made using criteria adapted from Croft *et al*. (2005), as follows:

- Large trees bearing nesting hollows H, M, L (2,1,0)
- Diversity of Vegetation Structures (grasses, low shrubs, tall shrubs, trees) H, M, L (2,1,0)
- Part of a Habitat Corridor Y, N (1,0)
- Diversity of Native Plant Species present H, M, L (2,1,0)
- Number of Native Bird Species Present H, M, L (2,1,0)
- Native / Exotic dominance N / E (1,0)

This gives a range of 0 – 10, with the overall classification as follows:

0-2	very low
3-4	low
5-6	moderate
7-8	high
9-10	very high

Using these criteria, all of the watercourses were generally classified as being low to very low habitat condition. However, as indicated by Shackley in his submission, information is now available which indicates that these were not woodland watercourses but were in places native grasses with few trees and shrubs. While there have been major impacts since European settlement, important remnants of native remain, particularly of native grasses, and are of conservation and ecological significance.

2.3 Potential Presence of threatened fauna and flora species

Threatened flora species listed in various studies and databases as potentially occurring in the Gawler area, are given in Appendix 1. In addition, some birds, reptiles, mammals and amphibians of Regional, State and National conservation significance that have also been recorded in the Gawler East and Gawler region recently (KBR 2009, KBR 2010) are:

- *Gallinago hardwickii* (Latham's snipe)
- *Merops ornatus* (rainbow bee-eater)
- *Melithreptus gularis gularis* (south-eastern subspecies) (black-chinned honeyeater)
- *Falco peregrinus* (peregrine falcon)
- *Haliastur sphenurus* (whistling kite)
- *Corcorax melanorhamphos* (white-winged chough)
- *Aprasia pseudopulchella* (Flinders Ranges worm-lizard)
- *Pseudophryne bibroni* (brown toadlet)

Reviewing the information in Appendix 1 and based on the available habitats and their condition, it is unlikely that any of these species are present, as their preferred habitat is either not available, or marginal at best. Nevertheless, should any works be proposed in any of the tributaries a more detailed survey should be undertaken.

Table 1 Main Tributaries within Study Area (Tributaries and photograph locations are shown on Figure 1)	
Tributary 1 –Lower Reach	
 Plate 1 Looking south along channel, dirt channel with no aquatic flora	**Stream Order 3** Tributary flows directly into North Para River Steep bank eroded on outside of bends **Riparian habitat–** Generally low value Occasional mature *Eucalyptus camaldulensis* with minor regeneration, over exotic grasses, herbs. Planting being undertaken. Scope for development and enhancement with plantings and weed control **Aquatic habitat** Virtually no aquatic habitat.
 Plate 2 Looking west along channel – unstable banks	 Plate 3 Eroded banks held together by exotic grasses
 Plate 4 Looking west to steep western bank	 Plate 5 Small gully – occasional large redgum

<table>
<tr><td>
Plate 6 Narrow grassy channel</td><td>
Plate 7 Small pool with aquatic vegetation, within weed dominated area</td></tr>
<tr><td colspan="2">Tributary 1 – Upper Reaches</td></tr>
<tr><td>
Plate 9 View east, adjacent agricultural land</td><td>Stream Order 2
highly modified minor drainage line in rolling low hills of low elevation
Riparian
Planted mixed varieties of mature Eucalyptus spp. over exotic grasses, herbs. Occasional larger tree may have small hollows. Adjacent to intensive agricultural land use.
Aquatic
No natural aquatic habitat flows only in regional flood events No permanent water, except for a farm dam, refer Figure 1.</td></tr>
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6

Plate 10 Indistinct grassy channel

Additional information on flora from AS:

- Gully creek into North Para opposite EMS photo points 15.16 (upstream slightly) area c 2.5 hectares. in the order of 50% of the site is moderate condition native tussock grassland. 31 native species, 5 have a regional or sub-regional conservation status. A few old remnant trees with hollows are present.
- Gully creek into North Para opposite EMS photo points 15.16 (downstream slightly) area c 3.2 hectares. Despite the long term effects of grazing and weeds and the planted trees, many important native species are present in significant numbers including 15 native grass species, 4 Lomandra species and 25 herbaceous species. Total 56 native species identified. 16 of these species have a regional or sub-regional conservation status. No remnant trees present but two old Mallee Box trees in adjacent paddock.
- Whitelaw Creek Bushcare site - 1.4 hectares. The work of the Whitelaw Creek Bushcare group since 2000 has been very successful in removing woody weeds and encouraging native species. 19 native grass species, 4 Lomandra species and 24 herbaceous species is very high for this area which has been regularly grazed (but only very occasionally over the last 15 years at least). 28 of 69 native species have a regional or sub-regional conservation status. Dianella longifolia var. grandis and Maireana rohrlachii are State Rare species.
- Whitelaw Creek gully downstream of dam to Bushcare site. There is a high number of native species present but many are only in the wet creek bed (fed by a spring/s in the vicinity of the rocky ledge just below the dam). Grassland species on the banks are often in low numbers. The riparian area has a good range of species, biased somewhat towards salt tolerant species such as Juncus kraussii suggesting the spring water is rather saline. 13 native grass species, 4 Lomandra species and 34 herbaceous species is very high for this grazed area. 27 of 70 native species have a regional or sub-regional conservation status. Trees with hollows present providing excellent habitat, including a few very old and one large dead Red Gum and some ancient Eucalyptus porosa.
- Whitelaw Creek dam area to Harris Road. This area is dominated by the constructed dam and its periphery of planted and germinated trees and shrubs. The riparian area of the creekline upstream of the dam is more or less permanently wet because of the spring water coming down from the southern side of Harris Road. 16 native grass species, 3 Lomandra species and 10 herbaceous species is high for this grazed area. 14 of 43 native species have a regional or sub-

7

regional conservation status. Wetland species of conservation significance include Triglochin striatum, Suaeda australis, Bolboschoenus caldwellii and Alternathera denticulata. Dry grassy ecosystem species of conservation significance Maireana rohrlachii (State Rare species).

- Southof Harris Road **(**Harnett paddock). This part of Whitelaw Creek is unique in the Survey area and other minor creeks along the foothills near Gawler in having Eucalyptus odorata (a dozen or so old remnant trees many pre-dating European settlement) rather than Eucalyptus porosa as the main tree species. There are a couple of Eucalyptus porosa present including the 2 trees in the tributary feeding in from the north-east (Concordia Creek). It is also significant in having a permanent spring/soak providing the water for a wetland area on the northern side of the block. 16 native grass species, one Lomandra species and 8 herbaceous species is high for grasses but low for herbs for this previously grazed area. 11 of 41 native species have a regional or sub-regional conservation status. Riparian species regional/subregional conservation rated species include - Alternathera denticulata, Myoporum montanum and Schoenoplectus pungens.
- Whitelaw Creek West of Concordia Road to Harnett paddock. Six native grass species, one Lomandra species and 7 herbaceous species is moderate for grasses but low for herbs for this previously grazed and cultivated (paddock) area. Five of 21 native species have a regional or sub-regional conservation status. The first section of Whitelaw Creek at the western end includes a few ancient Eucalyptus odorata trees.
- Whitelaw Creek East of Concordia Road to Lyndoch Road. The creekline contains 7 large Red Gum (Eucalyptus camaldulensis), 5 large Sugar Gum (Eucalyptus cladocalyx) - all look to have been planted 1880-1900 based on their position (Map page 65) and hollow status. Seven native grass species, no Lomandra species and 8 herbaceous species is moderate for grasses but low for herbs for this previously grazed and cultivated (paddock) area. Five of 19 native species have a regional or sub-regional conservation status.

Tributary 2

Plate 8 looking east up small, short gully in urbanised area

Stream Order 1

steep rocky banks in urban area

Riparian

Mostly planted, immature *Eucalyptus spp., Melaleuca spp.* and *Acacia spp.* over exotic grasses, herbs. Continuous canopy. Ground level dominated by Soursob and Kikuyu. Scope for development and enhancement with plantings and weed control.

Aquatic

short-term season flow, virtually no natural aquatic habitat. Farm dam may act as refugia pool

8

Tributaries 3, 4 and 5 These are highly modified and are now just shallow channels across agricultural land, with virtually no remaining native fauna habitat value.
Additional information on flora from AS: • EMS Creek 3 area c 2.0 hectares. A generally good quality native grassland remnant apart from the eastern end which is very weedy. 13 native grass species, 4 Lomandra species and 18 herbaceous species is high for a regularly grazed area. 17 of 44 native species have a regional or sub-regional conservation status. Several skinks observed here during Survey visits. • Gully creek just downstream of EMS 3 area c 1.3 hectares. A generally good quality native grassland remnant apart from the eastern end which is very weedy. 12 native grass species, 3 Lomandra species and 15 herbaceous species is high for this grazed area (now protected by some fencing). 13 of 38 native species have a regional or sub-regional conservation status. The grassland area has fair cover for reptiles. • Western part of Creek 4 Bergen Creek. It is the only creek with a significant area of Eucalyptus porosa grassy woodland – currently in fair condition in terms of understorey and with a range of shrubs in the rocky creek banks. 9 native grass species, 2 Lomandra species and 19 herbaceous species. 16 native species with a regional or sub-regional conservation status. The area of Eucalyptus porosa grassy woodland is of high conservation significance. The ecosystem is rated as one of the highest conservation priorities for the State by DEW. Trees with hollows are a significant presence. The rocky creekline and moderate tree and shrub cover provide a variety of habitat for birds and reptiles.

Tributary 6 – Lower reach

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<td>
Plate 11 Small pool near confluence with South Para River</td>
<td>Stream Order 3

Direct tributary of South Para River.

In lower reach (approx. 1 km), steep banks with minor erosion near base of spring fed channel. Lower slopes in upper reaches.

Riparian

Occasional mature Eucalyptus camaldulensis and E. porosa over exotic pasture grasses, herbs. Dense Juncus usitatus, Bolbochoenus caldwellii and Cyperus sp. in permanently moist base of channel.

Scope for development and enhancement with plantings and weed control

Aquatic

A small permanent pool and the swathes of aquatic flora along the channel in the lower reach will provide habitat for a range of aquatic fauna. In the upper reaches aquatic habitat is minimal.</td>
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<td>
Plate 12 Swathe of aquatic flora along channel</td>
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<tr><th colspan="2">Tributary 6 – Upper Reaches</th></tr>
<tr><td>
Plate 13 Looking east further upstream – occasional large gums in channel</td><td>Drainage line in rolling low hills of low elevation. Banks less steep further upstream
Riparian
Occasional mature planted or self-sown Eucalyptus spp. in channel over exotic grasses, herbs.
Aquatic
Minimal aquatic habitat</td></tr>
<tr><td colspan="2">Additional information on flora from AS:

Yaringa/Spring Creek Gawler East. 17 native grass species, 4 Lomandra species and 27 herbaceous species is very high for this previously and mostly currently grazed area. 14 of 65 total native species have a regional or sub-regional conservation status. Juncus kraussii (not Juncus usitatus), Bolboschoenus caldwellii, Schoenoplectus pungens, Typha domingensis, Phragmites australis, Triglochin striatum, Hydrocotyle verticilata and Cyperus gymnocaulos are the native aquatic species known to inhabit the spring fed wetland area.</td></tr>
</table>

<table>
<tr><td colspan="2">Tributary 7</td></tr>
<tr><td>
Plate 15 Sparse E. porosa with olives</td><td>Stream Order 2

direct tributary of South Para River. Steep rocky banks with shallow soil. Rock exposed in steep banks near base of channel.

Riparian

Occasional mature Eucalyptus porosa with no regeneration, over exotic grasses, herbs. Occasional Austrostipa sp. native grass. Some small hollows in big old sprawling E. porosa. Limited, marginal quality habitat for Flinders Ranges worm lizard.

Scope for development and enhancement with plantings and weed control

Aquatic

Flows only during major events. Virtually no aquatic habitat.</td></tr>
<tr><td>
Plate 16 High grazing impact</td><td></td></tr>
<tr><td colspan="2">Additional information on flora from AS:

• DPTI creek running into SE side of Dead Mans Pass Gawler South. 7 native grass species, 1 Lomandra species and 18 herbaceous species is moderate for this previously grazed area. 5 of 40 total native species (6 are in Dead Mans Pass only) have a regional or sub-regional conservation status. 1 state rated. Contain some ancient Mallee Box trees with hollows.</td></tr>
</table>

Tributary 8

Plate 17 Looking east – plantation in private garden

Stream Order 1

Minor drainage line , artificial for much of its length

Riparian

In upper reach, planted mixed *Eucalyptus sp.* and *Acacia spp.*, over exotic grasses, herbs. Some occasional remnant *Eucalyptus porosa* downstream, dominated by exotic invasive species. Occasional *Austrostipa* sp. native grass. Some small hollows in big old sprawling *E. porosa.* Very limited (50-100m), marginal quality habitat for Flinders Ranges worm lizard in parts.

Scope for development and enhancement with plantings and weed control

Aquatic

Flows only during major events. Virtually no aquatic habitat.

Plate 18 Olives over exotic grasses and herbs

Additional information on flora from AS:

- Creek just S of Gawler One Tree Hill Road Gawler South 18 native grass species, 3 Lomandra species and 13 herbaceous species is high for this mainly previously grazed area. 7 of 41 total native species have a regional or sub-regional conservation status. Both converging creeks contain ancient Mallee Box trees with many hollows.

<table>
<tr><th colspan="2">Tributary 9</th></tr>
<tr><td>
Plate 19 Upstream of urban area, just below confluence of to order 1 streams</td><td>Stream Order 3
Minor drainage line to confluence with Tributary 10. Below confluence is a highly modified channel. Watercourse formally discharged onto plain, now drained to Gawler River by man-made channel.
Riparian
Highly modified, with planted mixed Eucalyptus sp. Acacia spp. and Melaleuca spp. over exotic grasses, herbs. No remnant vegetation. Variety of created habitats available for suburban birds, but dominated by exotic invasive species.
Scope for development and enhancement with plantings and weed control
Aquatic
Virtually no aquatic habitat, only a grassy channel, which only has flow during storm events.</td></tr>
<tr><td>
Plate 20 Downstream, wide maintained grassy channel</td><td>
Plate 21 View of northern tributary above confluence</td></tr>
</table>

Plate 22 View of southern tributary above confluence

Additional information on flora from AS:

- Potts Road creek (3 tributaries) running N side and in to Tingara Road Evanston Park. 15 native grass species, 3 Lomandra species and 16 herbaceous species is high for this previously and currently grazed area. 9 of 47 total native species have a regional or sub-regional conservation status. This group of creeks is the one place where Mallee Box trees are present in most of the creek riparian areas and the description Mallee Box grassy woodland would apply.

Tributary 10

Plate 23 Highly modified, managed grassy channel

Very similar to Tributary 9. Highly modified and maintained landscape. Watercourse is between levees, with the upstream boundary of the tributary in the study area being the embankment flood control bank across the watercourse, with culverts for controlled release.

Plate 24 Between levees, maintained flat grassy channel

Plate 25 Bank across watercourse with culverts, minor scour

Plate 26 Watercourse upstream of bank

16

Additional information on flora from AS:

- Creek entering along Sunnyside Drive including upstream of Bentley Road Evanston Park. 16 native grass species, 3 Lomandra species and 24 herbaceous species is high for this previously and currently grazed area. 11 of 50 total native species have a regional or sub-regional conservation status. A number of native plant species only found here for Gawler area as reported in BMP.

Tributary 11

Plate 27 Wide channel, dominated by exotic species, such as thistle, thin topsoil

Stream Order 3

Drainage line dissipates onto plains south of Gawler

Riparian

Historically cleared and heavily grazed. No remnant vegetation. Dominated by exotic invasive species

Aquatic

No aquatic habitat

Additional information on flora from AS:

- Creek entering Trinity College including upstream of Bentley Road Evanston Park 14 native grass species, 3 Lomandra species and 23 herbaceous species is high for this previously and currently grazed area. 11 of 52 total native species have a regional or sub-regional conservation status. Planted trees in Northern side of Trinity campus have affected understorey species.

Tributary 12

Plate 28 View along channel, note small shallow

Stream Order 4

minor low gradient, drainage line dissipates onto plains south of Gawler

Riparian

Historically cleared. All planted trees (in lower reach only), no remnant vegetation. High levels of human disturbance. Understorey dominated by exotic invasive species.

Aquatic

channel	No aquatic habitat, shallow grassed channel.
Additional information on flora from AS: • Creek entering adjacent Tiver Road and Gordon Road including upstream of Bentley Road Evanston Park. 9 native grass species, 3 Lomandra species and 11 herbaceous species is relatively low for this previously and currently grazed area. Grazing in particular upstream of Main North Road has removed many less tenacious species. 3 of 28 total native species have a regional or sub-regional conservation status. DPTI roadworks on Gordon Road have affected that area.	

Tributaries 13 and 14 Not examined, but from an examination of aerial photographs they are similar to 12 in that they are highly modified with little remnant vegetation.
Additional information on flora from AS: • Tributary 14. 11 native grass species, 3 Lomandra species and 27 herbaceous species is high for this previously and currently grazed area. Grazing in upstream of Adams Road has removed many less tenacious species in that area. 9 of 51 total native species have a regional or sub-regional conservation status. Many tree and shrub species including some local species have been planted in the creekline near the caravan park and on the banks upstream. Creek 14 has a significant spring upstream from Adams Road – currently blocked by a dam at the property boundary. This spring had a much stronger flow after the 1954 earthquake and ran west to the rail corridor and south along the corridor towards Smithfield for many years. Some remnant riparian species still present from this time.

Tributary 15 – east of Sturt Highway (runs south)

<table>
<tr>
<td>
Plate 29 looking downstream Sparse E. porosa with olives</td>
<td>Stream Order 1
Minor low gradient, drainage line flows into main channel of North Para River north of Gawler. Modified through cultivation of minor catchment as part of a cereal cropping paddock.
Riparian
Historically cleared. Remnant vegetation limited to one very small patch with Eucalyptus porosa and E. camaldulensis over weeds. High levels of human disturbance. Understorey dominated by exotic invasive grass and herb species.
Very low habitat value for native fauna.
Aquatic
No aquatic habitat, shallow channel that holds no standing water.</td>
</tr>
<tr>
<td>
Plate 30 looking upstream - High human impact</td>
<td></td>
</tr>
</table>

Tributary 16 – east of Sturt Highway (runs east)

Plate 31 Managed exotic vegetation / garden

Stream Order 1

Minor low gradient, drainage line flows into main channel of North Para River north of Gawler

Riparian

Historically cleared. All planted trees and shrubs around dwelling and sheds. Highly managed cottage garden with planted *Eucalyptus* spp. over numerous shrub and undershrub varieties. No remnant vegetation. High levels of human disturbance. Occasional *Schinus molle* (pepper tree) over weeds at lower end. Very occasional *E. porosa*. Understorey dominated by exotic invasive species.

Very low habitat value for native fauna.

Aquatic

No aquatic habitat, shallow channel that holds no standing water.

Plate 32 looking downstream towards North Para River

20

Tributary 17 – Green Gully	
 Plate 33 Planted and regenerated non-indigenous trees and shrubs in remnant of quarry at western end	**Stream Order 1** Minor low gradient, drainage line that dissipates and goes underground in the centre of the commercial section of urban Gawler. All on private land. Western end is a remnant quarry. **Riparian** Historically extensively cleared. All planted trees at western end, with no remnant vegetation. Eastern end planted with numerous garden/non-indigenous trees and shrubs including *Eucalyptus* spp., *Cupressus* sp., *Acacia* spp., *Agonis flexuosa*. Occasional remnant *E. porosa.* High levels of human disturbance throughout. Understorey dominated by exotic invasive grass and herb species. Very low habitat value for native fauna. **Aquatic** No aquatic habitat, shallow channel that holds no standing water.
 Plate 34 eastern upstream end mostly planted *Eucalyptus* spp. over exotic grasses	
Additional information on flora from AS: 2 properties between Duffield St and Gozzard/East Tce surveyed in 2012. 35 native species recorded (excluding planted species).	

21

Tributary 18 – west of Lundie Crs	
 Plate 35 Planted *Eucalyptus* spp. and Acacia spp. over mown grass at upper end	**Stream Order 1** Minor low gradient, drainage line flows into main channel of South Para River on south-eastern fringe of Gawler township. Part of Dead Man's Pass Reserve. **Riparian** Historically cleared. All planted trees and no remnant vegetation at upper end. Some *Eucalyptus camaldulensis* at lower end near river channel. High levels of human disturbance. Understorey dominated by exotic invasive species. Kikuyu grass provides main stabilisation of channel against soil erosion. Very low habitat value for native fauna. **Aquatic** Catchment mainly urban stormwater. No aquatic habitat, shallow channel that holds no standing water.
 Plate 36 lower part heavily infested with exotic grasses and Olives	

Tributary 19 – east of Lundie Crs	
 Plate 37 looking downstream to Olives over exotic grasses and herbs	**Stream Order 1** Minor low gradient, drainage line flows into main channel of South Para River on south-eastern fringe of Gawler township. **Riparian** Historically cleared. All planted or self-sown Olives, with no remnant vegetation. High levels of human disturbance. Understorey dominated by exotic invasive grasses and herbs. Very low habitat value for native fauna. **Aquatic** No aquatic habitat, shallow channel that holds no standing water.

3.0 Soil Erosion Risk

This assessment forms part of a high level assessment looking at water quality, habitat assessment and other factors to help define limitations on future land use in the Gawler area.

3.1 Methods

Digital data from currently available mapping has been used to provide geographical output to assist with the interpretation of land factors that affect the potential for soil erosion, refer Figure 2. It is based on the methods described and used in the soil landscape analysis and mapping described comprehensively in Hall *et al*. (2009). The "Soil Erosion Risk" modeled for this project has been derived from two of the basic determinants of soil erosion due to water flow, the slope of the land, and the inherent erodibility of the soil.

3.2 Inherent Water Erosion Potential

Soil landscape mapping at a scale of 1:50,000 was carried out by a team of soil scientists over a period of many years in the agricultural areas of South Australia. This mapping process and the soil descriptions are summarised in Hall *et al.* (2009). A measure of the inherent water erosion potential was assigned to all these described soils, and their spatial distribution mapped as "Soil Landscape Units" within a broader framework of "Land Systems". The soil landscape units are shown on Figure 3.

This water erosion potential is soil specific, derived from physical and chemical properties of a soil type, and independent of other factors such as vegetation cover and climate.

The Inherent Water Erosion Potential used in the modelling for this project was derived from the dominant water erosion potential ratings (E1 to E7) for the Soil Landscape Units as described in Maschmedt (2002), and included as Appendix 2

3.3 Slope

Slope analysis was based on the currently available 5 m contour digital terrain model.

Data were processed by interpolating contours to provide 1 m X 1 m cells with a slope in degrees. These cells were amalgamated into seven slope classes. Slope classes were chosen with reference to Table 45 of Maschmedt (2002).

The slope map was then intersected with the soil landscape map, and the appropriate risk value assigned as set out in the matrix below.

Soil Erosion Risk Matrix

Slope class Inherent Water Erosion Potential	< 2°	2° – 4°	4° – 7°	7° – 10°	10° – 15°	15° – 45°	> 45°
1 (E1andE2)	Very Low	Very Low	Low	Low	Moderate	Moderate	Moderate
2 (E3)	Very Low	Low	Low	Moderate	Moderate	Moderate	High
3 (E4)	Low	Low	Moderate	Moderate	Moderate	High	High
4 (E5)	Low	Moderate	Moderate	Moderate	High	High	Very High
5 (E6 and E7)	Moderate	Moderate	Moderate	High	High	Very High	Very High

Using the matrix classification, the erosion risk potential is shown on Figure 4, which actually covers all watercourses within the study area, not those specifically defined. These are shown separately on Figure 5. This digital coverage is able to be overlain by other mapped variables relevant to the planning objectives.

3.4 Interpretive Notes for Mapping

Spatial resolution is 1 m, and slope classes were derived by amalgamating "single degrees of slope over an area of 1 square metre" into discrete groups and it appears to produce some odd-shaped polygons. These do not represent sharp changes in slope, but a change from one slope class to another.

Soil landscape mapping at a scale of 1 to 50,000 requires some extrapolation of point data to broader areas based on some assumptions, and what is described in Hall et al (2009) and Maschmedt (2002) are the most dominant characteristics within the mapped soil landscape unit area.

In many cases where the Soil Erosion Risk is mapped as Very High, these areas are steep rocky cliffs on the outside of major bends in the drainage lines. As slope is an important landscape factor that affects other aspects of development or town planning, high soil erosion potential in these areas may be less of a limiting factor than other aspects.

Mapping at this level of detail is intended only to highlight potential hotspots where further consideration or information may be required.

Figure 2: Sample Mapping from GIS

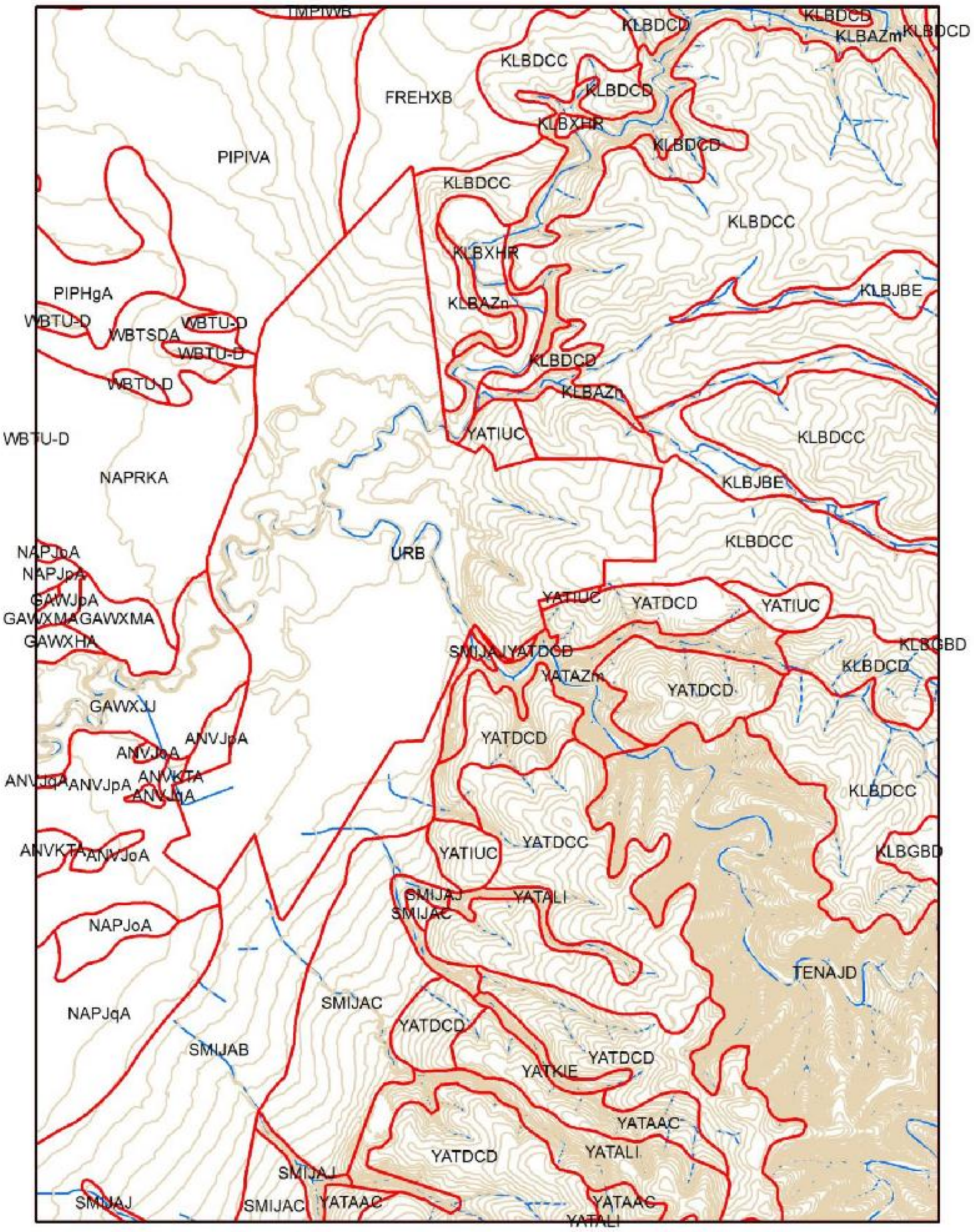
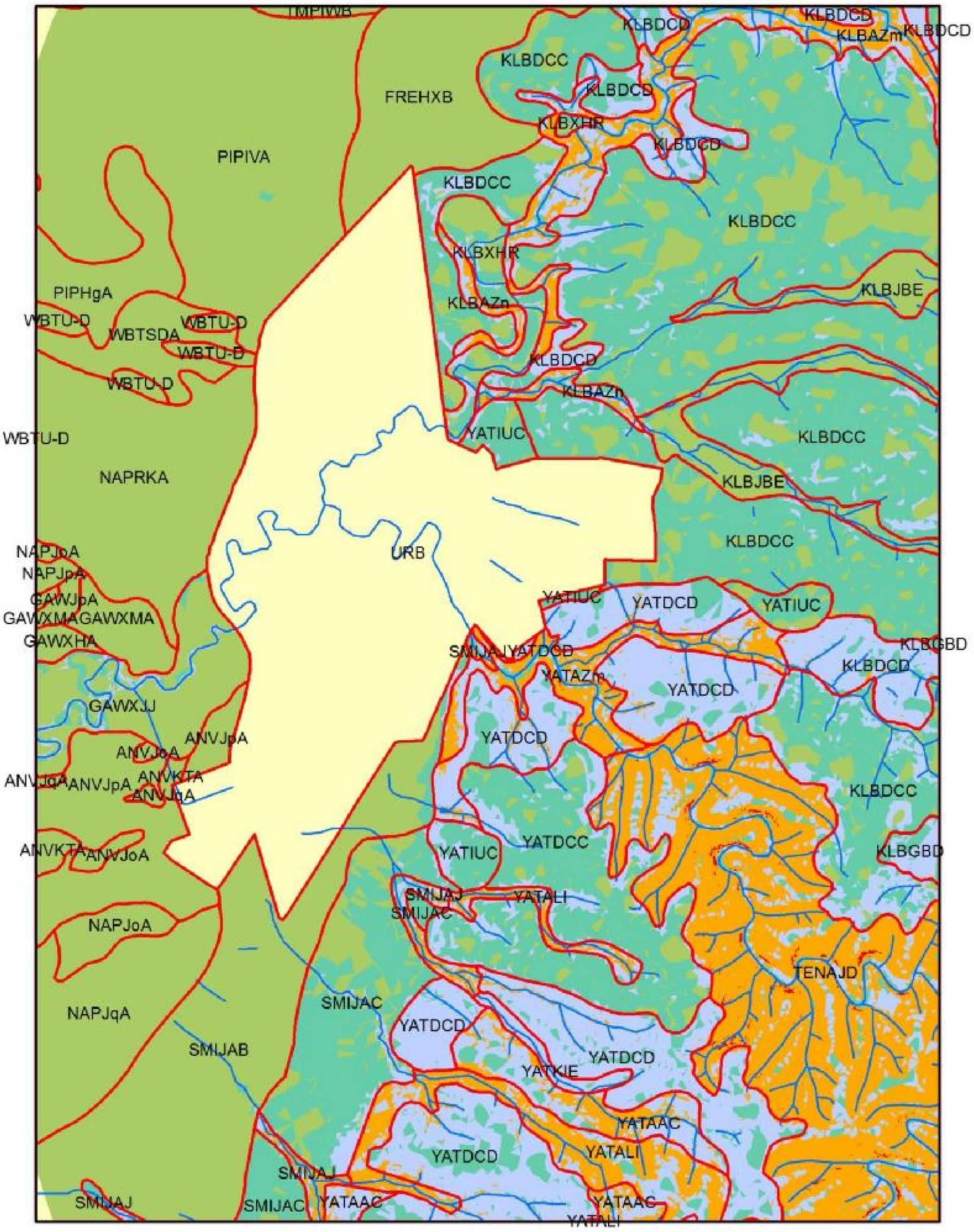
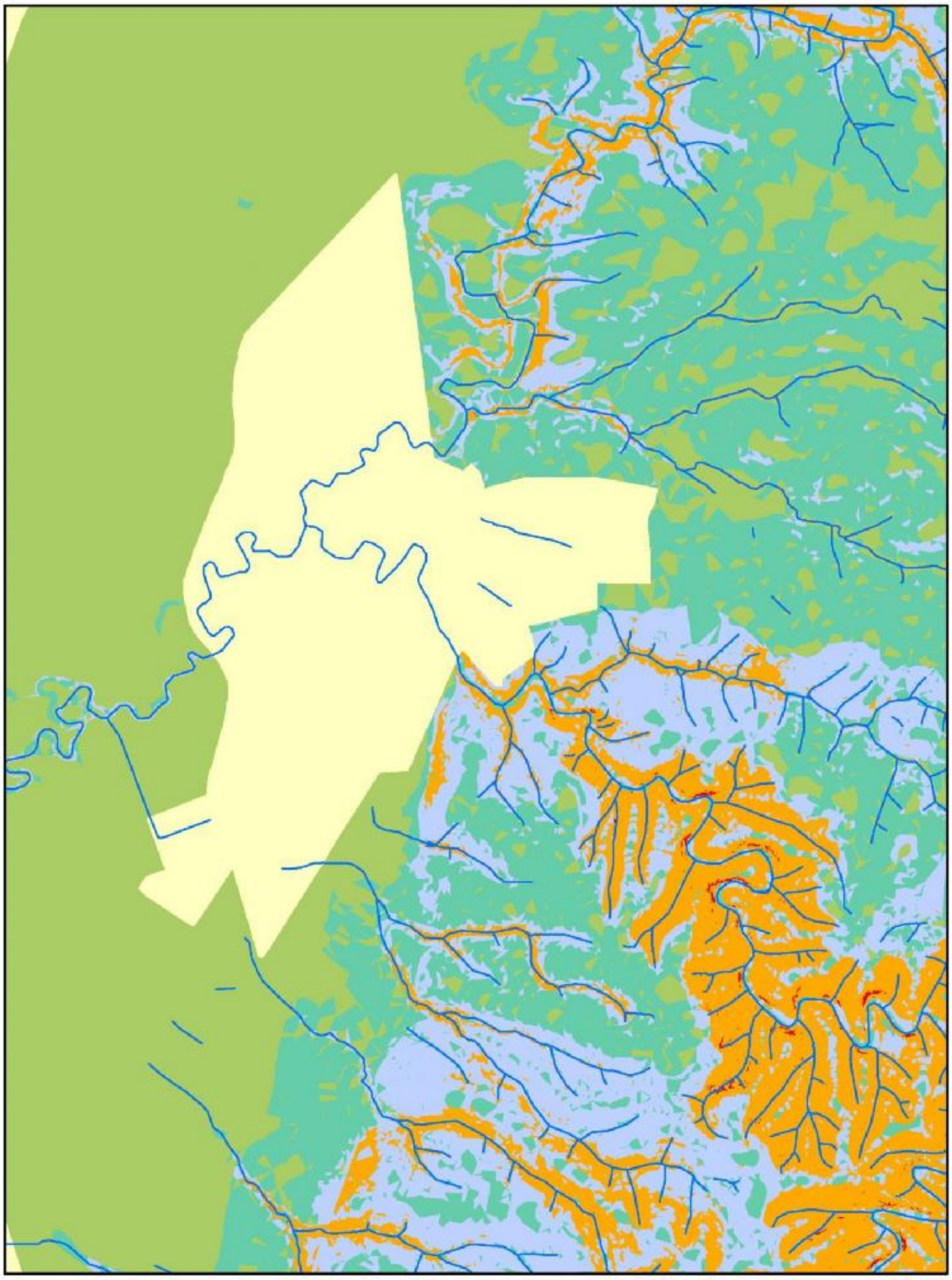


Figure 3: Soil Landscape Units



28

Figure 4: Soil Erosion Risk Classes within Soil Landscape Units



29

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Maschmedt, D J (2002) *Assessing agricultural Land: Agricultural land classification standards used in South Australia's land resource mapping program* - CD-ROM

Land System Reports available on-line

https://data.environment.sa.gov.au/content/land-system-reports/forms/allitems.aspx

DEWNR Soil and Land Program on-line

http://www.environment.sa.gov.au/Science/Information_data/soil-and-land

Key References and data sources for Threatened Species

Atlas of Living Australia – online database http://www.ala.org.au/

Department of the Environment Species Profile and Threats Database, Department of the Environment, Canberra.: http://www.environment.gov.au/sprat.

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eFloraSA – Electronic Flora of South Australia http://www.flora.sa.gov.au/census.shtml

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Bates, R. (2011) South Australian Native Orchids CD, Native Orchid Society of South Australia: Adelaide.

Numerous Recovery Plans for a range of threatened species from various sources

Appendix 1 Threatened Species and migratory birds listed as potentially occurring in the Gawler area

Table 1 Threatened Species listed as potentially occurring in or near the Gawler area

Fauna Type	Name	Conservation status* SA	EPBC	Habitat type	Noted	Comments
Bird	*Botaurus poiciloptilus* Australasian Bittern	**V**	**E**	wetlands	N	In Australia, the species occurs from south–east Queensland to south–east South Australia, Tasmania and in the south–west of Western Australia. The Australasian Bittern's preferred habitat is wetlands with tall dense vegetation. No habitat occurs in or near the surveyed area. Species very unlikely to be present.
Bird	*Leipoa ocellata* Malleefowl	**V**	**V**	unburnt mallee with deep litter	N	Malleefowl are found in semi-arid to arid shrublands, and low woodlands dominated by mallee and/or acacia. Generally they are only able to nest in long unburnt areas where leaf litter has built up. Very unlikely to occur
Bird	*Rostratula australis* Australian Painted Snipe	**-**	**V**	shallow inland wetlands	N	The Australian Painted Snipe is infrequently and irregularly recorded from throughout much of Australia, excluding Tasmania. The Australian Painted Snipe generally inhabits shallow terrestrial freshwater (occasionally brackish) wetlands, including temporary and permanent lakes, swamps and claypans. Typical sites include those with rank emergent tussocks of grass, sedges, rushes or reeds, or samphire; often with scattered clumps of lignum or canegrass or sometimes tea-tree, particularly shallow wetlands with areas of bare wet mud and both upper and canopy cover nearby. No suitable habitat occurs in or near the surveyed area.
Mammal	*Isoodon obesulus obesulus* Southern Brown Bandicoot	**V**	**E**	woodland with dense ground layer understorey	N	Since European settlement, the Southern Brown Bandicoot (eastern) has been recorded from four separate regions of South Australia, one being the Mount Lofty Ranges. This species is quite timid and susceptible to predation from foxes, dogs and cats. Very unlikely to occur
Reptile	*Aprasia pseudopulchella* Flinders Ranges Worm-lizard	**-**	**V**	fissured or loose rocks, cracking clay, deep litter	N	Found mainly north of the surveyed area. Closest records are from Para Wirra Conservation Park, 15 km southeast of the surveyed area in 1993, 1994. Habitat requirements are very variable, and it can be found in quite degraded areas, though preference is for moist places where protection is available, for example, under fallen timber, loose rocks or deep leaf litter. Very few areas of fissured rocks, cracking clay or deep litter are available in the surveyed area (Tributaries 7, 8) to provide protection. Proximity to a major urban area (<2km) where predatory domestic animals roam would make survival difficult. Unlikely to occur.

SA = South Australian National Parks & Wildlife Act 1972; EPBC = Commonwealth Environmental Protection & Biodiversity Conservation Act, 1999 **U** = Uncommon; **R** = Rare; **V** = Vulnerable; **E** = Endangered; **CE** = Critically Endangered

33

Table 2 Migratory Species Listed as potentially occurring in the Gawler area

Species	EPBC Status	NPWSA Status	Comments
BIRDS			
Haliaeetus leucogaster White-bellied Sea-Eagle	**Mi, Ma**	**E**	The species occurs along coastlines throughout Australia and it can occur inland and found near the major wetlands, including along the River Murray. It requires large areas of habitat and including open water characteristic of the larger rivers, lakes, swamps. Very unlikely to occur in the Gawler area.
Apus pacificus Fork-tailed Swift	**Mi, Ma**	**-**	In South Australia the Fork-tailed Swift is widespread from the Victorian border west to the Spencer Gulf. Almost exclusively an aerial species and summer visitor (October-April). Species has very large foraging range
Ardea ibis Cattle Egret	**Mi, Ma**	**R**	In Australia the principal breeding sites are the central east coast from about Newcastle to Bundaberg. In South Australia breeding has been recorded around Lakes Albert-Alexandrina. No breeding sites known to occur in vicinity of study area. May forage in coastal areas, tidal flats and salt fields. Very unlikely to occur in the Gawler area.
Ardea alba White Egret	**Mi, Ma**	**-**	In Australia, the largest breeding colonies, and greatest concentrations of breeding colonies, are located in near-coastal regions of the Northern Territory. Minor breeding sites are widely scattered across the species' distribution and include sites in western Cape York Peninsula, the central coast of Queensland, north and north-eastern NSW, south-eastern South Australia. No breeding sites known to occur in vicinity of study area. The White Egret has been reported feeding in a wide range of wetland habitats (for example inland and coastal, freshwater and saline, permanent and ephemeral, open and vegetated, large and small, natural and artificial) including swamps and marshes; margins of rivers and lakes; damp or flooded grasslands, pastures or agricultural lands. Very unlikely to occur in the Gawler area.
Gallinago hardwickii Japanese Snipe	**Mi, Ma**	**R**	Breeding in Japan and adjacent parts of Siberia this species forages in freshwater wetlands on inland, upland and coastal plains, preferring soft moist ground or shallow flooded areas. No Australian sites have been identified as internationally important. Very unlikely to occur in the Gawler area.
Hirundapus caudacutus White-throated Needletail	**Mi**	**-**	A visitor to South Australia from South-east Asia, mostly from October to April. It is almost exclusively aerial when present in Australia. The White-throated Needletail is widespread in eastern and south-eastern Australia. In eastern Australia, it is recorded in all coastal regions of Queensland and NSW, extending inland to the western slopes of the Great Divide and occasionally onto the adjacent inland plains. Further south on the mainland, it is widespread in Victoria, though more so on and south of the Great Divide, and there are few records in western Victoria outside the Grampians and the South West. The species occurs in adjacent areas of south-eastern South Australia, where it extends west to the Mount Lofty Ranges and Yorke Peninsula. Species has very large foraging range.

Species	EPBC Status	NPWSA Status	Comments
BIRDS			
Merops ornatus Rainbow Bee-eater	Mi	-	The Rainbow Bee-eater occurs mainly in open forests and woodlands, shrublands, and in various cleared or semi-cleared habitats, including farmland and areas of human habitation. It also occurs in inland and coastal sand dune systems, and in mangroves in northern Australia, and has been recorded in various other habitat types including heathland, sedgeland, vine forest and vine thicket, and on beaches. Southern populations spend non-breeding, winter season in the North of Australia. The Rainbow Bee-eater is currently considered to be a low priority for management. The population size and population trends have not been quantified, but the population size is assumed to be reasonably large, and there is little documented evidence of population declines.

Table 3 Threatened Plant Species Listed as potentially occurring in the Gawler area

Species	Conservation status*		Comments
	SA	EPBC	
Caladenia (Arachnorchis) argocalla White-beauty Spider Orchid	E	E	The White-beauty Spider-orchid is endemic to the Mount Lofty Ranges Region of South Australia (Robertson & Bickerton 2000). Historically it has been recorded in and around the Barossa Valley, on the Fleurieu Peninsula, in the hills just south of Adelaide, east of Beevor Estate Hill and north near Clare. The species' former range, based on herbarium collections, was approximately 200 km from north to south. It no longer occurs south of Adelaide, where it has not been recorded since 1918, and is assumed to be extinct over the southern half of its former range. The present north-south range of the White-beauty Spider-orchid is approximately 130 km. There is a high probability that the species' range will continue to decline due to the very small size of two populations which are now at the southern limit of the species. All known populations of more than 10 plants occur within an area of 10 km² and the area of occupancy, as of the year 2000, was less than 5 ha. Closest records are from Sandy Creek and Cockatoo Valley, 10-15 km east of the surveyed area. Species very unlikely to occur.
Cdenia (Arachnorchis) behrii Pink-lipped Spider Orchid	E	E	In 1999, the Pink-lipped spider-orchid distribution was known to be limited to two small disjunct areas at least 25 km apart; approximately 60 km² in the Kersbrook/Williamstown region, and approximately 35 km² in the Belair/Clarendon region, giving a total estimated extent of occurrence of 95 km². It is generally found in quartzite-derived soils on steep south facing slopes, but also on ridge tops and occasionally near creek beds, often growing alongside bushwalking paths, vehicle tracks or roads due to the openness of these locations. Closest known population is in Para Wirra Conservation Park, 10 km southeast of the surveyed area. The species is currently known to be confined to the higher parts of the Mount Lofty Ranges. This species is very sensitive to grazing by native and introduced vertebrates, and does not persist in weed infested areas. Given the level of human and weed influences , this species is very unlikely to occur.

Species	Conservation status*		Comments
	SA	EPBC	
Caladenia (Arachnorchis) gladiolata Bayonet Spider-orchid	E	E	*Caladenia gladiolata* is endemic to South Australia. In 2006 the species was known from four sub populations in two disjunct localities in the Flinders Ranges and Southern Lofty herbarium regions. Known habitat is under *Eucalyptus leucoxylon* woodland on moderate to steep slopes in sandy loam soils with scattered shale and quartzite. Closest known populations are more than 60 km away. Species very unlikely to occur.
Caladenia (Arachnorchis) macroclavia *Large-club Spider-orchid*	E	E	This is part of the *Arachnorchis dilatata* complex and previously included under that name. Distribution is unsure in South Australia. It occurs in the South East, Murraylands, Northern Lofty region and Flinders Ranges, perhaps on Kangaroo Island. Habitat is dry woodland, low scrub and about rock outcrops in a variety of soil types. The remaining populations are threatened by weed invasions, browsing by introduced and native herbivores and human interference. Given the level of human and weed influences in the surveyed area, this species is unlikely to occur. Closest known population is near Snowtown 70 km from the surveyed area. Species very unlikely to occur .
Caladenia (Arachnorchis) rigida Stiff White Spider Orchid	E	E	The White Spider-orchid is endemic to the southern Mt. Lofty Ranges in South Australia. Closest known population is in Para Wirra Conservation Park, 10 km southeast of the surveyed area. Its distribution was known to extend from Macclesfield, north to Williamstown in the early 1990s. Historically *Caladenia rigida* was known to occur over 1,153 km². At least 18 sub-populations of *C. rigida* have become extinct in the last 50-100 years, and the extent of occurrence has reduced by at least 60%. The main cause of this decline is thought to be habitat loss and fragmentation. Current main threats are from herbivory, weed invasion and lack of recruitment. Given the level of human and weed influences, this species is very unlikely to occur.
Caladenia (Arachnorchis) tensa Greencomb Spider Orchid	-	E	This is part of the *Arachnorchis dilatata* complex and previously included under that name. Distribution is unsure in South Australia. It is probably not on Eyre Peninsula but certainly in the South East, Murraylands, Northern Lofty region and Flinders Ranges, perhaps on Kangaroo Island. Habitat is dry woodland, low scrub and about rock outcrops in a variety of soil types. The remaining populations are threatened by weed invasions, browsing by introduced and native herbivores and human interference. Given the level of human and weed influences in the surveyed area, occurrence is unlikely.
Caladenia (Arachnorchis) woolcockiorum Woolcock's Spider-orchid	E	V	*Caladenia woolcockiorum* is endemic to South Australia. In 2006 the species was known only from nine sub-populations within Mount Remarkable National Park, 200 km north of the surveyed area. Species very unlikely to occur.
Olearia pannosa subsp. pannosa Silver Daisy-bush	V	V	Distributed in South Australia, Victoria and New South Wales. In South Australia populations are scattered in various regions and within the South Australian Murray Darling Basin populations are known to occur between Mannum, Goolwa, Murray Bridge and Strathalbyn, and near Keith in the Upper South-east. Recent survey work indicates that there are approximately 1100 individual plants remaining in the South Australian Murray Darling Basin. Occurs in a variety of mallee and woodland communities with common native understorey plants including *Acacia*, *Melaleuca*, chenopod shrubs, sedges and grasses. Found in areas with flat, sandy terrain, and woodland or mallee areas with rocky soils. Closest record is from Para Wirra Conservation Park, 10 km south east of the surveyed area. Species very unlikely to occur.
Prasophyllum pallidum Pale Leek-orchid	R	V	Pale Leek-orchid is known singly or in groups in well-grassed open forests with average annual rainfall exceeding 750 mm from the Flinders Ranges to the Northern and Southern Lofty regions of South Australia. Closest records are 7-10 km from the surveyed area. Unlikely to occur in surveyed area, due to dense exotic grass understorey and suboptimal rainfall.

Species	Conservation status*		Comments
	SA	EPBC	
Prasophyllum pruinosum Plum Leek Orchid	**V**	**E**	Endemic to the Adelaide Hills and Barossa region as far north as Rowland Flat, once common on the Adelaide Plains but extinct there now; it has suffered a rapid decline throughout its limited range in the last 50 years. Occurs in open woodland and grassy forest, in the open or in the shelter of broom-like shrubbery growing in fertile loams. Closest records are 5-10 km east of Gawler.
Pterostylis arenicola Sandhill Greenhood	**V**	**V**	The Sandhill Greenhood is endemic to South Australia and is known from Tailem Bend, Grange (suburban Adelaide), Potters Scrub in Coorong National Park, and Poltalloch and other locations on the Narrung Peninsula. In 1990, the species was considered to be restricted to less than 1% of its original distribution, however more populations have since been found. The population is severely fragmented, and known to exist at no more than 10 locations. Closest records are near Strathalbyn, 60 km south of the surveyed area. Species very unlikely to occur in the surveyed area.
Thelymitra cyanapicata Blue Top Sun-orchid	**E**	**CE**	The Dark-tipped Sun-orchid occurs at one location on the Fleurieu Peninsula near Kuitpo in low-lying seepages, creeks and swamps with wet sandy soils. Very unlikely to occur.
*SA = South Australia; **U** = Uncommon; **R** = Rare; **V** = Vulnerable; **E** = Endangered; **CE** = Critically Endangered Note - if species is listed on the Commonwealth EPBC Act, 1999, then that Act will apply			

Appendix 2

Land System reports Maschmedt, D J (2002) – Kalbeeba, Yattalunga, Smithfield, Tenafeate.

Pages 79-81 from Maschmedt (2002).

ESRI GIS Project – Gawler_92.mxd in ArcGIS version 9.2 format

YAT Yattalunga Land System

West facing slopes of the Mount Lofty Ranges between Gawler and Little Para Reservoir

Area: 57.6 km^2

Annual rainfall: 475 - 600 mm average

Geology: The landscape is underlain predominantly by siltstones, slates and fine sandstones, variably capped by fine carbonates. In places, the carbonates are indurated to moderately cemented rubbly or sheet calcrete. On gentle upper slopes, the rocks have deeply weathered in situ, forming heavy clays from which distinctive soils are formed. Scattered throughout the basement rocks are strata of coarser sandstones and quartzites, usually marked by rockier land surfaces. Locally derived silty, sandy and light clayey sediments have accumulated in minor drainage depressions. There are isolated remnants of Tertiary sediments in the north. These are capped by calcareous rubble. Small exposures of relic Tertiary sands on the eastern margin are free of carbonate.

Topography: The landscape is essentially a west facing slope, extensively dissected by watercourses flowing to the plains. With the exception of the South Para River which cuts through the northern part of the land system, drainage originates from within the land system. Short watercourses have cut narrow valleys up to 80 m deep through the rocky substrate. Slopes are highly variable, but generally are less than 30%. In the south east are two more or less flat topped crests, which are the relatively intact remnants of an old land surface.

Elevation: 70 m in the west to 298 m in the east

Relief: Local relief is typically 50 - 100 m

Soils: Most of the soils are moderately deep to shallow over basement rock. Typically they have hard loamy surfaces overlying either weathering rock, or more commonly a red friable clay loamy to clayey subsoil. Some are calcareous throughout. On rising ground there are limited areas of deep clay loamy to clayey gradational soils or black cracking clays on highly weathered rocks. On minor lower slopes and creek flats, deep red loam over clay loam to clay soils predominate, with small areas of deep sandy loams. There are minor rubbly calcareous loams over Tertiary sandstones.

Main soils:

Soils formed on calcified basement rock
D1a Shallow loam over red clay
L1 Shallow stony loam
C2 Shallow gradational red loam

Minor soils:

Soils formed on calcified / calcreted basement rock
B6 Shallow loam over red clay on calcrete
A2 Shallow calcareous loam
B2 Shallow calcareous loam on calcrete
D1b Shallow sandy loam over red sandy clay
C5 Shallow dark clay loam
Deep soils formed on highly weathered rocks
A6 Gradational calcareous clay loam
C3 Gradational friable red clay loam
E1 Black cracking clay

Soils formed on calcreted Tertiary sandstones
A4 Deep (rubbly) calcareous loam
Soils formed in alluvium
C1 Gradational red sandy loam
D2 Loam over red clay
M1 Deep sandy loam

Main features: The Yattalunga Land System is a west facing slope, extensively dissected by watercourses flowing to the plains. There is a regular pattern of moderate to moderately steep slopes and narrow drainage depressions. The soils are characteristically shallow to moderately deep, with loamy surfaces either grading directly to weathering rock, or underlain by red more clayey subsoils. Often there is a soft to hard carbonate layer between the soil and the rock. The soils are naturally fertile and well drained, but variable depth limits productivity of dryland crops and pastures. Only 15% of the area is fully arable, but about 95% is suitable for perennial crops. Viticulture in particular has potential where water is available, although westerly exposure may be a limitation.

Soil Landscape Unit summary: 15 Soil Landscape Units (SLUs) mapped in the Yattalunga Land System

SLU	% of area	Main features #
AAC AAD AAI	12.5 0.3 15.2	Moderately steep to steep slopes underlain by siltstones, slates and fine sandstones. Slopes are 18-50% and relief is up to 80 m. There is up to 10% surface stone and rock outcrop. Watercourses are well defined in narrow drainage depressions. Soils are generally loamy and shallow over rock, but many have more clayey subsoils. **AAC** Moderate slopes of 18-30% up to 50 m high. **AAD** Steep slopes of 30-50% up to 50 m high. **AAI** Moderate slopes of 18-30% up to 80 m high, with some eroded watercourses. Most soils are loamy and shallow over calcified siltstone, or siltstone mantled by soft to semi-hard carbonate. Many are calcareous. Main soils: Shallow stony loam - **L1** (E) } all formed on Shallow loam over red clay - **D1a** (C) } weathering rock Shallow calcareous loam - **A2** (L) } Shallow gradational red loam - **C2** (L) } Shallow loam over red clay on calcrete - **B6** (M) } Shallow dark clay loam - **C5** (M) } These slopes are too steep and rocky, and the soils too shallow for cropping, although they are inherently fertile. They are used for rough grazing, but have potential for viticulture where water is available and sites are protected from westerly exposure.
ALD ALI	2.9 7.2	Moderately inclined to steep rocky hillslopes formed on calcified sandstones and siltstones. Slopes range from 15% to 50%, and are up to 60 metres high. This land includes those areas where the basement rocks are mainly sandstones. These occur as rocky reefs in a landscape of generally finer grained rocks. **ALD** Steep rocky hillslopes with relief to 50 m, slopes of 30-50% and up to 20% stone and rock outcrop. **ALI** Moderately inclined hillslopes with relief to 60 m, slopes of 15-30%, some eroded watercourses, and up to 10% stone and rock outcrop. All soils are shallow to moderately shallow over sandstone or siltstone mantled by carbonates. These occur as fine deposits in rock fissures through to semi-hard calcrete. Sandy to loamy surface soils over red brown clays are common, together with shallow loamy sands to loams which may be either calcareous or non calcareous. Main soils: Shallow stony loam - **L1** (E) } all formed on Shallow sandy loam over red sandy clay - **D1b** (C) } weathering rock Shallow loam over red clay - **D1a** (L) } Shallow calcareous loam - **A2** (M) } Shallow calcareous loam on calcrete - **B2** (L)

		This land is rough grazing country, with extensive rock and shallow soils, all on moderately steep to steep slopes. Much of the land retains scattered tree cover. There is some potential for viticulture where water is available, exposure is not excessive and land is accessible (**ALI** only).
AZm	1.9	Steep slopes created by the down cutting of the South Para River. Slopes are variable up to 100% and relief is up to 70 m. There is up to 50% surface stone and rocky outcrop. Minor discontinuous flats adjoin the river. Main soils: Shallow stony loam - **L1** (V) } over basement rock on slopes Shallow loam over red clay - **D1a** (L) } Deep sandy loam - **M1** (L) on flats This land is either steep and rocky, or subject to flooding, so has very limited agricultural potential, but high conservation and water resource protection value.
DCC DCD DCI	5.8 27.3 7.7	Undulating rises and rolling low hills formed on calcified siltstones, slates and fine sandstones. Slopes range from 4% to 18%. Rock outcrop is sporadic, but there is up to 10% surface stone. **DCC** Undulating rises with relief to 40 m and slopes of 4-10%. **DCD** Moderate slopes of 10-18%, up to 50 m high. **DCI** Moderate slopes of 10-18%, up to 50 m high with some eroded watercourses. Most soils are moderately deep to shallow over calcified siltstone, or siltstone mantled by soft to semi hard carbonate. Main soils: Shallow loam over red clay - **D1a** (E) } on weathering rock on slopes Shallow gradational red loam - **C2** (C) } Shallow stony loam - **L1** (L) } Shallow loam over red clay on calcrete - **B6** (L) Loam over red clay - **D2** (M) on alluvium on lower slopes and creek flats The soils are fertile and well drained, although often shallow, thereby restricting waterholding capacity. Surface soils set hard, creating workability and emergence problems, and increasing erosion susceptibility. However, the land is potentially productive - **DCC** is suitable for cropping provided that adequate erosion control measures are used, but **DCD** and **DCI** are marginal due to the potential for erosion. The land is suited to horticultural development where water is available and exposure is not excessive.
DFC DFI	5.1 3.8	Undulating to gently rolling rises and low hills to 60 m high formed on calcified siltstones and slates, commonly deeply weathered. Slopes are 3-20%. **DFC** Undulating rises and low hills to 50 m high with slopes of 3-12%. **DFI** Gently rolling low hills to 60 m high with slopes of 12-20% and some eroded watercourses. A wide variety of soils occurs, differences being mainly attributable to parent materials. Common profiles include loams over red brown clays, cracking clays, and calcareous and non-calcareous loams. Main soils: Shallow loam over red clay - **D1a** (C) } on basement rocks Shallow gradational red loam - **C2** (C) } Shallow stony loam - **L1** (L) } Gradational calcareous clay loam - **A6** (L) } on deeply weathered rocks Gradational friable red clay loam - **C3** (L) } Black cracking clay - **E1** (L) } Loam over red clay - **D2** (M) on alluvium on lower slopes The shallower soils on basement rock are similar to those of **DCC/DCD**, but the deeper soils on highly weathered rocks or alluvium are fertile and have high waterholding capacities. Although some have poor surface structure, they are potentially highly productive. Boron toxicity may be a problem on the deeper soils.
GBD	0.5	Undulating upper slopes of 2-10% formed on Tertiary sandstones, with reworked sandy sediments in hollows and depositional areas. There is negligible surface stone and there are no defined watercourses. Soils are invariably sandy surfaced, usually with more clayey subsoils, but some deep gritty sands occur on reworked sediments. Main soils: Bleached sand over sandy clay loam - **G2** (E) Sandy loam over poorly structured brown clay - **F2** (C) Thick sand over clay - **G3** (L) Deep loamy sand - **M1** (L) These soils are moderately deep, but highly infertile and prone to acidification and water repellence. Drainage is variable, usually moderately well to well, but some hollows are imperfectly

		drained with seepage areas. The sands are highly erodible, to both wind and water, so cropping is not generally sustainable. Most of the land is suitable for perennial horticulture and viticulture, although drainage management is required in some parts.
IUC	3.3	Undulating crests and upper slopes of 4% to 10% and relief up to 50 metres formed on calcreted Tertiary clayey sands, sandy clays, sandstones and limestones. Minor watercourses drain the slopes. Main soil: Deep (rubbly) calcareous loam - **A4** (D) These are moderately deep and well drained, but alkaline due to the high carbonate content. This condition affects the availability of some nutrients. With appropriate attention to nutrition, they are productive soils for field crops and viticulture.
KIE	1.9	Drainage depressions, including concave lower slopes and creek flats, formed on alluvium associated with hillslopes of calcified siltstones and slates. Slopes range from 2% on flats to 10% on lower slopes adjacent to surrounding rising ground. Deep sandy or loamy soils with clayey subsoils, together with a range of miscellaneous alluvial soils occur on the floors of the depressions. On lower slopes, shallower soils are more common, formed on siltstone, or siltstone capped by soft to semi-hard carbonate. Main soils: Gradational red sandy loam - **C1** (C) } on flats Deep sandy loam - **M1** (C) } Shallow calcareous loam - **A2** (L) } on rock on lower slopes Shallow gradational red loam - **C2** (L) } Shallow loam over red clay - **D1a** (L) } The soils of the flats are deep, well drained and moderately fertile, but small in area, so development potential is limited. The soils of the lower slopes are moderately shallow (restricted waterholding capacity), but well drained and fertile.
TBZ	4.6	Undulating summit surfaces formed on clays derived from the deep weathering of siltstone and claystone bedrock. Slopes vary from 0% on crests to 10% on margins. Watercourses are very weakly defined. Soils are clayey to clay loamy. Main soils: Black cracking clay - **E1** (E) Gradational friable red clay loam - **C3** (E) These soils are deep and highly fertile, although sometimes alkaline to the surface. Drainage is impeded by the clayey textures, and soils are prone to wetness at times. Boron toxicity may be a problem in places. Productive potential for field crops is high, although exposure may reduce yields. The soils are less favourable for horticulture and viticulture.

PROPORTION codes assigned to soils within Soil Landscape Units (SLU):

(D)	Dominant in extent (>90% of SLU)	(C)	Common in extent (20–30% of SLU)
(V)	Very extensive in extent (60–90% of SLU)	(L)	Limited in extent (10–20% of SLU)
(E)	Extensive in extent (30–60% of SLU)	(M)	Minor in extent (<10% of SLU)

Detailed soil profile descriptions:

Soils formed on calcified basement rock

A2 Shallow calcareous loam on rock (Paralithic, Calcic Calcarosol)
Medium thickness calcareous reddish brown stony loam, overlying a brown highly calcareous stony clay loam, increasingly calcareous and paler coloured with depth. Highly calcareous weathering siltstone or slate occurs at about 50 cm.

C2 Shallow gradational red loam on rock (Hypercalcic, Red Dermosol)
Medium thickness red brown loam to clay loam, grading a red well structured clay loam, grading to massive semi hard carbonate, over weathering siltstone below 50 cm.

D1a Shallow loam over red clay on rock (Hypercalcic, Red Chromosol)
Medium thickness hard setting loam with a paler and stony A2 horizon, overlying a dark reddish brown, well structured clay which is highly calcareous from about 50 cm. Weathering, calcified siltstone or slate occurs within 100 cm.

D1b Shallow sandy loam over red sandy clay on rock (Hypercalcic, Red Chromosol)
Medium thickness hard sandy loam, with a very stony and paler coloured A2 horizon, overlying a red sandy clay to clay which is highly calcareous from about 50 cm. Weathering calcified sandstone occurs within 100 cm.

L1 Shallow stony loam (Calcareous, Paralithic, Leptic Tenosol)
Thick, stony, reddish brown loam, grading to highly calcified weathering siltstone or fine sandstone within 50 cm.

Soils formed on calcreted basement rock

B2 Shallow calcareous loam (Petrocalcic, Calcic Calcarosol)
Medium thickness calcareous reddish brown stony loam, grading to a brown highly calcareous stony clay loam, increasingly calcareous and paler coloured with depth, over a moderately cemented massive to nodular calcrete pan at about 30 cm, with weathering rock at about 60 cm.

B6 Shallow loam over red clay on calcrete (Petrocalcic, Red Chromosol)
Medium thickness hard setting loam with a paler and stony A2 horizon, overlying a dark reddish brown well structured clay with a massive calcrete pan at 55 cm, overlying a highly calcareous clay loam which grades to weathering calcified rock at variable depths averaging 100 cm.

C5 Shallow dark clay loam (Supracalcic, Black Dermosol)
Medium thickness dark crumbly clay loam, overlying a well structured dark reddish brown to black clay loam to light clay. A carbonate pan or semi hard carbonate layer occurs before 50 cm, grading to weathering calcareous siltstone, marble or limestone by 100 cm.

Deep soils formed on highly weathered rocks

A6 Gradational calcareous clay loam (Pedal, Calcic Calcarosol)
Medium thickness reddish brown calcareous loam to clay loam, grading to a well structured reddish brown clay subsoil, becoming more clayey and calcareous with depth. Coarsely structured brown heavy clay continues below 200 cm.

C3 Gradational friable red clay loam (Calcic, Red Dermosol)
Medium thickness dark reddish brown clay loam, overlying a dark reddish brown well structured clay subsoil which is calcareous with depth. Highly calcareous clay continues below 100 cm.

E1 Black cracking clay (Self-Mulching, Black Vertosol)
Medium thickness brown to black well structured light clay, grading to dark brown to black strongly structured heavy clay, calcareous with depth. Coarsely structured brown heavy clay with soft calcareous segregations continues below 200 cm.

Soils formed on calcreted Tertiary sandstones

A4 Deep (rubbly) calcareous loam (Lithocalcic / Hypercalcic Calcarosol)
Medium thickness dark brown calcareous sandy loam to sandy clay loam, overlying a dark brown highly calcareous clay loam with up to 50% carbonate nodules, grading to a pale brown very highly calcareous clay with more than 50% calcrete nodules (Class III C carbonate) from 50 cm. Weak calcrete pans occur sporadically. Highly calcareous sandstone or limestone from 120 cm.

Soils formed on alluvium

C1 Gradational red sandy loam (Calcic, Red Kandosol)
Thick reddish brown sandy loam to fine sandy loam with a pink A2 horizon, overlying a yellowish red weakly structured clay loam to clay, calcareous with depth.

D2 Loam over red clay (Sodic, Calcic, Red Chromosol)
Thick loam with a paler coloured A2 horizon, overlying a dark reddish brown well structured clay, highly calcareous (Class I carbonate) from about 60 cm. The soil grades to medium to fine grained alluvium below 100 cm.

M1 Deep sandy loam (Basic, Regolithic, Brown-Orthic Tenosol)
Thick brown sandy loam to loamy sand, overlying a reddish brown clayey coarse sand to silty sand, grading to variable sandy and gritty alluvial sediments.

Further information: DEWNR Soil and Land Program

TEN Tenafeate Land System

Strongly dissected slopes of the South Para catchment immediately south east of Gawler

Area: 30.1 km^2

Annual rainfall: 475 – 625 mm average

Geology: The land is underlain by siltstones, slates and fine sandstones, and minor quartzites and dolomites. The rocks are variably capped by fine carbonates of aeolian origin, which occur as a veneer of soft segregations in rock fissures and in the lower soil profile. Locally derived alluvium, usually fine grained, occurs in minor drainage depressions. There are minor remnant laterites and Tertiary gravel deposits. These materials, which presumably covered most of the area at some time, have been all but completely eroded away by the down cutting of the streams.

Topography: The landscape is dominated by steep to moderately steep slopes created by the downcutting of the South Para River just prior to its exit from the ranges on to the plains. The main river channel runs more or less through the centre of the System. It is deeply incised between its point of entry on the eastern side of the System, to its exit in the north west corner. Short closely spaced tributaries draining from the edges of the System to the river in the centre have also cut valleys up to 100 m deep. Drainage depressions are narrow, and where mappable (ie more than 100 m wide) are very well defined. There is typically an abrupt boundary between the creek flat and the adjacent slope.

Elevation: 50 m in the north west where the South Para River flows out, to 290 m in the south west.

Relief: Up to 100 m

Soils: Most soils are shallow to moderately deep over basement rock. Loamy surfaces are usual, but subsoils vary. Well structured red clays are common, particularly on lower slopes. These may or may not be calcareous with depth. However soils with weakly developed or no subsoil are more extensive. They are usually very stony. There is a range of deep soils over alluvium on creek flats. Black clay loams are most characteristic.

Main soils:

Acidic soils formed in weathering basement rock

K2a Acidic loam over red clay
K2b Acidic loam over brown and red clay
L1a Shallow stony loam

Soils formed on calcified basement rock

C2 Shallow gradational red loam
D1 Shallow loam over red clay
L1b Shallow stony loam

Minor soils:

Soils formed in alluvium

F1 Sandy loam over brown sandy clay to clay
M1 Deep sandy loam
M2 Deep black clay loam

Main features: The Tenafeate Land System is dominated by steep slopes. Almost 70% of the area is steeper than 30% and as such is inaccessible to conventional agricultural machinery. The majority of the rest of the land is moderately steep and non arable, although accessible. The soils throughout are loamy with subsoils ranging from thick well structured red clays to nothing (ie soils are shallow over parent rock). They are inherently fertile and well drained, although of highly variable depth. This affects waterholding capacity and therefore pasture productivity. Perennial horticulture and viticulture are options on the accessible slopes where water is available.

Soil Landscape Unit summary: 6 Soil Landscape Units (SLUs) mapped in the Tenafeate Land System

SLU	% of area	Main features #
AJC AJD	25.8 68.4	Moderately steep to steep strongly dissected low hills and hills, formed on weakly calcified siltstones, slates and fine sandstones, and minor quartzites and dolomites. Gully slopes are up to 50% (100% in extreme cases), grading to more gently inclined upper slopes and crests (10% to 30% slopes, down to 4% on narrow crests). Maximum relief is 100 metres. Water courses are well defined in narrow drainage depressions. Rock outcrop is sporadic, but extensive in places. There is variable surface stone. **AJC** Moderate slopes and rolling low hills with relief to 80 m and slopes of 20-30%. **AJD** Steep hillslopes with relief to 100 m and slopes of 30-100%. Most soils are shallow to moderately deep over siltstone which may be non-calcified or contain soft carbonate in rock fissures. Common profiles include loams over red brown clays, shallow non-calcareous stony loams, and shallow loams over calcified rock. Main soils: Acidic loam over red or brown clay - **K2a** / **K2b** (E) Shallow stony loam - **L1a** / **L1b** (C) Shallow loam over red clay - **D1** (L) Shallow gradational red loam - **C2** (L) Variation in soil depth is considerable, but otherwise the soils are inherently fertile and well drained. The slopes preclude any cultivated agriculture, but gentler slopes where water is available are suitable for perennial horticulture or viticulture.
DGD	1.8	Moderate slopes of 10-20% and up to 80 m high formed on weakly calcified siltstones, slates and fine sandstones, and minor quartzites and dolomites. There is no rock outcrop and up to 10% surface stone. Most soils are shallow to moderately deep over siltstone which may be non-calcified or contain soft carbonate in rock fissures. Surfaces are mostly loamy. Main soils: Acidic loam over red or brown clay - **K2a** / **K2b** (E) Shallow stony loam - **L1a** / **L1b** (L) Shallow loam over red clay - **D1** (L) Shallow gradational red loam - **C2** (L) These soils are moderately deep to shallow, fertile and well drained. The slopes are semi arable, and cropping is not a viable option in the long term. However the land is suitable for perennial horticulture or viticulture where water is available.
FiZ	0.8	Upper slopes and summit surfaces (flat topped crests) underlain by deeply weathered and lateritized schists. Slopes are variable, up to 15%, with some surface ironstone. Soils are characterized by ironstone gravel. Main soils: Ironstone soil - **J2b** (E) Acidic sandy loam over brown clay on kaolinized rock - **K4b** (E) These soils are deep, but imperfectly drained, infertile and acidic. Productive potential is low.
GBD	0.9	Undulating upper slopes of 2-10% formed on Tertiary sandstones, with reworked sandy sediments in hollows and depositional areas. There is negligible surface stone and there are no defined water courses. Soils are invariably sandy surfaced, usually with more clayey subsoils, but some deep gritty sands occur on reworked sediments. Main soils: Bleached sand over sandy clay loam - **G2** (E) Sandy loam over poorly structured brown clay - **F2** (C) Thick sand over clay - **G3** (L) Deep loamy sand - **M1** (L) These soils are moderately deep, but highly infertile and prone to acidification and water repellence. Drainage is variable, usually moderately well to well, but some hollows are imperfectly drained with seepage areas. The sands are highly erodible, to both wind and water, so cropping is not generally sustainable. Most of the land is suitable for perennial horticulture and viticulture, although drainage management is required in some parts.

LdE	2.3	Creek flats formed on clayey alluvium. Main soils: Deep black clay loam - **M2** (E) Sandy loam over brown sandy clay to clay - **F1** (E) Deep sandy loam - **M1** (L) These soils are deep and fertile, but imperfectly drained. Productive potential is high although useable areas are very limited. Irrigation must be carefully managed to avoid waterlogging. Sporadic salinity should be monitored and measures to control water course erosion are required.

PROPORTION codes assigned to soils within Soil Landscape Units (SLU):

- (D) Dominant in extent (>90% of SLU)
- (V) Very extensive in extent (60–90% of SLU)
- (E) Extensive in extent (30–60% of SLU)
- (C) Common in extent (20–30% of SLU)
- (L) Limited in extent (10–20% of SLU)
- (M) Minor in extent (<10% of SLU)

Detailed soil profile descriptions:

Acidic soils formed on weathering basement rock

K2a Acidic loam over red clay (Eutrophic, Red Kurosol)
Medium thickness reddish loam to clay loam with a gravelly and paler coloured A2 horizon, overlying a red very well structured clay grading to weathering siltstone from about 100 cm, but deeper on lower slopes.

K2b Acidic loam over brown and red clay (Eutrophic, Brown Kurosol)
Thick sandy loam to loam surface soil with a paler coloured and gravelly A2 horizon, overlying a yellowish brown, brown and red well structured clay subsoil grading to weathering siltstone or fine sandstone by 100 cm.

L1a Shallow stony loam (Basic, Paralithic, Leptic Tenosol)
Thick stony loam, forming in weathering siltstone at 50 cm or less.

Soils formed on calcified basement rock

C2 Shallow gradational red loam on rock (Hypercalcic, Red Dermosol)
Medium thickness red brown loam to clay loam, grading a red well structured clay loam, grading to massive semi hard carbonate, over weathering siltstone below 50 cm.

D1 Shallow loam over red clay on rock (Hypercalcic, Red Chromosol)
Medium thickness hard setting loam with a paler and stony A2 horizon, overlying a dark reddish brown well structured clay which is highly calcareous from about 50 cm. Weathering calcified siltstone or slate occurs within 100 cm.

L1b Shallow stony loam (Calcareous, Paralithic, Leptic Tenosol)
Thick stony reddish brown loam, grading to highly calcified weathering siltstone or fine sandstone within 50 cm.

Soils formed in alluvium

F1 Sandy loam over brown sandy clay to clay (Hypocalcic, Brown Chromosol)
Thick loamy sand to sandy clay loam with a strongly bleached A2 horizon, sharply overlying a yellowish brown, grey and red mottled sandy clay to clay grading to medium or fine grained alluvium.

M1 Deep sandy loam (Regolithic, Red-Orthic Tenosol)
Thick brown sandy loam to loamy sand, overlying a reddish brown clayey coarse sand to silty sand, grading to variable sandy and gritty alluvial sediments.

M2 Deep black clay loam (Melanic, Eutrophic, Black Dermosol)
Thick black silt loam to clay loam with strong granular structure, overlying a black to dark brown clay with strong blocky structure, becoming yellow and grey mottled with depth.

Further information: DEWNR Soil and Land Program

SMI Smithfield Land System

Gentle slopes between Elizabeth and Gawler

Area: 21.0 km^2

Annual rainfall: 450 – 525 mm average

Geology: Alluvial clays of the Pooraka Formation, derived from the ranges to the east. The clays are mantled by a veneer of fine grained carbonates of aeolian origin.

Topography: The land comprises a simple outwash fan with very gentle to gentle slopes abutting the Gawler Escarpment. Slopes are 2% to 10%. Well defined watercourses enter the land system from the escarpment, but dissipate as the slope wanes.

Elevation: 150 m on the eastern side to 50 m on the western side

Relief: The land surface has a uniform westward gradient with no internal relief other than a few metres in occasional eroded water courses.

Soils: The soils are red, medium to fine grained, and calcareous with depth. The principal variations between the different soils are the degree of contrast between the surface soils and the clayey subsoil. Some soils are clay loamy to clayey throughout, others have a distinct contrast between a loamy surface and the subsoil, and others have a gradual increase in clay content with depth.

Main soils

D2	Loam over red clay
C3	Gradational red loam
C4/M2	Gradational red clay loam

Main features: The Smithfield Land System comprises gentle slopes with deep, inherently fertile and moderately well drained soils. Apart from minor limitations caused by hard setting surfaces and some poorly structured subsoils, they have high productive potential, especially for dryland crops. Drainage problems are likely in some soils under irrigation.

Soil Landscape Unit summary: 3 Soil Landscape Units (SLUs) mapped in the Smithfield Land System

SLU	% of area	Main features #
JAB JAC JAJ	37.5 58.8 3.7	Very gently to gently inclined outwash fans. **JAB** Very gently inclined fans with slopes of 2-4%. **JAC** Gently inclined fans with slopes of 4-10%. **JAJ** Eroded watercourses. The soils are deep and loamy. Main soils: Loam over red clay - **D2** (E) Gradational red loam - **C3** (E) Gradational red clay loam - **C4/M2** (E) These soils are deep and inherently fertile. They are neutral to slightly alkaline at the surface, and alkaline to strongly alkaline with depth. They are moderately well to well drained. Hard setting surfaces and coarsely structured subsoils (C4/M2 soils) are somewhat limiting in terms of infiltration rates, workability, seedling emergence and optimum root growth, but overall productive potential is high. The more clayey types (especially C4) have potential drainage problems under irrigation.

PROPORTION codes assigned to soils within Soil Landscape Units (SLU):

(D) Dominant in extent (>90% of SLU)
(V) Very extensive in extent (60–90% of SLU)
(E) Extensive in extent (30–60% of SLU)
(C) Common in extent (20–30% of SLU)
(L) Limited in extent (10–20% of SLU)
(M) Minor in extent (<10% of SLU)

Detailed soil profile descriptions:

D2 Loam over red clay (Sodic, Calcic, Red Chromosol)
Thick hard loamy surface soil with a paler coloured A2 horizon, overlying a dark reddish brown well structured clay subsoil, highly calcareous (Class I carbonate) from about 60 cm. The soil grades to medium to fine grained alluvium below 100 cm.

C3 Gradational red loam (Sodic, Calcic, Red Dermosol)
Medium thickness reddish brown loam, overlying a dark reddish brown clay loam with granular structure, grading to a red light clay. There is abundant soft Class I carbonate from 70 cm.

C4/M2 Gradational red clay loam (Vertic, Calcic / Eutrophic, Red Dermosol)
Thick reddish brown clay loam to light clay with granular structure, overlying a red clay with strong blocky structure and variable soft carbonate segregations (Class I carbonate) from 65 cm.

Further information: DEWNR Soil and Land Program

KLB Kalbeeba Land System

Undulating rises in the Sandy Creek - Concordia - Sheoak Log area

Area: 74.8 km²

Annual rainfall: 435 – 570 mm average

Geology: The land is underlain by basement siltstones, slates and fine sandstones, so deeply weathered in places that there is no rock-like material within the upper 200 cm. The rocks and deep weathering materials are commonly capped by a veneer of carbonate of aeolian origin, which has been leached into the upper layers of the rock. In places it has become indurated to calcrete. There are localized deposits of outwash clays, silts and sands on lower slopes and drainage depressions. Remnant Tertiary sediments occur in the south.

Topography: The landscape is typically undulating with slopes of 2 - 12%. However, the North Para River flowing across the System from east to west, together with its short tributaries, has gouged a gully up to 50 m deep, with moderately steep to steep rocky slopes. There are minor moderately steep rocky slopes elsewhere, due to localized dissection. Outwash fans and creek flats make up about 15% of the land area, undulating to gently rolling rises about 75%, and moderately steep to steep rocky slopes about 10%.

Elevation: 50 m in the west where the North Para River flows out on to the plains, to 200 m in the south east.

Relief: Up to 50 m

Soils: Most of the soils are moderately deep to shallow over basement rock. Typically they have hard loamy surfaces overlying either weathering rock, or more commonly a red friable clay loamy to clayey subsoil. Some are calcareous throughout. On rising ground there are limited areas of deep clay loamy to clayey gradational soils on highly weathered rocks. On minor lower slopes and creek flats, deep red loam over clay soils predominate, with small areas of deep sandy loams and heavy dark soils. Sandier soils occur on Tertiary remnants.

Main soils
Soils formed on calcified basement rock
D1 Shallow loam over red clay
C2 Shallow gradational red loam
L1 Shallow stony loam

Minor soils
Soils formed on strongly calcified basement rock
A2 Shallow calcareous loam
B6 Shallow loam over red clay on calcreted rock
Deep soils formed on highly weathered rock
A6 Gradational calcareous clay loam
C3 Gradational friable red clay loam
E1 Black cracking clay
Soils formed on alluvium

C1 Gradational red sandy loam
D2 Loam over red clay
D3a Sandy loam over poorly structured red clay
M1 Deep sandy loam

Soils formed on Tertiary sediments

D3b Gravelly sandy loam over poorly structured red clay
G2 Bleached sand over sandy clay loam
H3 Moderately deep sand

Main features: The Kalbeeba Land System is characterized by undulating to gently rolling rises and low hills. The soils are moderately deep to shallow over basement rock, and usually have loamy surfaces and red more clayey subsoils. They are inherently fertile and well drained, with high production potential. They are especially suited to viticulture where water is available. Mixed with these soils are deeper clay loamy soils over highly weathered materials. These soils are fertile with very high water holding capacities, but may suffer from waterlogging and high boron levels in places. Deep loamy texture contrast soils on creek flats and outwash fans are potentially productive but often poorly structured with hard setting surfaces and dispersive clayey subsoils. The steep rocky slopes, mainly associated with the North Para River, are non arable with mainly shallow stony loams.

Soil Landscape Unit summary: 13 Soil Landscape Units (SLUs) mapped in the Kalbeeba Land System:

SLU	% of area	Main features #
AAC	2.1	Moderately steep rocky slopes underlain by siltstones, slates and fine sandstones. Slopes are 18-30% with relief of 20-50 m. There is up to 20% surface stone and rock outcrop. Soils are generally loamy and shallow over rock, but some have more clayey subsoils. Main soils: Shallow stony loam - **L1** (E) Shallow calcareous loam - **A2** (C) Shallow loam over red clay on calcrete - **B6** (L) Shallow gradational red loam - **C2** (L) Shallow loam over red clay - **D1** (M) all on weathering rock These slopes are too steep and rocky, and the soils too shallow for cropping. They are used for rough grazing.
AZm AZn	7.7 0.5	Moderately steep to steep slopes created by the down cutting of the North Para River. Slopes are variable up to 100% and relief is 20-50 m. There is up to 50% surface stone and rocky outcrop. Minor discontinuous flats adjoin the river. **AZm** Slopes are generally not eroded. **AZn** Slopes are commonly eroded. Main soils: Shallow stony loam - **L1** (V) on rocky slopes Shallow loam over red clay - **D1** (L) on slopes Deep sandy loam - **M1** (L) on flats This land is either steep and rocky, or subject to flooding, so has very limited agricultural potential, but high conservation and water resource protection value.
DCC DCD	32.0 13.3	Undulating rises and rolling low hills formed on calcified siltstones, slates and fine sandstones. Slopes range from 4% to 18%. Rock outcrop is sporadic, but there is up to 10% surface stone. **DCC** Undulating rises with relief to 40 m and slopes of 4-10%. **DCD** Moderate slopes of 10-18%, up to 40 m high. Most soils are moderately deep to shallow over calcified siltstone, or siltstone mantled by soft to semi hard carbonate. Main soils: Shallow loam over red clay - **D1** (E) } on slopes Shallow gradational red loam - **C2** (C) } Shallow loam over red clay on calcrete - **B6** (L) }

		Shallow stony loam - **L1** (L) } Deeper loam over red clay - **D2** (L-M) on lower slopes and creek flats Gradational friable red clay loam - **C3** (M) on gently inclined upper slopes The soils are fertile and well drained, although often shallow, thereby restricting water holding capacity. Surface soils set hard, creating workability and emergence problems, and increasing erosion susceptibility. However, the land is potentially productive - DCC is suitable for cropping provided that adequate erosion control measures are used, but DCD is marginal due to the potential for erosion. The land is suited to horticultural development where water is available.
DFC	27.4	Undulating rises and low hills to 50 m high formed on calcified siltstones and slates, commonly deeply weathered. Slopes are 3-10%. A wide variety of soils occurs, differences being mainly attributable to parent materials. Common profiles include loams over red brown clays, cracking clays, and calcareous and non-calcareous loams. Main soils: Shallow loam over red clay - **D1** (C) } on basement rock Shallow gradational red loam - **C2** (C) } Shallow stony loam - **L1** (L) } Gradational calcareous clay loam - **A6** (L) } on deeply weathered rocks Gradational friable red clay loam - **C3** (L) } Black cracking clay - **E1** (M) } Loam over red clay - **D2** (M) on alluvium on lower slopes The shallower soils on basement rock are similar to those of DCC. The deeper soils on highly weathered rocks or alluvium are fertile and have high water holding capacities. Although some have poor surface structure, they are potentially highly productive. Boron toxicity may be a problem on the deeper soils.
DHC	2.0	Undulating rises to 40 m high with slopes of 4-10%. There is negligible rock outcrop, but minor surface slate, sandstone, quartz and calcrete. Water courses are moderately well defined in shallow broad drainage depressions. These are occasionally salinized. Main soils: Shallow loam over red clay - **D1** (V) on slopes Loam over red clay - **D2** (C) on lower slopes and drainage depressions These soils are moderately deep to deep, inherently fertile and mostly adequately drained. Poor surface structure and associated erosion potential, together with sporadic lower slope salinity, require appropriate management, but productive potential for both field and horticultural crops is nevertheless high.
GBD	1.6	Undulating to gently rolling slopes of 6-16%, to 30 m high, formed on Tertiary clayey sands, sandy clays and sandstones. Sandy loam to sand over clay soils, with uniform to gradational sands, are characteristic. Main soils: Bleached sand over sandy clay loam - **G2** (E) Gravelly sandy loam over red clay - **D3b** (E) Moderately deep sand - **H3** (L) The soils are variable, with low natural fertility characterizing the sandy soils (G2 and H3), and poor structure / drainage typical of the loamier soils (D3b). The soils are highly erodible to both wind and water, so care is needed during crop establishment. The land is generally suited to perennial horticulture and viticulture, where water is available.
JBB JBE JBJ	4.5 3.6 0.5	Very gently sloping outwash fans and drainage depressions formed on alluvial clays derived from the erosion and deposition of basement rock materials, mantled by fine grained carbonates of aeolian origin. **JBB** Very gently inclined fans with slopes of 2-4%. **JBE** Drainage depressions with well defined and sometimes eroded water courses. **JBJ** Drainage depressions with well defined, eroded water courses. Most soils have red texture contrast profiles with a range of surface textures from sandy loam to clay loam, and clayey subsoils. Main soils: Loam over red clay - **D2** (E) Sandy loam over poorly structured red clay - **D3a** (E) Gradational red sandy loam - **C1** (L) These soils are deep and inherently fertile. Poor structure (especially in D3a soils) and associated drainage, infiltration, workability and emergence problems are the main limitations. Improved surface management and gypsum applications will help to alleviate the problem. Sheet/rill erosion

		in paddocks, and gully erosion in water courses are potential problems. Provided erosion is controlled, productive potential is high.
TBB	3.8	Gentle slopes formed on clayey sediments or deeply weathered basement rock. **TBB** Slopes of 2-4%. Main soils: gradational clay loam - **C3a** (E), brown cracking clay - **E3** (E) and hard sandy loam over friable red clay - **D2a** (L), with calcareous loam to clay loam - **A6** (M), red cracking clay - **E2** (M), black cracking clay - **E1** (M) and loam over red clay on calcrete or rubble - **B6/D1** (M). Hard sandy loam over dispersive red clay - **D3a**, brown gradational loam - **M4** and calcareous sandy loam **- A4** occur sporadically. These soils are predominantly deep, fertile and well structured. Exceptions are the D3, D2 and M4 soils which set down hard, shed water and are prone to patchy emergence. The clayey soils are difficult to manage when wet, but are inherently highly productive. High subsoil boron levels are likely in these soils, so tolerant varieties will be needed where symptoms occur.
XHR	1.0	Alluvial flats of the lower North Para River including watercourses, terraces and banks. Underlying sediments are variable silts, clays and sands of relatively recent alluvial deposition, usually mantled by fine grained soft carbonates. Because of the variability of parent sediments, there is a range of soils with sandy to loamy surfaces and reddish or dark coloured sandy clay loam to sandy clay subsoils, calcareous at depth. Near watercourses there are deep medium to coarse grained alluvial soils. Main soils: Deep sandy loam - **M1** (E) Gradational red sandy loam - **C1** (E) These flats are subject to flooding, but are potentially productive, with deep, albeit often sandy and silty soils. Watercourse protection is a significant issue.

PROPORTION codes assigned to soils within Soil Landscape Units (SLU):

(D) Dominant in extent (>90% of SLU)
(V) Very extensive in extent (60–90% of SLU)
(E) Extensive in extent (30–60% of SLU)
(C) Common in extent (20–30% of SLU)
(L) Limited in extent (10–20% of SLU)
(M) Minor in extent (<10% of SLU)

Detailed soil profile descriptions:

A2 Shallow calcareous loam on rock (Paralithic, Calcic Calcarosol)
Medium thickness calcareous reddish brown stony loam, overlying a brown highly calcareous stony clay loam, increasingly calcareous and paler coloured with depth. Highly calcareous weathering siltstone or slate occurs at about 50 cm.

A6 Gradational calcareous clay loam (Pedal, Calcic Calcarosol)
Medium thickness reddish brown calcareous loam to clay loam, grading to a well structured reddish brown clay subsoil, becoming more clayey and calcareous with depth. Coarsely structured, brown heavy clay continues below 200 cm.

B6 Shallow loam over red clay on calcrete (Petrocalcic, Red Chromosol)
Medium thickness hard setting loam with a paler and stony A2 horizon, overlying a dark reddish brown, well structured clay with a massive calcrete pan at 55 cm, overlying a highly calcareous clay loam which grades to weathering, calcified rock at variable depths averaging 100 cm.

C1 Gradational red sandy loam (Calcic, Red Kandosol)
Thick reddish brown sandy loam to fine sandy loam with a pink A2 horizon, overlying a yellowish red weakly structured clay loam to clay, calcareous with depth.

C2 Shallow gradational red loam on rock (Hypercalcic, Red Dermosol)
Medium thickness red brown loam to clay loam, grading a red, well structured clay loam, grading to massive semi hard carbonate, over weathering siltstone below 50 cm.

C3 Gradational friable red clay loam (Calcic, Red Dermosol)
Medium thickness dark reddish brown clay loam, overlying a dark reddish brown, well structured clay subsoil which is calcareous with depth. Highly calcareous clay continues below 100 cm.

D1 Shallow loam over red clay on rock (Hypercalcic, Red Chromosol)
Medium thickness hard setting loam with a paler and stony A2 horizon, overlying a dark reddish brown well structured clay which is highly calcareous from about 50 cm. Weathering, calcified siltstone or slate occurs within 100 cm.

D2 Loam over red clay (Sodic, Calcic, Red Chromosol)
Thick loam with a paler coloured A2 horizon, overlying a dark reddish brown, well structured clay , which is highly calcareous (Class I carbonate) from about 60 cm. The soil grades to medium to fine grained alluvium below 100 cm.

D3a Sandy loam over poorly structured red clay (Calcic, Red Sodosol)
Thick reddish brown massive sandy loam to loam with a pink very hard A2 horizon, overlying a reddish brown clay with prismatic structure and many soft carbonate segregations (Class I carbonate) from 65 cm.

D3b Gravelly sandy loam over poorly structured red clay (Calcic, Red Sodosol)
Medium thickness hard massive sandy loam with variable quartz and ironstone gravel, sharply overlying a coarsely structured red, brown and grey mottled heavy clay, calcareous with depth, grading to Tertiary sandy clay or sandstone between 100 and 150 cm.

E1 Black cracking clay (Self-Mulching, Black Vertosol)
Medium thickness brown to black well structured light clay, grading to dark brown to black strongly structured heavy clay, calcareous with depth. Coarsely structured, brown heavy clay with soft calcareous segregations continues below 200 cm.

G2 Bleached sand over sandy clay loam (Bleached, Mesotrophic, Brown Chromosol)
Thick grey sand with a bleached A2 horizon containing ironstone and sandstone gravel, overlying a brown, yellow and red sandy clay loam to clay, grading to weakly cemented Tertiary sandstone within 100 cm.

H3 Moderately deep sand (Basic, Arenic, Bleached-Orthic Tenosol)
Thick bleached sand grading to yellowish sand, clayey sand or soft sandstone within 100 cm.

L1 Shallow stony loam (Calcareous, Paralithic, Leptic Tenosol)
Thick, stony, reddish brown loam, grading to highly calcified weathering siltstone or fine sandstone before 50 cm.

M1 Deep sandy loam (Regolithic, Brown-Orthic Tenosol)
Thick brown sandy loam to loamy sand, overlying a reddish brown clayey coarse sand to silty sand, grading to variable sandy and gritty alluvial sediments.

Further information: DEWNR Soil and Land Program

Government of South Australia
Department of Environment, Water and Natural Resources

13 WATER EROSION POTENTIAL

This section deals with the susceptibility of land to erosion by overland flow of water. Removal of a more or less uniform thickness of soil is called sheet erosion. The formation of shallow gutters which can be obliterated by cultivation is rill erosion. Gully erosion caused by concentrated flow in unprotected watercourses, subsurface (or tunnel) erosion, landslip, mass movement and stream bank erosion are dealt with separately.

This discussion is also confined to the inherent potential of land in a clean cultivated condition to erode, as determined by soil properties, topography and rainfall. It does not deal with the susceptibility of land to erosion as a result of a particular land use or management practice. Thus a steep well grassed hill slope has a high erosion potential due to its slope, but a low erosion hazard because it is well protected by vegetation.

Factors affecting water erosion potential

Topography

Three elements of topography influence erosion potential. Potential increases with:

- Slope steepness
- Slope length
- Proximity to rising ground (source of run-on water)

Soil

The inherent potential of a particular soil type to erode on a specified slope in a clean cultivated condition is called its erodibility. Erodibility is influenced by the capacity of soil to absorb the rain that falls on it and the resistance of the surface soil to raindrop impact and to being dragged along (entrained) by overland flow. The rate at which water enters the soil surface (infiltration), the rate at which it moves through the soil (permeability) and the stability of the soil surface are therefore the key soil properties. As discussed in Section 7, the stability of the surface is largely determined by its texture and organic matter content.

Rainfall

Rainfall affects erosion potential in three ways:

- If the infiltration of rainfall into the soil is impeded the surface soil becomes saturated, loses strength and is more likely to erode.
- Rainfall which is unable to infiltrate will run off, thereby providing a medium in which soil particles can move downhill.
- The impact of raindrops dislodges surface soil particles and thereby makes it easier for them to become entrained in overland flow. The kinetic energy of rainfall as it strikes the earth is defined as its erosivity.

The intensity and duration of rainfall events are key factors, modified by the moisture status of the soil before the rain.

Consequences of water erosion

On-site effects

Sheet and rill erosion removes the most valuable layer of the soil profile, the surface. This is the zone of concentration of nutrients and organic matter. Loss of topsoil usually exposes soil of lower fertility and less organic matter with poorer structure and stability. Erosion therefore makes the soil even more erodible. Erosion also reduces the moisture holding capacity of the soil.

Rills and small gullies, which sometimes occur on inadequately protected land during heavy rain, can affect access across the land until they are removed by cultivation.

Soil formation rates are usually so slow that for practical purposes erosion represents a permanent loss of the resource.

Rill erosion

Erosion rill exposing calcrete substrate

Silt deposit at bottom of slope

Off-site effects

Eroded soil is often deposited on lower ground where it can damage or bury fences, block culverts, silt up dams and water courses and cover roads. These all involve public or private expense to rectify. Finer grained material, particularly clay, remains suspended in runoff water and can eventually pollute creeks and reservoirs. Nutrients, particularly nitrogen and phosphorus, attached to clay particles cause eutrophication of water supplies, pesticides adsorbed on clay colloids poison water and the clay particles themselves make the water turbid.

Assessing water erosion potential

Rainfall erosivity

All districts in South Australia are subject to annual rainfall events of sufficient erosivity to warrant precautionary management practices for susceptible soils on all but the gentlest of slopes. Although there are differences in rainfall intensity across the state, they are not sufficently large to warrant the designation of rainfall erosivity zones for the purpose of land classification.

Slope

Slope length and run-on potential are not included in the classification of land with respect to water erosion potential, even though they must be taken into account when assessing land. In general, recommended practices for erosion control include agronomic or engineering techniques which effectively break slopes into smaller segments and divert water flow away from susceptible land.

Gradient is the major determinant of erosion potential. Erosion potential classes are based on slope categories, but the actual criteria used to define the categories vary depending on soil erodibility.

Soil erodibility

Six categories of erodibility are defined based on field observations. The categories are incomplete and represent a preliminary attempt to rank soil erodibility easily in the field. They should be treated only as a guide.

Draft erodibility categories for a range of soil profiles are defined in Table 45.

Table 45 Draft soil erodibility categories (water)

Soil profile characteristics	Erodibility
Soils with sandy to loamy surfaces, shallower than 30 cm, overlying clayey subsoils.	
- Loose or soft surface	Very high
- Dispersive surface	Very high
- Hard setting loamy sand to loam surface	High
- Structured sandy loam to clay loam surface	Moderate
- Weakly structured, friable sandy loam to loam surface	Moderate
Note: - Increase erodibility by one category if subsoil is dispersive	
- Decrease erodibility by one category if depth to clay is more than 30 cm	
Calcareous soils	
- Loamy sand to sand over Class IV carbonate:	
Deeper than 50 cm	Negligible
Shallower than 50 cm	Very low
- Sandy loam to clay loam grading to :	
Class III B or III C carbonate	Very low
Class III A carbonate	Low
Class I carbonate shallower than 50 cm	Moderate
Class I carbonate deeper than 50 cm	Low
- Loamy sand to loam over Class II carbonate	Moderate
- Loam over calcareous weathering rock:	
Deeper than 50 cm	Low
Shallower than 50 cm	Moderate
Deep sands (more than 80 cm)	
Non water repellent	Negligible
Water repellent	Low
Strongly water repellent	Moderate
Deep (more than 80 cm) uniform sandy loams to clay loams	
Well structured	Very low
Massive	Low
Clay soils	
Well structured	Low
Massive	Moderate
Skeletal soils (shallow over bedrock)	
Gritty, stony sands on sandstone, quartzite	High
Stony loams on shale, siltstone	Moderate

81

Appendix B – Hydraulic modelling summary report

Gawler and Surrounds Stormwater Management Plan

Hydrologic and Hydraulic Modelling Report

Town of Gawler, Light Regional Council, Barossa Council

June 2018

Ref No. 20141387R003A

Tonkin CONSULTING

a better approach

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Contents

1	**Introduction**	**1**
1.1	**Study area**	**1**
1.2	**Scope of works**	**1**
1.3	**Study tasks**	**1**
2	**Hydrologic modelling**	**4**
2.1	**Overview**	**4**
2.2	**Catchment description**	**4**
2.3	**Parameters used in hydrologic modelling**	**4**
3	**Two dimensional hydraulic modelling**	**5**
3.1	**Introduction**	**5**
3.2	**Modelling software**	**5**
3.3	**Digital elevation model**	**5**
3.4	**TUFLOW model setup**	**5**
3.4.1	Computational grid cell size	5
3.4.2	Computational time step	7
3.5	**Boundary and initial conditions**	**7**
3.5.1	Outflow boundary conditions	7
3.5.2	Inflow boundary conditions	7
3.5.3	Initial conditions	7
3.6	**Existing stormwater drainage infrastructure**	**8**
3.6.1	Modelling of the pipe network	8
3.6.2	Modelling of the inlet pits	8
3.6.3	Modelling of open channels	8
3.6.4	Gutter flows	9
3.6.5	Allowance for blockages	9
3.7	**Future drainage infrastructure**	**9**
3.8	**Bed resistance**	**9**
3.9	**Modelling uncertainty**	**10**
3.10	**TUFLOW simulations**	**10**
3.10.1	Events modelled	10
3.10.2	Scenarios modelled	10
4	**One dimensional hydraulic modelling**	**12**
4.1	**Introduction**	**12**
4.2	**Catchments and hydrology**	**12**
4.3	**Drainage network**	**12**
4.3.1	Stormwater Inlets	12
4.3.2	Junction boxes	12
4.3.3	Junctions and other intersections	12
4.3.4	Headwalls	12

4.3.5 Detention basins 12
4.4 Overflow routes 13
4.5 Open channels 13

5 Modelling results 14
5.1 Model verification 14
5.2 Validation of results 14

Tables

Table 3.1 Adopted bed resistance parameters 9

Figures

Figure 1.1 Study area and model boundary 3
Figure 3.1 LiDAR derived digital elevation model 6

Appendices

Appendix A Hydrology discussion paper
Appendix B Long term development scenario discussion paper

1 Introduction

1.1 Study area

This report is concerned with the preparation of a 2D hydrodynamic model of the Gawler township and surrounding areas relevant to the preparation of the Gawler and Surrounds Stormwater Management Plan (SMP). The study area is presented in Figure 1.1.

The primary purpose of the work undertaken has been to define the extent and magnitude of flooding during events of differing annual exceedance probability (AEP) and to identify areas of significant inundation relevant to the preparation of the SMP. The risk to public safety, otherwise known as the 'flood hazard' has also been categorised for some of the flood events investigated.

1.2 Scope of works

The general scope of works for the study was to determine the extent of flood inundation during various flood events within the Gawler urban areas and surrounding rural living zones, including the Gawler Belt. The project included the following tasks:

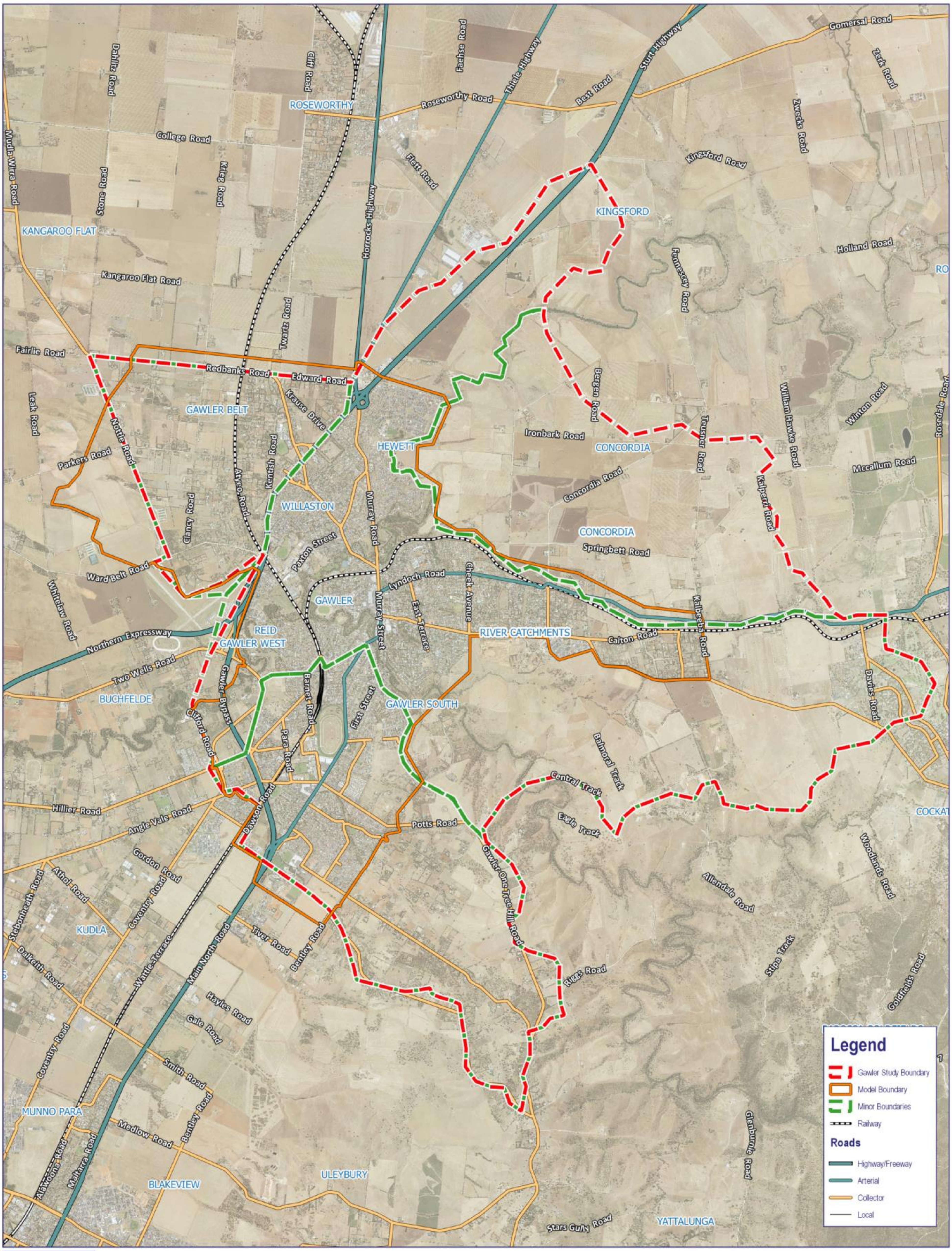
- Hydrological modelling of external inflows.
- Obtaining details of the hydraulic structures, including underground pipe systems and flood detention basins.
- Obtaining an accurate digital elevation model (DEM) across the study area.
- Preparing a combined 1D–2D hydrodynamic computer model of the study area based on the existing and long-term levels of development,.
- Analysing the resulting flooding for the following storm events:
  - 20% AEP storm event
  - 5% AEP storm event
  - 1% AEP storm event
  - 0.2% AEP storm event
- Alter the long-term model to include proposed mitigation measures.
- Producing flood inundation and hazard zone maps for various specified flood events within the study area.
- Issuing a modelling report and associated flood maps.

1.3 Study tasks

The project tasks consisted of the following:

- Topographic information
  - Obtain DEM data across the study area.
  - Modify DEM data where necessary to reproduce known flooding behaviour.
- Hydrological modelling
  - Delineating sub-catchments internal and external to the hydraulic model extents.
  - Obtaining approvals for the methodology to produce hydrographs for all events.
  - Determine sub-catchment properties, such as impervious surface coverage and response time for various development scenarios.

- Prepare hydrographs for input to the hydraulic model from both internal and external catchments.
- Hydraulic modelling
  - Collating hydraulic structure data (inverts and dimensions) and infilling missing data.
  - Developing a TUFLOW model of the study area.
  - Conducting initial model runs and resolving any stability issues.
  - Review and validate model outputs.
  - Conducting final model runs.
- Flood mapping
  - Creating flood inundation maps.
  - Creating flood hazard maps.



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Town of Gawler, Light Regional Council and The Barossa Council

STUDY AREA AND MODEL BOUNDARY

Tonkin CONSULTING

Job Number:	20141387
Filename:	20141387GQ001
Revision:	REV A
Date:	2018-05-31
Drawn:	Michael McEvoy

Data Acknowledgement:
Aerial Imagery from Metromap, 2017
Roads and Railways from DataSA, 2017
Cadastre from PBI, 2015

Figure 1.1

2 Hydrologic modelling

2.1 Overview

The hydrologic modelling aims to determine the rate of runoff given a particular rate of rainfall. This information is then applied to the hydraulic model which dynamically models the path of runoff through the study area.

The hydrologic modelling for this study involves determining runoff from local, predominantly urban catchments, and from external, predominantly rural catchments. For local catchments a Time-Area method was applied to create hydrographs for each sub-catchment. For external catchments runoff-routing models were developed to produce inflow hydrographs at the boundary of the hydraulic model.

All components of the hydrological modelling were assessed and approved by the Steering Committee prior to flood modelling being undertaken.

A full discussion of the hydrology applied in this study can be found in the *Hydrology Discussion Paper* (Appendix A).

2.2 Catchment description

The catchment is mostly urban with some rural living and hills face areas. The topography is relatively steep and dominated by the North Para and South Para rivers which join to form the Gawler River.

There is a well-documented history of issues caused by flooding from the main rivers, but little has been recorded about flooding urban centre and surrounding rural living areas.

2.3 Parameters used in hydrologic modelling

Development of the hydrologic parameter values is discussed in the *Hydrology Discussion Paper* (Appendix A). Hydrologic parameters for the long term development scenario are discussed in a second discussion paper (Appendix B).

3 Two dimensional hydraulic modelling

3.1 Introduction

Hydraulic modelling uses the outputs of hydrologic modelling to determine the extent, depth and behaviour of flood flows within the study area. The resulting outputs provide an estimate of areas subject to flooding.

A detailed 1D–2D flood model was created for this study. The model was run to simulate storm events within the study area and generate flood inundation and hazard maps for the existing level of development an agreed predicted future development scenario.

3.2 Modelling software

The modelling was carried out using the TUFLOW computer program. The program simulates depth averaged, two and one-dimensional, free surface flows.

TUFLOW has the ability to dynamically link to the 1D model ESTRY, which enables the creation of models containing both 1D and 2D domains. The TUFLOW simulation engine is based on a finite difference, alternating direction implicit (ADI) scheme that solves the full 2D free surface flow equations. The ESTRY component is based on a numerical solution of the unsteady momentum and continuity fluid flow equations.

TUFLOW was initially developed to model tidal estuaries. However, Tonkin Consulting assisted in pioneering the use of TUFLOW for urban flood inundation mapping. The drainage network is modelled in 1D and dynamically linked at each inlet/outlet structure to the floodplain represented in 2D. This allows for the integrated modelling of the drainage network and floodplain.

3.3 Digital elevation model

A digital elevation model (DEM) of the study area was prepared by AAM Pty Ltd using data captured by LiDAR in May 2015. LiDAR is a remote sensing method that uses laser pulses to measure the distance to features in the terrain. The laser pulses are obtained and processed to create a 3D model of the landscape.

Tonkin Consulting reviewed the DEM to ensure it was free of major errors. This review found some issues around bridge structures, which were fixed before the DEM was used for modelling.

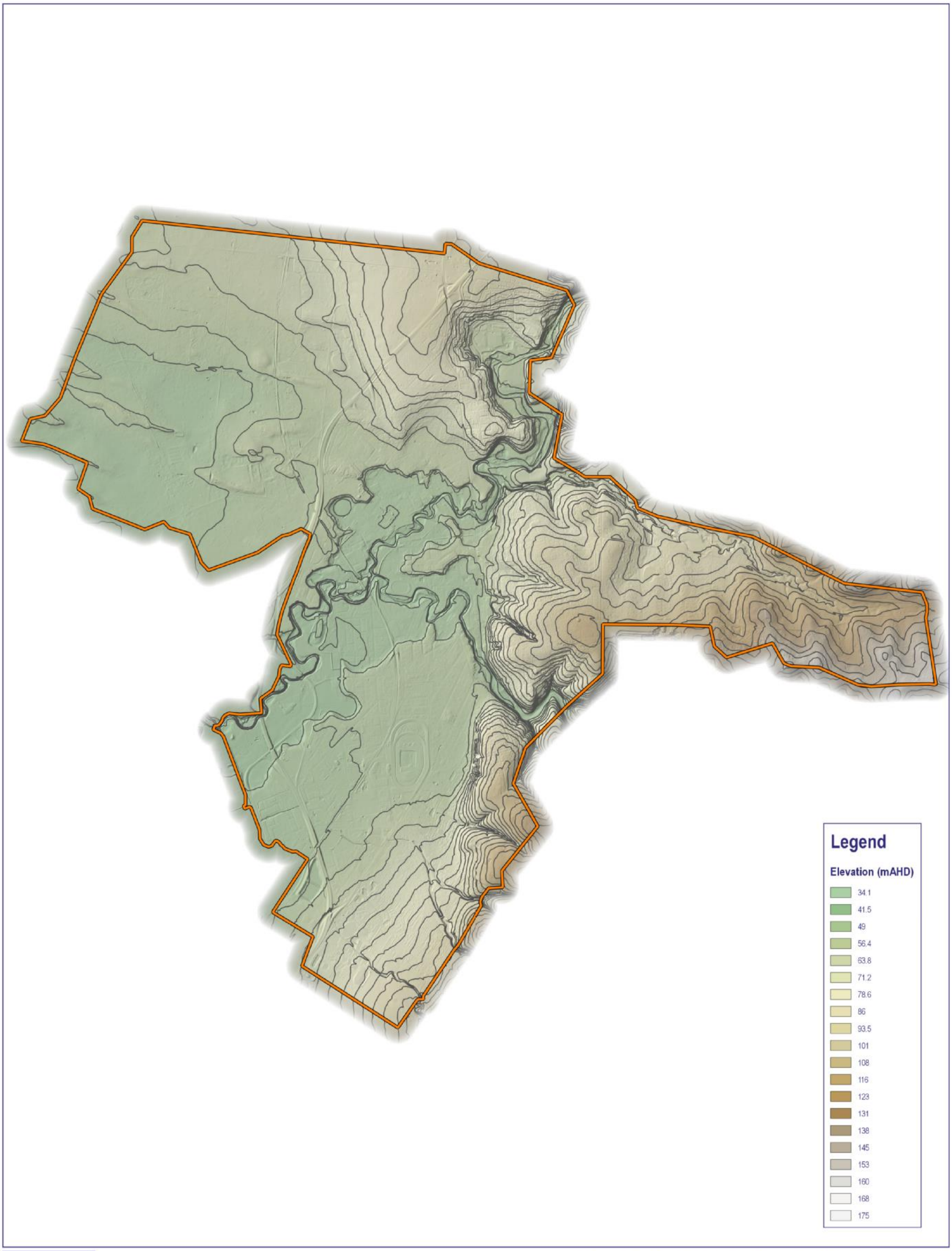
The full DEM obtained (before modification) is presented in Figure 3.1

3.4 TUFLOW model setup

3.4.1 Computational grid cell size

Determining an appropriate cell size for the computation grid used by TUFLOW requires a compromise between the resolution of flood mapping and the simulation time and memory required to run the models. Smaller 2D cell sizes more accurately reproduce detailed topography and the hydraulic behaviour, but significantly increase the amount of memory and computational power required to run the model. An understanding of the specific requirements for each study is needed in order to select an appropriate 2D cell size.

A cell size of 4 m is considered by Tonkin Consulting as a good compromise between resolution and computational power and has been used for many studies previously undertaken by Tonkin Consulting. A cell size of 4 m was considered suitable to adequately represent the hydraulic behaviour of the rural areas and surface flood flows within the urban street network.



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Drawn: Michael McEvoy

Data Acknowledgement:
Digital Elevation Model provided by AAM, 2015

Town of Gawler, Light Regional Council and The Barossa Council

DIGITAL ELEVATION MODEL

Figure 3.1

3.4.2 Computational time step

The selection of an appropriate time step for the 2D domain of TUFLOW is critically important to the accuracy of the model output. Time steps that are too large may result in overestimation of the derivatives within the model which decreases the numerical accuracy of the computations. The choice of a smaller time step helps prevent numerical diffusion but increases the simulation time of models. An appropriate time step will balance simulation time with the model's stability and numerical accuracy.

For this study, a time step of 1 second was adopted for the 2D domain. This achieved an acceptable balanced between simulation time and stability of the model results.

Ninety nine percent of computational effort is expended solving the 2D surface flow equations and very little effort is needed to resolve the 1D domain. Consequently, the 1D domain time step has a negligible impact on simulation times. A time step of 0.1 seconds was used for the 1D domain.

3.5 Boundary and initial conditions

3.5.1 Outflow boundary conditions

Where water interacts with the boundaries of the model, special attention is required to ensure the correct hydraulic conditions at the boundary are recreated.

Where shallow sheet flow was expected to reach a model boundary, the boundary condition at that location was set to allow flow to freely leave the model. For channelised flows, the boundary condition was set to represent the hydraulic conditions downstream using an automatically generated, stage–discharge relationship based on the topography and expected hydraulic grade at that location.

For this model there were few boundaries that required special attention. South of the Gawler Bypass, the study area is highly incised by water courses which drain into the main river channels. Consequently, only the Gawler River channel crosses the downstream boundary of the model. This boundary was assigned an automatically generated, stage–discharge relationship based on the expected hydraulic grade. Of note is that this boundary is so removed from any of the drainage infrastructure that its effects on flood behaviour are negligible. North of the Gawler Bypass, in the Gawler Belt area, the landscape falls to an obvious low spot and there are no deep channelised outflow locations, therefore, sheet flow boundary conditions were set.

3.5.2 Inflow boundary conditions

Inflow hydrographs were generated for each AEP and duration of storm event analysed, as outlined in *Hydrology Discussion Paper* (refer Appendix A). The inflows for each sub-catchment were applied to each inlet pit, grate, or headwall throughout the catchment. Inlet capacity tables were used to provide an approximate inlet capacity for each inlet type. This allowed the inflows to pass directly into the drainage network until the pit or pipe capacity was exceeded, with the excess spilling into the street network (2D floodplain).

Where no drainage infrastructure was present within the sub -catchment (i.e. creek channels, basins, wetlands and the north-western agricultural areas), the inflow was applied directly over regions of the 2D model surface. Flow is initially applied to the lowest grid cell in the region. As the flood level increases the inflow is distributed over the flooded area.

Inflow hydrographs for the creeks along the upstream boundary of the study area were extracted from the RORB models (see Section 3.6).

3.5.3 Initial conditions

The catchment was assumed to be “dry” before the onset of rainfall. Consequently, it was not necessary to apply any initial conditions to the model.

3.6 Existing stormwater drainage infrastructure

3.6.1 Modelling of the pipe network

The drainage network consists mostly of underground drainage network discharging directly to the North Para, South Para or Gawler rivers. There are also a number of wetlands and detention basins within the drainage network, as well as a few major flood protection basins on the upper slopes of the catchment.

Base drainage infrastructure data (conduits and inlet structures) was provided by each of the three Councils. This data was extensively reviewed and updated to correct obvious errors.

Where previously unidentified drains were added or there were uncertainties within the drainage database, locations and sizes were discussed with Council and either confirmed on site or taken from design drawings.

Invert elevations for the underground drainage were absent from the Light Regional Council (LRC) and Barossa Council's GIS data. Invert elevations for these Council areas were instead assumed based on the surface level of the DEM and dimensions of the pipe.

In the Gawler Council area, many drainage pits had depth measurements which allowed some pipe networks to be assigned invert elevations with greater certainty. Gaps in the depth data were filled in the same manner as the LRC and Barossa Council areas. The final assigned inverts for all pipes were then reviewed and manipulated to ensure all drainage networks graded downhill.

In addition to the above, the drainage network was checked as follows:

- Pipe diameters and box culvert sizes were reviewed to check for consistency with standard dimensions and to ensure that sizes generally increased in the downstream direction.
- Checks were carried out to ensure all drains were digitised in the downstream direction. For flood modelling it is preferable that drains be drawn in the downstream direction, so that flow results are positive in the downstream direction.
- Checks were made to ensure connectivity of the drainage network.

The review and modifications resulted in a greatly improved GIS database of drainage infrastructure for the study area, and allowed the development of a TUFLOW model to represent the drainage infrastructure to an appropriate level of accuracy for the flood mapping study.

Department of Transport drawings were sourced to better model the drainage of the Gawler Bypass, Northern Expressway, and Sturt Highway. Of particular importance was the proper representation of the large culvert that leads from Trinity College beneath the Gawler Bypass to the Dawson Road detention basins.

3.6.2 Modelling of the inlet pits

Inlet pits were modelled using head-flow relationships to provide a good estimate of the inlet capacity of each pit. Different curves were created for single, double and triple side entry pits (SEPs) as well as 900×900 and 450×450 grated inlet pits (GIPs).

3.6.3 Modelling of open channels

There are a number open channels across the study area. While the larger of these channels can be adequately represented within the 2D model domain, the smaller channels were modelled as 1D channel structures with cross section data to ensure they were represented accurately within the TUFLOW model.

Particular attention was given to the Clifford Road outfall channel and the unnamed creek channel passing under Main North Road near the Gawler Park shopping complex.

3.6.4 Gutter flows

While the grid cell size was demonstrated to provide sufficient detail to model the urban environment in the flatter areas, errors were identified in the steeper regions of the model area. It was found that where roads ran across the slope, the model resolution was not sufficient to accurately represent the kerb profile. This resulted in flow travelling downhill rather than travelling along the road kerb. To counteract this, the cells on the lower side of the roads in the affected areas were artificially raised to approximately 0.15 m above the closest road level. This pushed low flows along the road kerbs and allowed for the kerb capacity to be appropriately represented in the model.

3.6.5 Allowance for blockages

During large storm events, objects could be swept into inlet pits, headwalls and creek channels, exacerbating flooding in the local area. Siltation could also reduce the capacity of the stormwater network exacerbating flooding in the local area. Due to the broad scale objective of this flood study, no specific allowance has been made to account for blockages that may occur during storm events.

3.7 Future drainage infrastructure

After the existing and long-term development scenarios were completed a set of mitigations measures were devised to reduce flood inundation in the modelled area. After initial assessments of effectiveness, selected mitigation measures were added to a modified version of the TUFLOW model.

3.8 Bed resistance

The TUFLOW model requires bed resistance be specified by the modeller. In this model a GIS layer of Manning’s n roughness coefficients is used to define the bed resistance. The bed resistance is the primary determinant of water depth within the 2D model domain.

Roughness values in urban areas were based on cadastral information and aerial photography. Buildings were modelled using high bed resistance values applied to residential and commercial areas.

The Manning’s n roughness coefficients used in this model are listed in Table 3.1. These values were selected based on current literature and the prior experience of Tonkin Consulting.

Table 3.1 Adopted bed resistance parameters

Land Use	Manning’s n
Houses/Residential areas, obstructions to flow	0.200
Medium and high density residential and commercial areas	0.300
Parklands with scattered trees	0.045
Grassed areas and bare ground	0.035
Roads (including verges)	0.020
Unlined creek channels	0.040–0.065
Plastic pipes	0.011
Brick-lined conduits	0.019
Concrete pipes and box culverts	0.013

3.9 Modelling uncertainty

While every care has been taken in preparation of the TUFLOW model and the choice of the adopted parameters, all hydrological and hydraulic modelling has an inherent level of uncertainty. This inherent uncertainty is due a number of factors which may include any of the following:

- The accuracy and resolution of the DEM used and the interpretation of this information by the hydraulic model
- Dynamic changes to topography due to erosion or deposition of soil during a flood event; which can lead to changes in the distribution of flow. These processes have not been included in this model.
- Uncertainty in the rainfall pattern and catchment conditions prior to a flood. Actual flood events are dependent on the antecedent moisture conditions prior to rainfall, initial detention storage levels at the beginning of rainfall runoff and the intensity and uniformity of the rainfall event itself. The floods modelled by this study are based on design storm bursts which attempt to reproduce the expected average temporal pattern of a storm burst within specified rainfall zones (see ARR2016 for greater explanation). As such, individual rainfall events may exhibit a differing temporal pattern than those modelled.
- Estimation of input parameters to the model (such as runoff coefficients, time of concentration, Manning's roughness, entry and exit losses, and accuracy of the drainage network provided).

3.10 TUFLOW simulations

3.10.1 Events modelled

Five different flood events were modelled in 2D:

- 20% AEP flood event
- 5% AEP flood event
- 1% AEP flood event
- 0.2% AEP flood event

For each flood event, a number of different storm durations were modelled in order to obtain the peak flood level at different points within the catchment. The durations modelled were:

- 30 minutes
- 1 hour
- 3 hours
- 6 hours
- 9 hours
- 12 hours
- 24 hours

3.10.2 Scenarios modelled

For each set of ARIs and durations above three different scenarios were modelled. A scenario is a combination of hydraulic and hydrologic inputs to the model. The scenarios modelled included:

- Existing infrastructure combined with existing development levels.
- Existing infrastructure combined with predicted long-term development levels.

- Existing infrastructure with proposed modifications and upgrades combined with predicted long-term development levels.

A single long-term post mitigation model was used to reduce the computational expense and duration of the modelling undertaken.

4 One dimensional hydraulic modelling

4.1 Introduction

A DRAINS model of the urban catchments of Gawler was also developed. The model was developed to a standard of accuracy sufficient for broad scale stormwater risk management and planning. The following sections describe how elements of the model were developed.

4.2 Catchments and hydrology

Hydrology parameters and sub-catchment properties were assigned as per the methods outlined in the *Hydrology Discussion Paper* (Appendix A). The only modification was the replacement of three small RORB models with rural catchments within the DRAINS model at the southern end of the model. Losses for these rural catchments were assigned according to Table 4.4 of the *Hydrology Discussion Paper* (Appendix A).

4.3 Drainage network

The layout and attributes of the drainage network were developed from the drainage network prepared for the 2D flood model.

The elements of the DRAINS model were created using the process outlined in the following sections.

4.3.1 Stormwater Inlets

The location and type of inlet was copied from the network prepared for the 2D flood model. “Sag” or “On-grade” classifications were assigned to all pits based on surface contours and the digital elevation model (DEM). All sag pits were assigned a default ponding depth of 0.25 m and a ponding volume of 10 m^3. The surface elevation at inlets was extracted from the DEM.

4.3.2 Junction boxes

Known junction boxes and their properties were copied from Council GIS datasets. The surface elevation at all junction boxes was extracted from the DEM. All pipe junctions modelled with pits or junction boxes were initially assigned a junction loss factor (k_u) of 1.5. The loss factors were then revised iteratively using the QUDM charts implemented in DRAINS.

4.3.3 Junctions and other intersections

Nodes were added at the following locations: at the junction of two pipes (if a pit/junction box was not known to exist at that location); at the outlet of a catchment if there was no associated inlet pit; at the outlet of all drainage branches; and at confluences along open channels and overflow routes. The surface elevation at all nodes was extracted from the DEM.

4.3.4 Headwalls

Headwalls were added at the upstream end of a drainage network if there was no inlet pit. An entry loss factor of 0.5 was adopted for all headwalls. The surface elevation at all headwalls was extracted from the DEM.

4.3.5 Detention basins

A height–storage relationship was determined from the DEM for each detention basin. An entry loss factor of 0.5 was adopted for pipe outlets from basins.

4.4 Overflow routes

Overflow routes were digitised between pits, nodes, headwalls and basins, based on surface contours and the DEM. The length of the routes were assigned from GIS data and the upstream and downstream invert levels were extracted from the DEM. All overflow routes were assigned the "7.5 m roadway with 3% crossfall and barrier kerb" cross-section profile.

The following weir properties were adopted for all overflow routes leaving a headwall or basin:

- crest length of 3 metres,
- weir coefficient of 1.67,
- crest level as appropriate from the DEM.

4.5 Open channels

A number of open channels were selected and modelled as channel elements in DRAINS. All other channels were modelled as overflow routes. The cross section for each channel element was extracted from the DEM at the appropriate location. Where necessary, the depth of the cross section was exaggerated to contain all flows within the channel. The Manning's roughness coefficient for each channel element was determined from aerial imagery.

5 Modelling results

During each model run, the peak flooding depth and hazard category (20 and 100 year ARI events only) was recorded across the 2D model domain. Once modelling was complete, the results from each duration were spliced together to create a maximum depth and hazard envelope for each flood event modelled.

Flood inundation and hazard maps were produced so that the impact of flooding could be visually analysed. The flood inundation and hazard data was overlaid onto aerial imagery, with the drainage network and street names shown to allow for easy identification and assessment of flooding. The flood depth data was classified into discrete intervals to allow for easy discrimination of flood depths. Flooding less than 25 mm deep is not shown as it is not considered relevant to the wider flood map.

5.1 Model verification

A number of techniques were employed to verify the model implementation. Manual and automated checks of the pipe network to detect connectivity issues in addition to comparison of recorded peak flow against expected pipe capacity (based on size and longitudinal grade) ensured confidence in the correct modelling of the pit and pipe network.

5.2 Validation of results

To help validate the TUFLOW model results, the peak recorded flow rate in key drains was compared with the theoretical capacity of the drains. In the majority of cases, the results compared favourably, providing confidence in the modelling of the underground drainage network. A small number of conduits were found to be incorrectly sized, due to erroneous dimensions recorded in the Council's GIS database. Council staff were tasked with re-measuring these conduits. The updated dimensions were then added to the model.

As discussed in Section 3.6.4 visual inspection of the results showed that gutter flows in steeper areas were poorly modelled. Modifications were made to the DEM to better represent the full capacity of roadside gutters and the flow of surface water along the street network.

Draft flood inundation results were discussed with Council staff to identify areas of unexpected flooding. These locations were then scrutinised to determine the cause of the model output. Modifications to the model were then made where necessary to achieve the historically observed flood behaviour.

Appendix A

Hydrology discussion paper

Gawler and Surrounds Stormwater Management Plan

Hydrology Discussion Paper

Town of Gawler, Light Regional Council, Barossa Council

September 2016

Ref No. 20141387R002D

Tonkin CONSULTING

a better approach

Document History and Status

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B	Additional commentary regarding impervious area proportions	JDN	TAK	TAK	7 Jul 2016
C	Final for approval	JDN	TAK	TAK	20 Sep 2016
D	Approved	JDN	TAK	TAK	30 Sep 2016

Contents

1 Introduction 1

2 Catchment properties 2

2.1 Boundary delineation 2
2.1.1 Urban areas 2
2.1.2 Rural areas 2
2.1.3 Hills face 2

2.2 Imperviousness 2
2.2.1 Existing development scenario 2
2.2.2 Future development scenario 4

2.3 Time of concentration 4
2.3.1 Urban areas 4
2.3.2 Rural areas 4

3 Rainfall estimation 5

3.1 Rainfall depth and intensity 5
3.1.1 Frequent events 5
3.1.2 Rare events 5

3.2 Temporal distribution 5
3.2.1 Frequent events 5
3.2.2 Rare events 5

3.3 Spatial distribution 5

4 Runoff estimation 6

4.1 Urban and rural areas 6
4.1.1 Frequent event losses 6
4.1.2 Rare event losses 6
4.1.3 Extreme event losses 6

4.2 Hills face catchments 7
4.2.1 Rural and hills face losses 7
4.2.2 RORB modelling parameters 7

4.3 Gawler, North Para and South Para rivers 8

5 Bibliography 1

Tables

Table 2.1 Existing development scenario impervious area proportions 3
Table 4.1 Loss parameters used for frequent events 6
Table 4.2 Loss parameters used for the 0.2% AEP event 6
Table 4.3 Loss parameters used for extreme events 7
Table 4.4 Loss parameters for RORB models 7

Appendices

Appendix A RORB model areas
Appendix B Residential Total Impervious Area Sample Sites

1 Introduction

The following paper provides the methodology and assumptions that will be used for various hydrologic calculations of the Gawler and Surrounds Stormwater Management Plan (SMP).

The intent of this discussion paper is to summarise the reasoning behind selection of parameter values for hydrologic modelling used to generate hydrology inputs to the hydraulic model.

The parameter values proposed relate to three different catchment development scenarios:

1. existing development scenario
2. future development scenario (50 year time horizon)
3. future development scenario with flood mitigation measures

2 Catchment properties

2.1 Boundary delineation

2.1.1 Urban areas

Sub-catchment delineation of urban areas will be performed manually using the following information for guidance:

- the digital elevation model (DEM) of the area
- contours derived from the DEM
- aerial photography
- GIS data including property boundaries (cadastre), road network, and stormwater inlets

At least one sub-catchment will be delineated for each inlet pit within the urban areas. Large sub-catchments will be divided into smaller sub-catchments to allow better representation of pluvial flooding in the street network.

2.1.2 Rural areas

Delineation of rural areas will be performed automatically using software. Adjustments to the automatically generated catchments will be made manually where required.

2.1.3 Hills face

Sub-catchment delineation of Hills face areas will be performed manually using the following information for guidance:

- the DEM of the area (where possible)
- contours derived from the DEM
- 1:50,000 scale topographic maps (in areas not covered by the DEM)

Catchments will be subdivided following the appropriate procedures outlined by the RORB manual. Particular attention will be applied to ensuring that sub-catchment areas are between 5% and 25% of the total catchment area, and that reaches are less than one third of the total length of the main stream.

2.2 Imperviousness

2.2.1 Existing development scenario

Imperviousness of the Study Area is predominantly characterised by residential development of varying density. As such, the estimation of catchment runoff will be most sensitive to the adopted imperviousness of the residential areas. Therefore, it is essential to estimate the impervious fraction of residential areas as accurately as possible.

The ILSAX hydrologic model splits the total impervious area (TIA) into directly and indirectly connected sub-types. Acceptable estimates of TIA can be made from inspection of aerial imagery, but estimating the proportion of directly connected impervious area (DCIA) can be difficult due to complicating factors. For residential areas in particular, the age of the development (more recent development is commonly required to be connected to the street), the

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presence of rainwater tanks (which frequently overflow to pervious land), the visibility of downpipes (limiting visual assessment of "connectedness"), and the presence of rear-of-allotment drains (which may or may not be utilised by the land owner) all contribute to the "connectedness" of impervious area.

To assist determination of the catchment properties Tonkin Consulting have selected several land-use types that are representative of the variation in imperviousness within the Study Area. This simplifies the process of specifying the relationship between TIA and DCIA. The land-use types are listed in Table 2.1. It was determined that only the residential land uses warranted special investigation of DCIA (see below for discussion). Other land uses were assigned DCIA proportions consistent with previous studies.

Table 2.1 Existing development scenario impervious area proportions

Land use type	Directly connected	Indirectly connected
Residential areas (medium density, recently developed)	0.60	0.05
Residential areas (low density, not recently developed)	0.25	0.10
Rural residential	0.00	0.10
Commercial	0.75	0.02
Industrial	0.75	0.02
Government Institutions	0.30	0.10
Education Institutions	0.20	0.18
Public Institutions	0.30	0.10
Open land	0.01	0.05
Road reserve	0.55	0.15

For each sub-catchment, the proportion of directly and indirectly connected impervious area will be calculated using a weighted average (by area) based on the land use types within a catchment. Some calculated proportions will be overridden based on visual inspection to properly represent the expected hydrological response of a sub catchment.

Special investigation of TIA for residential land-use types

To determine average TIA for residential areas, the impervious area of several sample sites was mapped (a similar process to that used in ARR Revision Project 6 (Phillips et al., 2014)). Appendix B shows the nine sample sites and the mapped impervious areas. The mapping of impervious area provided an estimate of average TIA for areas of different residential development density. A site survey was conducted to assess the connectedness of each sample site. The site survey determined the number of the properties directly connected to the street kerb. The proportion of properties with direct connection provides an indication of the DCIA for the sample sites. For medium density residential areas, average connectivity was 100%, whilst for low density areas, average connectivity was 75%. Rural residential areas were determined to have no direct connection to street kerbs. These proportions were then used to split TIA between directly and indirectly connected impervious area. The final adopted split between directly and indirectly connected impervious area is listed in Table 2.1.

2.2.2 Future development scenario

Changes to catchment imperviousness will be determined in discussion with the Steering Committee. Recommendations for parameter values will be made after reviewing the existing scenario results.

2.3 Time of concentration

2.3.1 Urban areas

The time of concentration for each sub catchment in the urban areas will be calculated within MapInfo (a GIS software) based on the following information:

- The distance between the inlet pit receiving runoff and the most distant vertex of the digitised sub-catchment boundary from that pit.
- The change in elevation between the two aforementioned points.

During past flood studies conducted by Tonkin Consulting it was noted that the actual flow path is on average 10% longer than a direct line between the most distant vertex and the receiving inlet. Therefore, the automatically determined flow path length will be multiplied by a factor of 1.1 to account for this difference.

The flow path slope will be calculated by dividing the change in elevation across the catchment by the modified length of the flow path. A minimum slope of 0.2% is applied if the catchment slope is calculated to be less than this amount to prevent excessively large times and to represent likely minimum road grades.

In addition to the gutter-flow time, an allowance of 5 minutes for roof-to-gutter travel time for residential sub-catchments (or 10 minutes for commercial/industrial) will be included as recommended in *Stormwater Drainage Design in Small Urban Catchments: A Handbook for Australian Practice* (Argue, 1986).

Thus, the equation to calculate time of concentration will be as follows:

$$Time\ of\ Concentration\ (mins) = \frac{1.1 \times Flow\ path\ length\ (m)}{39.6 \times \sqrt{Max[Flow\ path\ slope\ (\%), 0.2\%]}} + (5\ or\ 10\ mins)$$

For urban areas, the pervious area time of concentration will be calculated as the impervious area time of concentration plus 15 minutes.

2.3.2 Rural areas

For rural areas, a combination of sheet-flow time (determined by the Kinematic Wave equation) and the overland flow travel time will be used to determine a time of concentration for the pervious areas of each rural sub-catchment.

3 Rainfall estimation

3.1 Rainfall depth and intensity

This section describes the methodology to determine rainfall depth for each storm event. It is assumed that the Annual Exceedance Probability (AEP) of a storm event is preserved and the resulting flood event has an equal AEP.

The following terminology is used:

- Frequent events: events with an AEP greater than or equal to 1%
- Rare events: events with an AEP less than 1% and greater than or equal to 0.05%
- Extreme events: events with an AEP less than 0.05%

All parameters apply to a point nearest to the Study Area centroid as is possible for each data set.

3.1.1 Frequent events

Frequent event design rainfall will be determined from Intensity–Frequency–Duration (IFD) data updated in 2013. The rainfall depths will be sourced from the Australian Bureau of Meteorology (BoM) website.

3.1.2 Rare events

For rare events, point rainfall sourced from the BoM will be used for storm durations greater than 24 hours. For durations less than 24 hours the growth factors listed in ARR2016 will be used to extrapolate the 1% AEP rainfalls. As this study is only considering the 0.2% AEP rare event, a growth factor of 1.344 will be used (refer Book 8, Section 3.6.3, ARR2016).

3.2 Temporal distribution

3.2.1 Frequent events

Temporal patterns for frequent events will be sourced from AR&R 1987. Zone 6 temporal patterns will be used.

3.2.2 Rare events

The 0.2% AEP (500 year ARI) event will use temporal patterns tabled in the Bureau of Meteorology's Generalised Southeast Australia Method (GSAM) (Bureau of Meteorology, 2006) and General Short Duration Method (GSDM) (Bureau of Meteorology, 2003).

Storms with durations less than or equal to 3 hours will use the GSDM temporal pattern. Storms with durations greater than 3 hours will use the GSAM temporal patterns.

3.3 Spatial distribution

Due to the size of the Study Area, a uniform spatial pattern will be used for all events.

4 Runoff estimation

4.1 Urban and rural areas

Hydrographs will be created using the Time–Area method and the ILSAX hydrological model. The ILSAX hydrological model splits each sub catchment into three sub areas: directly and indirectly connected impervious area, and pervious area. The pervious area losses will be based on an Initial Loss – Continuing Loss model.

Different initial loss values will be used for rural and urban areas.

The initial and continuing losses will be varied depending on the type of event.

4.1.1 Frequent event losses

The rainfall loss parameters proposed are set out Table 4.1. A higher initial loss is used in the urban areas to account for additional losses incurred by urban features, such as fences, that retain water within the catchment. These values match those recommended by ARR 2016 and Kemp & Lipp (2013).

Table 4.1 Loss parameters used for frequent events

Parameter	Unit	Value
Impervious area depression storage	mm	1
Urban pervious area depression storage (equivalent to an initial loss)	mm	45
Rural pervious area depression storage (equivalent to an initial loss)	mm	30
Pervious area continuing loss	mm/hr	3

4.1.2 Rare event losses

The rainfall loss parameters proposed are set out in Table 4.2 were logarithmically interpolated in accordance with procedures in AR&R to provide a smooth transition between frequent and extreme events (refer section 3.1). The interpolation is based on Equation 7 of Book VI (p34) within AR&R (updated in 1998).

Table 4.2 Loss parameters used for the 0.2% AEP event

Parameter	Unit	Value
Impervious area depression storage	mm	1
Urban pervious area depression storage (equivalent to an initial loss)	mm	15.5
Rural pervious area depression storage (equivalent to an initial loss)	mm	11.1
Pervious area continuing loss	mm/hr	2.5

4.1.3 Extreme event losses

The rainfall loss parameters in Table 4.3 are provided for reference only. The values in Table 4.3 represent the lower bound for interpolation of the rare event losses (refer section 4.1.2).

Table 4.3 Loss parameters used for extreme events

Parameter	Unit	Value
Impervious area depression storage	mm	1
Urban and rural pervious area depression storage (equivalent to an initial loss)	mm	0
Pervious area continuing loss	mm/hr	1

4.2 Hills face catchments

Hydrographs for (external) Hills face catchments will be generated using RORB models and will be applied at the upstream boundary of the 2D hydraulic model. The Initial Loss – Continuing Loss model will be used to generate subarea runoff.

The following parameter values for the RORB model have been selected to be consistent with those of the *Dry Creek Floodplain Mapping Study* (Tonkin Consulting, 2008). The parameters of that study were based on calibration against gauged values. The hydrology report that was prepared received the approval of the AMLR NRM Board, the City of Salisbury, the Bureau of Meteorology and the Department of Planning, Transport and Infrastructure. Use of the same parameters is considered to be appropriate given the similar topography of the two areas.

4.2.1 Hills face losses

A continuing loss between 1 mm/hr and 3 mm/hr is proposed depending on the probability of the storm event. The initial loss will be varied depending on the probability of the storm. The proposed losses are tabled below.

Table 4.4 Loss parameters for RORB models

Event Type	AEP	ARI (years)	Initial loss (mm)	Continuing loss (mm/hr)
Frequent	≤ 5%	20	25	3
Frequent	2%	50	30	3
Frequent	1%	100	40	3
Rare	0.2%	500	20*	2.5
Extreme	*10^{-4}*	*PMF*	*0*	*1.0*

*Selected in discussion with the SMA

The PMF values are shown for reference only; they are used to interpolate the parameter values of the 0.2% AEP event.

4.2.2 RORB modelling parameters

The routing in RORB is based on two parameters – the non-linearity exponent, m, and the routing parameter, k_c.

The k_c value for each catchment will be derived using Equation 3.25 from AR&R (as follows):

$$k_c = 0.6A^{0.67}$$

This equation applies to the south eastern area of South Australia and provides a value of k_c for catchments with an area less than 100 km^2.

Calibration guidance in AR&R suggests that m should be held constant at 0.8, whilst k_c is varied, unless there is good data to suggest another value of m is more appropriate. Since the local Gawler catchments are ungauged it is considered that there is no evidence to available to suggest an alternative value. Therefore, a value of 0.8 for the non-linearity exponent is recommended for this project.

4.3 Gawler, North Para and South Para rivers

Inundation due to riverine flooding in the Gawler, North Para or South Para rivers is not within the scope of the Stormwater Management Plan. Local drainage systems will be modelled discharging to these river systems, however, no hydrologic inputs from these rivers will be included in the hydraulic modelling.

5 Bibliography

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Pilgrim, DH (ed.), 1987, *Australian Rainfall and Runoff – A Guide to Flood Estimation*, Institution of Engineers Australia, Barwon.

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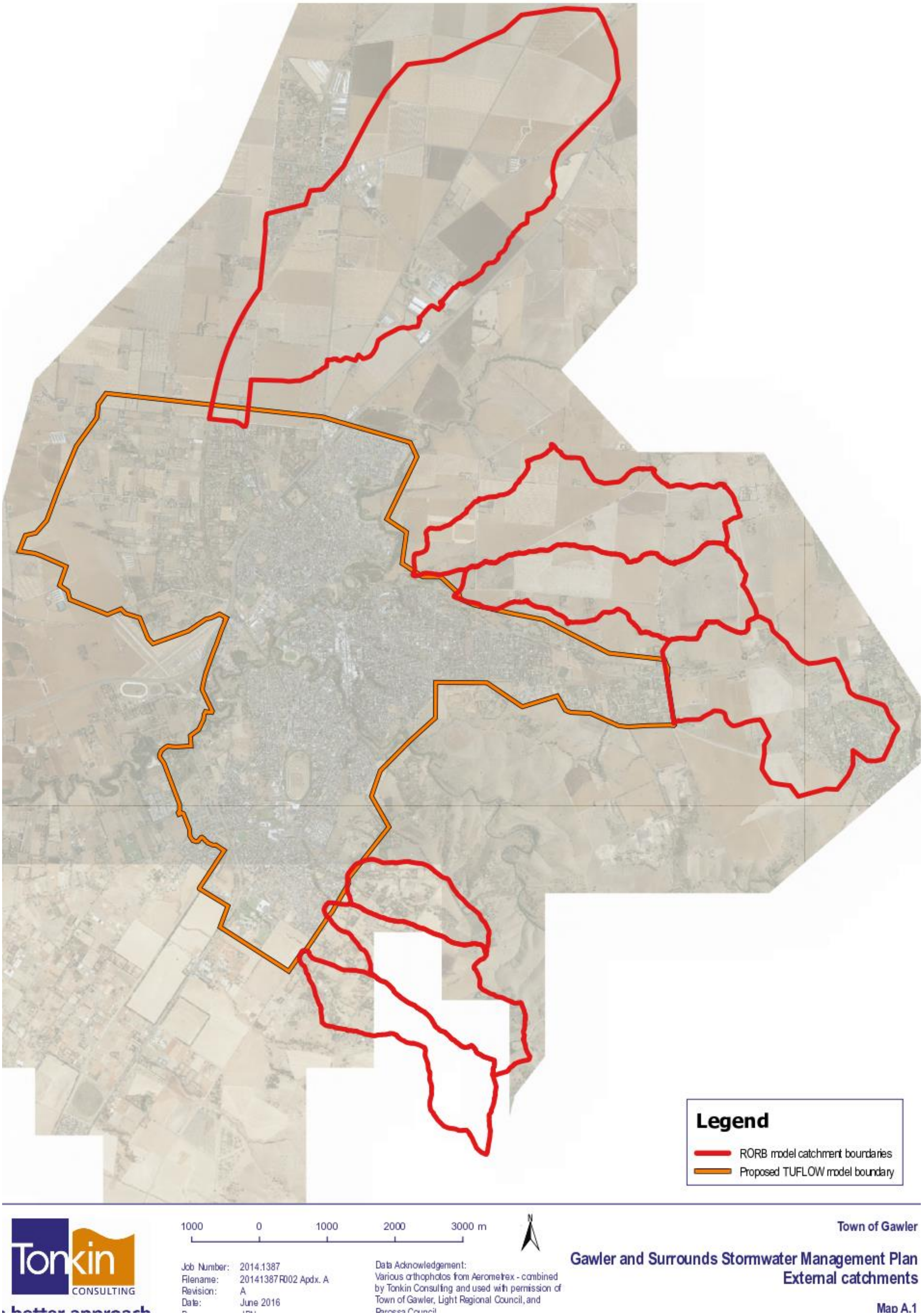
Appendix A

RORB model areas


Legend
RORB model catchment boundaries
Proposed TUFLOW model boundary
1000 0 1000 2000 3000 m
N
Job Number: 2014.1387
Filename: 20141387R002 Apdx. A
Revision: A
Date: June 2016
Data Acknowledgement:
Various orthophotos from Aerometrex - combined by Tonkin Consulting and used with permission of Town of Gawler, Light Regional Council, and
Town of Gawler
Gawler and Surrounds Stormwater Management Plan
External catchments
Map A.1

Appendix B

Residential Total Impervious Area Sample Sites

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Filename: 20141387 - impervious area estimation.qgs
Revision: Rev. A
Date: 1 Aug 2016
Drawn: JDN

Data Acknowledgement:
Imagery from Aerometrex Pty Ltd
(used with permission from Council)

Town of Gawler, Light Regional Council, Barossa Council

Gawler and Surrounds Stormwater Management Plan
Impervious area percentage

Figure B.1

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25 0 25 50 75 m

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Filename: 20141387 - impervious area estimation.qgs
Revision: Rev. A
Date: 1 Aug 2016
Drawn: JDN

Data Acknowledgement:
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N

Town of Gawler, Light Regional Council, Barossa Council

Gawler and Surrounds Stormwater Management Plan
Impervious area percentage

Figure B.2

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Data Acknowledgement:
Imagery from Aerometrex Pty Ltd
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Town of Gawler, Light Regional Council, Barossa Council

Gawler and Surrounds Stormwater Management Plan
Impervious area percentage

Figure B.3

45.54
16.98
32.48
15.5
24.74
19.56
38.26
13.35
26.6
30.2
30.6
25.47
26.06
Legend
Impervious areas
Total impervious area (%)
0 - 15
15 - 30
30 - 45
45 - 60
60 - 100
25 0 25 50 75 m
Tonkin CONSULTING
a better approach
Job Number: 2014.1387
Filename: 20141387 - impervious area estimation.qgs
Revision: Rev. A
Date: 1 Aug 2016
Drawn: JDN
Data Acknowledgement:
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(used with permission from Council)
N
Town of Gawler, Light Regional Council, Barossa Council
Gawler and Surrounds Stormwater Management Plan
Impervious area percentage
Figure B.4

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25 0 25 50 75 m

Job Number: 2014.1387
Filename: 20141387 - impervious area estimation.qgs
Revision: Rev. A
Date: 1 Aug 2016
Drawn: JDN

Data Acknowledgement:
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N

Town of Gawler, Light Regional Council, Barossa Council

Gawler and Surrounds Stormwater Management Plan
Impervious area percentage

Figure B.5

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25 0 25 50 75 m

Job Number: 2014.1387
Filename: 20141387 - impervious area estimation.qgs
Revision: Rev. A
Date: 1 Aug 2016
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Data Acknowledgement:
Imagery from Aerometrex Pty Ltd
(used with permission from Council)

N

Town of Gawler, Light Regional Council, Barossa Council

Gawler and Surrounds Stormwater Management Plan
Impervious area percentage

Figure B.6


34.52
36.97
40.05
26.17
15.3
28.5
24.8
23.67
26.87
16.81
23.23
30.06
34.61
22.84
30.56
33.54
41.3
32.31
49.91
23.22
20.55
27.08
19.2
36.99
Legend
Impervious areas
Total impervious area (%)
0 - 15
15 - 30
30 - 45
45 - 60
60 - 100
25 0 25 50 75 m
Job Number: 2014.1387
Filename: 20141387 - impervious area estimation.qgs
Revision: Rev. A
Date: 1 Aug 2016
Drawn: JDN
Data Acknowledgement:
Imagery from Aerometrex Pty Ltd
(used with permission from Council)
N
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Town of Gawler, Light Regional Council, Barossa Council
Gawler and Surrounds Stormwater Management Plan
Impervious area percentage
Figure B.7

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Gawler and Surrounds Stormwater Management Plan
Impervious area percentage

Figure B.8

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Filename: 20141387 - impervious area estimation.qgs
Revision: Rev. A
Date: 1 Aug 2016
Drawn: JDN

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Town of Gawler, Light Regional Council, Barossa Council

Gawler and Surrounds Stormwater Management Plan
Impervious area percentage

Figure B.9

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Appendix B

Long term development scenario discussion paper

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Memorandum

TO	Gawler and Surrounds SMP Steering Committee				
FROM	Tonkin Consulting	**DATE**	2017-05-16	**JOB NO.**	2014.1387
SUBJECT	Long Term Development Scenario				

For your information, please find attached a summary of the change in catchment imperviousness for the Long Term Development scenario based on the approved *Development Potential Assessment Discussion Paper* prepared by Jensen Planning+Design (now Jensen PLUS).

The Development Potential Assessment reviewed the current development planning policies and projected future development within the Study Area. The discussion paper concludes with a summary of the potential changes in development density and the likely impacts on catchment imperviousness. The discussion paper and its summary has been interpreted by Tonkin Consulting to arrive at specific estimates of changes in catchment imperviousness.

Table 4 (p. 55) of the *Development Potential Assessment Discussion Paper* is replicated and expanded here to demonstrate the process by which the adjusted long term impervious area values were determined.

Also included is a series of maps illustrating several attributes of the Development Zones and Policy Areas. Maps 1 and 2 show the average percent Directly Connected Impervious Area (DCIA) for each development zone. Map 1 shows the Existing Development Scenario and Map 2 the Long Term Development Scenario. Map 3 shows the change in DCIA between the Existing Development and Long Term Development scenarios (expressed as a percentage of the Existing DCIA).

In some zones the percent changes are very high (100-1000%). When examining the absolute values of DCIA, however, it becomes clear that the change is appropriate and commensurate with the findings of the Development Potential Assessment. Generally, this magnitude of change occurs in areas where there is little to no DCIA assigned in the Existing Development Scenario, such as rural areas or currently vacant land.

Kemp & Myers (2015) reviewed the hydrologic impacts of infill development within a gauged urban catchment of Glenelg using a calibrated hydrologic model. Kemp & Myers found close to a 15% change in directly connected impervious area over the 20 years between 1993 and 2013. This finding closely matched estimated increases in DCIA based on inspection of aerial photography of the catchment. In the catchment analysed infill development was projected to increase 0.65% per annum through to 2040, resulting in a further 17% increase in DCIA over 2013 levels. Interestingly, the authors appear to find little to no change in the mean indirectly connected impervious area between 1993 and 2013. The projected increase in DCIA in areas 3, 4, and 11 align closely with the findings of Kemp & Myers and gives some confidence in the process undertaken.

Finally, in zones that are already highly developed (such as Zone 1) there is very minimal change in DCIA. In residential areas, this reflects the existing levels of newer, medium density development on smaller allotments with little potential for infill. In commercial areas, this reflects to already high levels of impervious surface area from carparks and buildings.

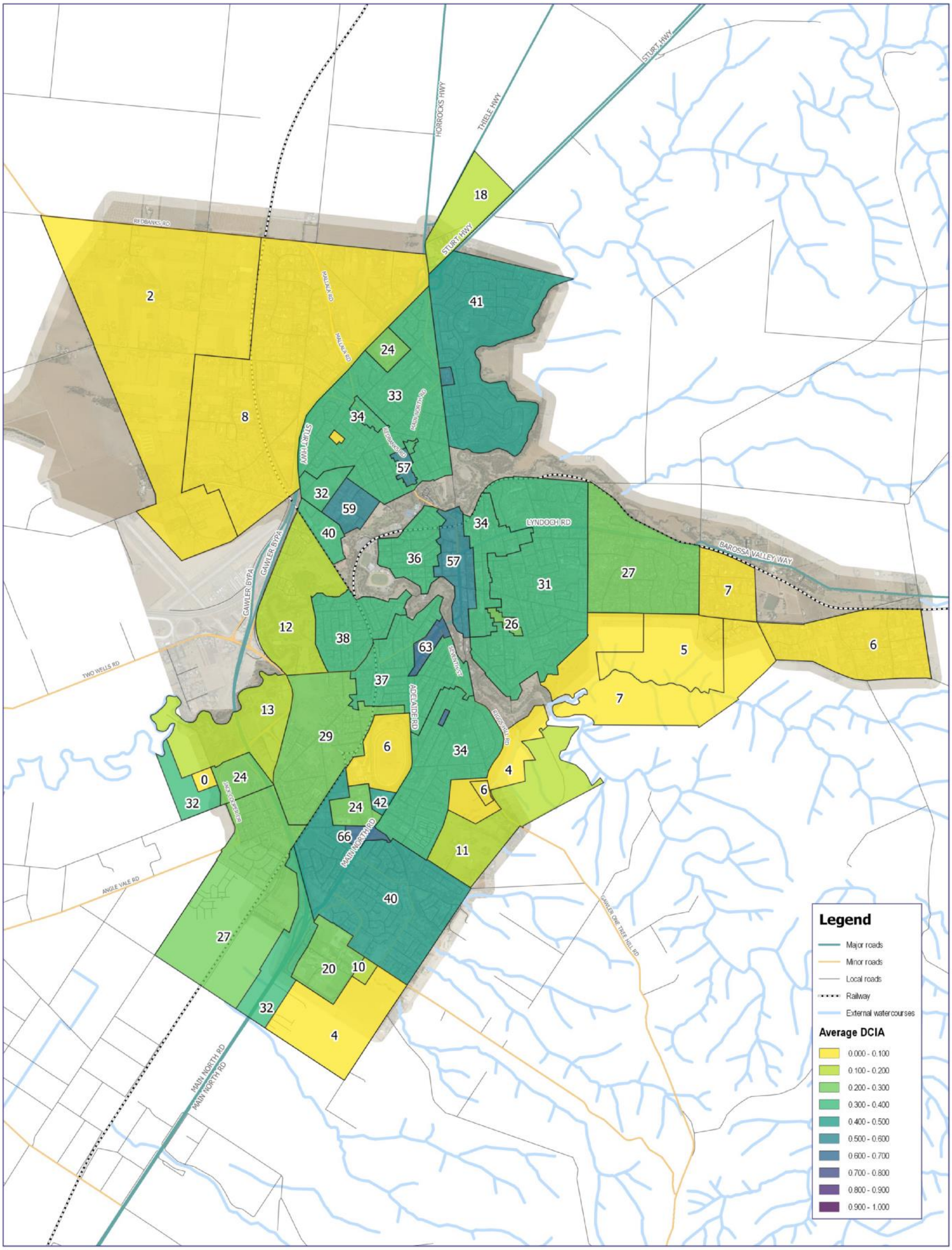
References

Kemp, DJ, and Myers, BR, 2015, A verification of the hydrological impact of 20 years of infill development in an urban catchment. In proceedings: *36th Hydrology and Water Resources Symposium: The art and science of water*, Engineers Australia, Barton, ACT, pp. 379-386.

Project Number: 2014.1387
Project Title: Gawler and Surrounds SMP
Author: JDN
Reviewer: TAK

Source: Table 4 from Development Potential Assessment Discussion Paper, Jensen Planning + Design, 2016.

Area	Zone/Policy Area	Potential for Change in Imperviousness	Tonkin interpretation
1	Gawler Belt Residential – Policy Area 7 (Light Regional Council)	Low – typical new suburban	This zone is mostly fully developed. Undeveloped vacant land is assumed to become fully developed and has been assigned 0.6 DCIA proportion. Existing low density allotments were increased from [0.25, 0.1] to [0.3, 0.15] direct-indirect proportions to account for minor infill over time.
2	Residential Zone - Willaston Policy Area	Medium – infill potential on many larger residential lots	Maximum site coverage for blocks < 300 m^2 in area is 55% according to current Town of Gawler policy (40% for blocks > 800 m^2). Therefore, all blocks have been assigned [0.45, 0.15] if < 300 m^2, [0.45, 0.05] if 300-450 m^2, and [0.45, 0.15] if greater than 800 m^2 on the assumption that these large allotments will eventually be subdivided.
2a	Residential Zone - Willaston Policy Area – Flood Risk	Low / medium – infill potential but within a flood risk area	Although technically with flood risk area existing development already exhibits high site coverage per allotment. It is assumed that this trend will continue in this area and proportions were assigned in the same way as Area 2.
3	Residential Zone – Gawler East Policy Area 6	Low / medium – infill potential but only on vacant (or larger) lots	Vacant allotments were assigned [0.45, 0.1] direct-indirect proportions (i.e. equalling 55% Town of Gawler policy). Existing lots changed from [0.25, 0.1] to [0.3, 0.1] to account for minor infill.
4	Residential Zone - Wheatsheaf Policy Area	Low – 2,000 m^2 minimum lot size and area is fully developed	This area is already fully developed. Minor infill and development of vacant land only. Therefore, increased existing low density development from [0.25, 0.1] to [0.3, 0.1]. Vacant land was also set to [0.3, 0.1] to account for minimum lot size of 2,000 m^2.
5	Residential (Gawler East) Zone	High – transition from greenfield to residential	Greenfield site with medium density housing. Mostly outside of modelled catchment area. Assigned [0.6, 0.05] direct-indirect to match other recent developments.
6	Residential Zone – Gawler West	Low – medium	This area has relatively high DCIA due to Maisonettes land use type. Therefore, updated low density allotments to [0.3, 0.1] up from [0.25, 0.1] to account for infill. Vacant allotments set to [0.45, 0.1] to equal Town of Gawler 55% site coverage allowance.
6a	Residential Zone – Gawler West – Flood Risk	Low – flood prone land but infill sites available	As per Area 6.
7	Residential Zone - Hillier Road Policy Area	Medium – infill potential on many larger residential lots	Existing infill development has been classed as medium density 0.6 direct runoff - new infill development would likely be similar. However, areas within the Gawler River Floodplain are prohibited from further infill. All remaining lots upgraded from 0.25 to 0.45 direct + 0.1 indirect (i.e. 55% Council allowance) - these lots are large and undergoing development to very high density.
7a	Residential Zone – Hillier Road Policy Area – Flood Risk	High – assuming development on flood risk vacant land is approved	This area is well within the Gawler River floodplain, therefore, it is assumed no development will be permitted to occur - no change in DCIA.
8	Residential Zone – Gawler South Policy Area	Low – fully developed newer homes	High coverage of newer homes. Therefore, residential allotments were set to [0.55, 0.1] direct-indirect to match.
8a	Residential Zone – Gawler South Policy Area	Low – fully developed new homes (minimum lot size of 2,000 m^2)	Due to minimum lot size, this area should have lower DCIA. Therefore, residential allotments set to [0.3, 0.1] direct-indirect proportion (similar to Area 4).
8b	Residential Zone – Gawler South Policy Area	Low / medium – infill potential on larger residential lots	Medium infill of vacant and large blocks. Therefore, residential allotments set to [0.4, 0.1] direct-indirect to account for slightly higher potential for subdivision.
9	Local Centre Zone	High – currently vacant	This area is zoned to be a local community hub with high density development, therefore, proportions [0.75, 0.15] to match other commercial areas in the study area.
10	Residential (Hills) Zone	High – assuming transition from rural living to residential	Entire area set to [0.6, 0.15] direct-indirect to represent medium density development similar to other recently developed sites.
11	Residential Zone – Evanston / Evanston Park Policy Area	Low – fully developed new homes	Minimal infill of vacant blocks. Proportions of residential allotments set to [0.35, 0.1] direct-indirect up from [0.25, 0.1].
12	Residential Zone – Evanston Gardens / Evanston South / Hillier Policy Area	High – mostly vacant (transition to residential)	New greenfield site. Area set [0.6, 0.1] direct-indirect to represent medium density new urban areas.
13	Town Centre Historic (Conservation) Zones	Low – fully developed	A few vacant allotments altered to match proportions of other commercial sites. Otherwise unchanged.
14	Residential Historic (Conservation) Zones	Low / medium – infill potential on larger sites and sites without heritage / contributory places, but within Historic (Conservation) Zone	All vacant residential allotments set to have medium density coverage [0.6, 0.1] direct-indirect. All other residential allotments set to have [0.27, 0.1] direct-indirect (changed from [0.25, 0.1]) to represent very minor infill of conservation allotments.
14a	Residential Historic (Conservation) Zones	Low	All vacant residential allotments set to medium density coverage [0.6, 0.1] direct-indirect.
14b	Residential Historic (Conservation) Zones	Low	All vacant residential allotments set to have medium density coverage [0.6, 0.1] direct-indirect. All other residential allotments set to have [0.27, 0.1] direct-indirect (changed from [0.25, 0.1]) to represent very minor infill of conservation allotments.
15	Rural Living Zones (including Light Regional Council)	Low – rural living, fully developed residential (although some additional land division may occur), flood prone	**Precinct 32:** Jensen Planning+Design suggests low increase due to subdivision. Ultimately, lot sizes will be similar to Precinct 31 (rural living east of railway), therefore, the imperviousness of allotments in Precinct 32 has been increased to similar levels (specifically 0.12 indirect, up from 0.03). Where the minimum allotment size is 4 ha, indirect changed to 0.05 since this area is mostly fully developed already. All Rural Living allotments were set to have 0.01 direct proportion to match Precinct 31. Final values for Rural Living allotments were [0.01, 0.12] direct-indirect. **Precinct 31:** Basically already fully developed. Vacant land and large agricultural allotments assumed to become Rural Living use, and some additional infill from sheds etc. Direct set to 0.01 and, indirect set to 0.15 up from 0.1.
16	Township Zone (Barossa Council)	High – further residential potential on 1,200 m^2 lots	Set to match medium density urban housing, [0.3, 0.1] direct-indirect. Limited affect on hydrology given size of surrounding catchment.
17	Rural Living – Precinct 21 Cockatoo Valley (Barossa Council)	Low - fully developed rural residential (minimum lot size of 1 ha)	No change.



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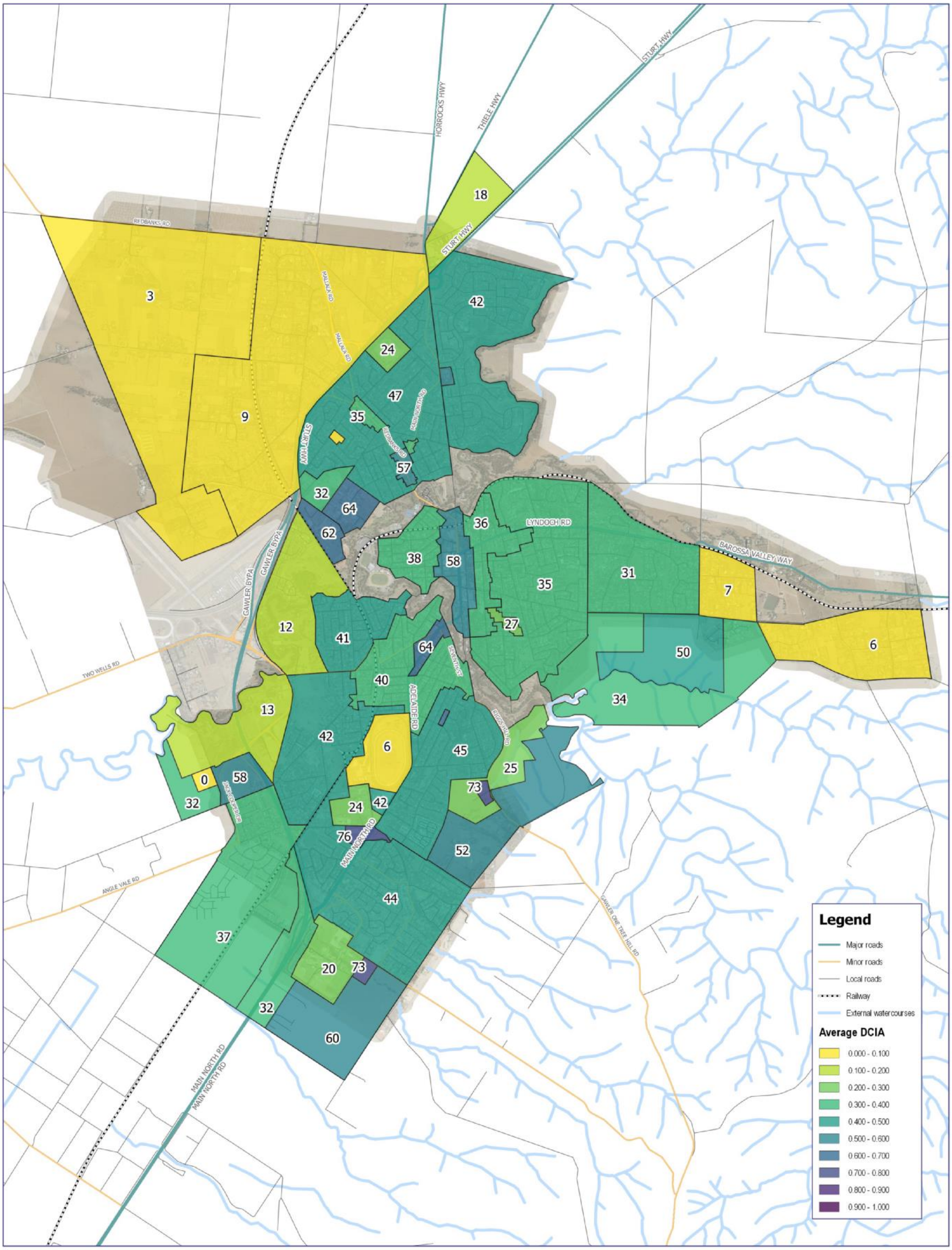
Composite aerial imagery from Aerometrex, used with permission of councils.
Development zones from DPTI, 2017, modified by Tonkin Consulting

TOWN OF GAWLER, LIGHT REGIONAL COUNCIL, and BAROSSA COUNCIL

GAWLER AND SURROUNDS STORMWATER MANAGEMENT PLAN
Average DCIA for Existing Development Scenario

Map 1



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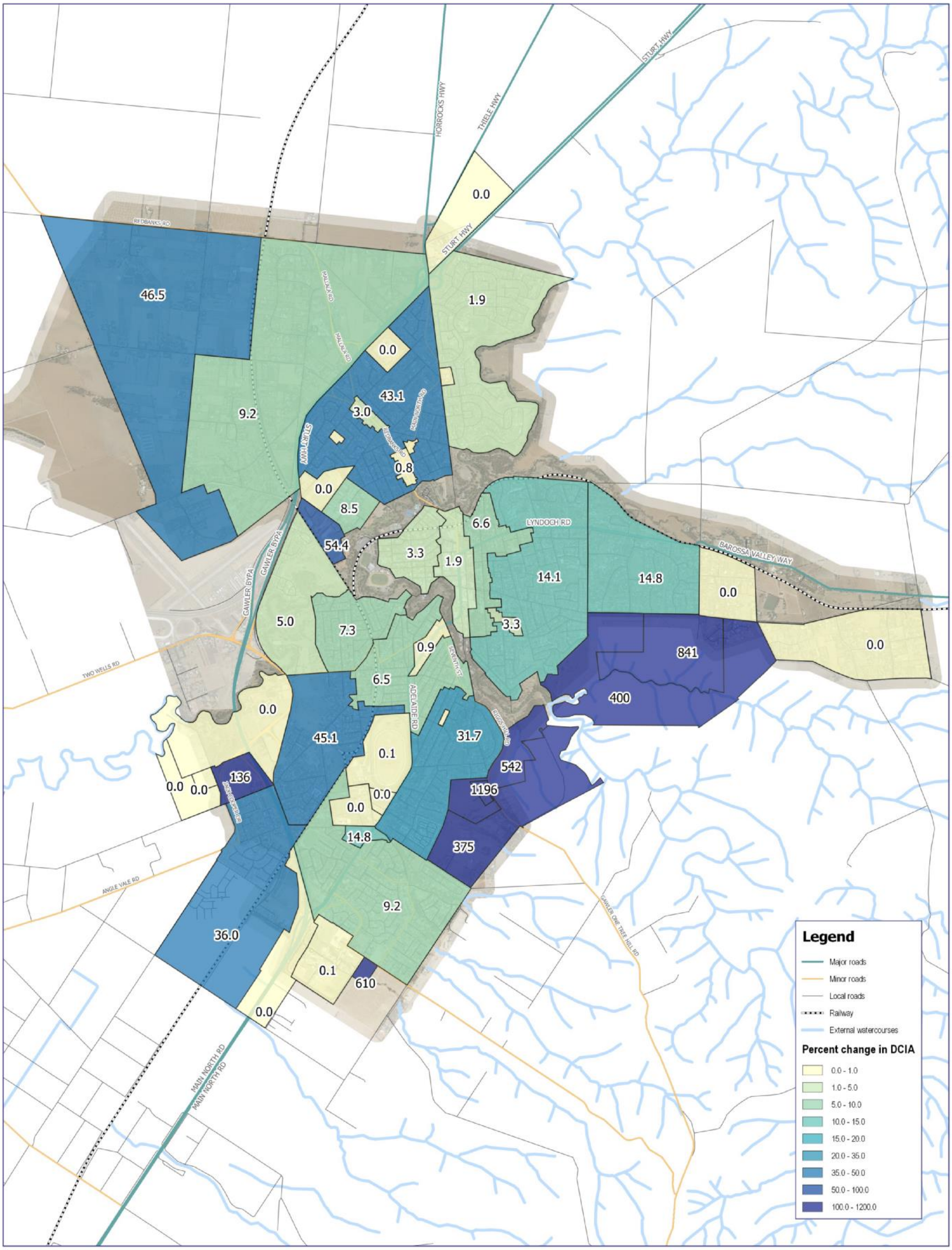
TOWN OF GAWLER, LIGHT REGIONAL COUNCIL, and BAROSSA COUNCIL

GAWLER AND SURROUNDS STORMWATER MANAGEMENT PLAN
Average DCIA Long Term Development Scenario

Map 2



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TOWN OF GAWLER, LIGHT REGIONAL COUNCIL, and BAROSSA COUNCIL

GAWLER AND SURROUNDS STORMWATER MANAGEMENT PLAN
Percent change in DCIA between Existing and Long Term scenarios

Map 3

Appendix C – Gawler River levee bank discussion paper

Levee Bank Discussion Paper

Town of Gawler

May 2018

Ref No. 20141387R007A

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Document History and Status

Rev	Description	Author	Reviewed	Approved	Date
A	Draft	TAK	MM	TAK	28/5/18

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Contents

1 Introduction 1

1.1 Background 1

2 Levee Options 2

2.1 Introduction 2

2.1.1 Type 1: Standard Levee 2
2.1.2 Type 2: Steep Batters 2
2.1.3 Type 3: Vertical Wall Levee 2
2.1.4 Temporary Levee 2

3 Levee Detailed Concept Design Discussion 3

3.1 Introduction 3

3.1.1 MC00 – Southern Levee 3
3.1.2 MC10 – Eastern Levee 3
3.1.3 MC20 – Drury Street Levee 4
3.1.4 MC30 – Bright Street Levee 4
3.1.5 MC40 – Kelly Road Levee 4

4 Vegetation Impact Assessment 6

Tables

Table 3.1 Southern Levee Design Comments 3
Table 3.2 Eastern Levee Design Comments 3
Table 3.3 Drury Street Levee Design Comments 4
Table 3.4 Bright Street Levee Design Comments 4
Table 3.5 Kelly Road Levee Design Comments 4
Table 4.1 Vegetation Impacts Assessment Summary 6

Appendices

Appendix A Levee Bank Preliminary Design Drawings
Appendix B Levee Bank Assessment Report

1 Introduction

1.1 Background

A concept levee bank alignment has been proposed through portions of the Gawler township to reduce flood risk due to break out from the Gawler River. The levee alignment levels have been set relative to predicted flood levels based on flood modelling undertaken by Australian Water Environments.

The alignment of the levee was only conceptual and did not take into consideration a number of factors that have now been considered in more detail as part of this study.

Since the levee alignments were initially determined, the Gawler River flood plain maps have been updated. These show less flooding in the vicinity of the levee banks at a number of locations and as such the extents of the levee could potentially be reduced. However, for completeness, the full original alignment has been assessed as part of this report.

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2 Levee Options

2.1 Introduction

The levee alignment has been digitised and overlaid onto the aerial photography and the digital terrain model (DTM). This has allowed for alignment iterations to be made to minimise clashes along the alignment with existing infrastructure.

There are three different levee options that have been considered along the alignment. The option selected in each area has typically been selected based on site constraints. The three types of levee are summarised below. The top of levee level has been set to be 300mm above the predicted 100-yr average recurrence interval (ARI) flood level.

2.1.1 Type 1: Standard Levee

The standard levee has been designed with a 2.5m top width to allow for a walking trail, if required, to be positioned on top of the levee. The levee batters are at 1 vertical to 4 horizontal, which allow for them to be maintained and easily traversable.

2.1.2 Type 2: Steep Batters

The Type 2 levee is similar to the Type 1 with the exception that one or both of the batters are steeper than 1 in 4. Batters as steep as 1 in 2 have been used. In these locations maintenance will be difficult, vegetation establishment will be more challenging and localised scour gullies may occur down the batters due to their steepness. These are typically required where there is not space to fit in a Type 1 levee.

2.1.3 Type 3: Vertical Wall Levee

The Type 3 levees are needed where space is constrained and the other types of levees would not fit. This type of levee would be in the form of a vertical wall and would not be traversable.

2.1.4 Temporary Levee

In a number of locations the levee will pass over areas that cannot be permanently blocked off, such as rail lines, roads and driveways. In these locations it is likely that a temporary levee would need to be installed by emergency services as part of flood response works.

3 Levee Detailed Concept Design Discussion

3.1 Introduction

The levee bank is comprised of five different sections. Each element has been designed along a separate design string. The name of each string, along with the design chainages is shown in Appendix A along with a layout plan, overlaid onto aerial photography.

3.1.1 MC00 – Southern Levee

Table 3.1 Southern Levee Design Comments

Chainage	Levee Type	Discussion
70-110	Type 1	All of levee within private property
110-240	Type 3	Limited space available between car park and building and top of river bank.
240-260	Temporary	Temporary levee needed to allow access along Fourteenth Street.
260-340	Type 1	Within reserve area
340-720	Type 2	Steeper batters needed to reduce total width of levee that drops down into lower lying land to the north. Potential pedestrian path impacts.
720-1000	Type 1	Top of levee matches closely with rail levels at chainage 790 and 840. Temporary levee potentially needed at these locations.
1000-1150	Type 2	Steeper batters needed to fit levee between properties, Argent Lane and the top of river bank
1150-1240	Type 1	Partly in private property
1240-1380	Type 3	Vertical levee needed due to lack of space between existing dwelling and driveway and top of river bank.
1380-1510	Type 1	Potential vegetation impacts
1510-1850	Type 2	Steeper batters needed to reduce total width of levee. Vegetation impacts in some locations.
1850-2490	Type 1	Relatively clear area for embankment works

3.1.2 MC10 – Eastern Levee

Table 3.2 Eastern Levee Design Comments

Chainage	Levee Type	Discussion
0-140	Type 3	Very limited space between footpath along Paterson Terrace and the top of bank. Visual impacts due to close proximity to residential areas.
140-160	Temporary	Temporary levee needed to allow access into sports facility
160-350	Type 1	Levee bank virtually all within open space. Alternative would be to have a vertical levee at the property boundary. Visual impacts due to close proximity to residential areas.
354-440	Type 3	Vertical levee bank needed at property boundary to prevent impact on infrastructure within private property. Visual impacts due to close proximity to residential areas.
440-450	Temporary	Temporary levee needed to allow access into community centre.
450-530	Type 3	Vertical levee bank needed at property boundary to prevent losing car parks.

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Chainage	Levee Type	Discussion
530-540	Temporary	Temporary levee needed to allow access into community centre.
540-660	Type 1	Significant tree impacts in this area.
660-780	Type 3	Limited space would require vertical levee in this area. Levee will cross main access path to rail station which may require use of a temporary levee.
780-900	Type 1	Significant tree impacts in this area.
900-980	Type 3	Limited space available.
980-1020	Temporary	Temporary levee needed across rail line and across Hallam Drive
1020-1050	Type 3	Limited space available.
1050-1210	Type 1	Within private property. Some access issues and removal of existing infrastructure required. Significant tree impacts. Vertical walls and temporary levees potentially needed in this area.
1210-1250	Type 3	Vertical levee likely to be required at back of footpath.

3.1.3 MC20 – Drury Street Levee

Table 3.3 Drury Street Levee Design Comments

Chainage	Levee Type	Discussion
0-50	Type 1	Crosses a pedestrian track that would need to be mounded, unless a temporary levee is used. Levee also crosses over a local overland flood flow path and therefore would have the potential to locally increase flood risk.
50-170	Type 3	Levee bank passes through private property that backs onto the river. Some existing fence and shed infrastructure would need removal and some blocks would be split into two.
170-200	Type 1	Levee would potentially hinder existing access to property from southern end of Drury Street.
200-270	Type 2	Steeper batters needed to ensure levee batters do not extend into main channel

3.1.4 MC30 – Bright Street Levee

Table 3.4 Bright Street Levee Design Comments

Chainage	Levee Type	Discussion
0-70	Type 1	Levee crosses over an access road at the southern end of Bright Street. The road would either need to be mounded or have a temporary levee installed.

3.1.5 MC40 – Kelly Road Levee

Table 3.5 Kelly Road Levee Design Comments

Chainage	Levee Type	Discussion
0-170	Type 1	Levee impacts on a large storage tank at chainage 120. A vertical wall may be needed at this location.

Chainage	Levee Type	Discussion
170-230	Type 3	Levee bank passes at the rear of a car park that is in close proximity to the main river top of bank. A small portion of the car park is likely to be impacted.
230-355	Type 1	A number of significant trees in this area. All of levee in private property and impacts on a driveway at chainage 290.
355-370	Temporary	Levee alignment crosses Kelly Road. A levee at this location will block a localised overland flood flow path
370-430	Type 1	All within private property
430-450	Temporary	Levee alignment crosses the main access road to a large commercial facility
450-750	Type 1	All within private property. Levee blocks a local overland flood flow path at chainage 745.

4 Vegetation Impact Assessment

A vegetation impact assessment was undertaken by Eco Management Services that involved a field assessment along the full length of the levee. The levee alignment was separated into 38 portions. The potential impact on each section of levee bank was rated as low, moderate or high as summarised in Table 4.1Table 4.1.

The assessment did highlight significant vegetation impacts with approximately 24% of the alignment having high vegetation impacts.

Table 4.1 Vegetation Impacts Assessment Summary

Impact	Number of Sections	Length (m)	% of total
Low	19	2,750	56
Moderate	6	620	13
High	10	1,190	24
Unclassified (no access)	3	330	7

The full assessment report is contained within Appendix B.

Appendix A

Levee Bank Preliminary Design Drawings

DATUM: 40.00

GRADE: 0% | -0.01% | 0% | 0% | -0.11% | -0.07% | -0.19%

VERTICAL GEOMETRY

HORIZONTAL GEOMETRY

CHAINAGE	DESIGN	EXISTING	+ CUT / - FILL
0.000		46.483	
25.000		49.794	
50.000		48.563	
75.000	47.130	46.645	-0.485
100.000	47.130	46.223	-0.907
125.000	47.130	46.619	-0.511
150.000	47.130	46.757	-0.373
175.000	47.130	46.485	-0.645
200.000	47.130	45.278	-1.852
225.000	47.129	46.083	-1.046
250.000	47.127	45.360	-1.767
275.000	47.126	46.335	-0.791
300.000	47.125	46.209	-0.916
325.000	47.124	46.280	-0.844
350.000	47.123	45.314	-1.808
375.000	47.121	44.027	-3.094
400.000	47.120	44.154	-2.966
425.000	47.120	44.471	-2.649
450.000	47.120	44.557	-2.563
475.000	47.120	46.739	-0.381
500.000	47.120	45.078	-2.042
525.000	47.120	44.135	-2.985
550.000	47.120	45.215	-1.905
575.000	47.120	45.315	-1.805
600.000	47.120	45.928	-1.192
625.000	47.120	45.564	-1.556
650.000	47.120	45.508	-1.612
675.000	47.120	45.116	-2.004
700.000	47.120	45.786	-1.334
725.000	47.120	45.775	-1.345
750.000	47.120	45.700	-1.420
775.000	47.120	44.340	-2.780
800.000	47.120	45.950	-1.170
825.000	47.091	46.081	-1.011
850.000	47.063	46.030	-1.033
875.000	47.034	45.788	-1.245
900.000	47.005	45.824	-1.181
925.000	46.976	45.546	-1.430
950.000	46.947	45.481	-1.467
975.000	46.919	45.526	-1.393
1000.000	46.890	45.555	-1.335
1025.000	46.874	45.618	-1.256
1050.000	46.858	45.536	-1.322
1075.000	46.841	45.572	-1.270
1100.000	46.825	45.702	-1.123
1125.000	46.809	45.770	-1.039
1150.000	46.792	45.650	-1.142
1175.000	46.776	45.486	-1.291
1200.000	46.760	45.714	-1.046
1225.000	46.712	45.426	-1.287
1250.000	46.665	45.095	-1.570
1275.000	46.618	44.480	-2.137
1300.000	46.570	45.070	-1.500
1325.000	46.523	45.232	-1.291
1350.000	46.475	45.264	-1.211
1375.000	46.428	45.207	-1.221
1400.000	46.380	45.071	-1.309
1425.000	46.369	44.921	-1.448
1450.000	46.358	44.949	-1.409

LONGITUDINAL PROFILE - MC00

HORIZONTAL SCALE 1 : 2000

VERTICAL SCALE 1 : 200

DATUM: 40.00

GRADE: -0.05% | -0.11% | -0.43% | -0.07% | -0.01% | 0%

VERTICAL GEOMETRY

HORIZONTAL GEOMETRY

CHAINAGE	DESIGN	EXISTING	+ CUT / - FILL
1450.000	46.358	44.949	-1.409
1475.000	46.346	45.255	-1.091
1500.000	46.335	44.706	-1.629
1525.000	46.324	43.452	-2.872
1550.000	46.313	42.779	-3.534
1575.000	46.301	42.616	-3.685
1600.000	46.290	43.002	-3.288
1625.000	46.264	43.900	-2.364
1650.000	46.237	44.483	-1.754
1675.000	46.211	43.804	-2.408
1700.000	46.185	43.591	-2.594
1725.000	46.159	43.349	-2.810
1750.000	46.133	43.239	-2.894
1775.000	46.106	42.627	-3.479
1800.000	46.080	42.709	-3.371
1825.000	45.971	43.353	-2.618
1850.000	45.862	44.395	-1.468
1875.000	45.754	44.894	-0.859
1900.000	45.645	44.731	-0.914
1925.000	45.536	44.528	-1.008
1950.000	45.428	44.483	-0.945
1975.000	45.319	44.407	-0.912
2000.000	45.210	44.347	-0.863
2025.000	45.191	44.395	-0.796
2050.000	45.172	44.325	-0.847
2075.000	45.154	44.281	-0.873
2100.000	45.135	44.769	-0.366
2125.000	45.116	44.850	-0.267
2150.000	45.098	44.899	-0.198
2175.000	45.079	44.891	-0.188
2200.000	45.060	44.787	-0.273
2225.000	45.057	44.087	-0.971
2250.000	45.054	43.909	-1.145
2275.000	45.052	43.377	-1.674
2300.000	45.049	43.363	-1.685
2325.000	45.046	43.274	-1.772
2350.000	45.043	43.258	-1.785
2375.000	45.041	43.189	-1.851
2380.000	45.040	43.088	-1.952
2400.000	45.040	43.321	-1.719
2425.000	45.040	43.050	-1.990
2450.000	45.040	43.131	-1.909
2475.000	45.040	43.093	-1.947
2487.872	45.040	43.796	-1.244

LONGITUDINAL PROFILE - MC00

HORIZONTAL SCALE 1 : 2000

VERTICAL SCALE 1 : 200

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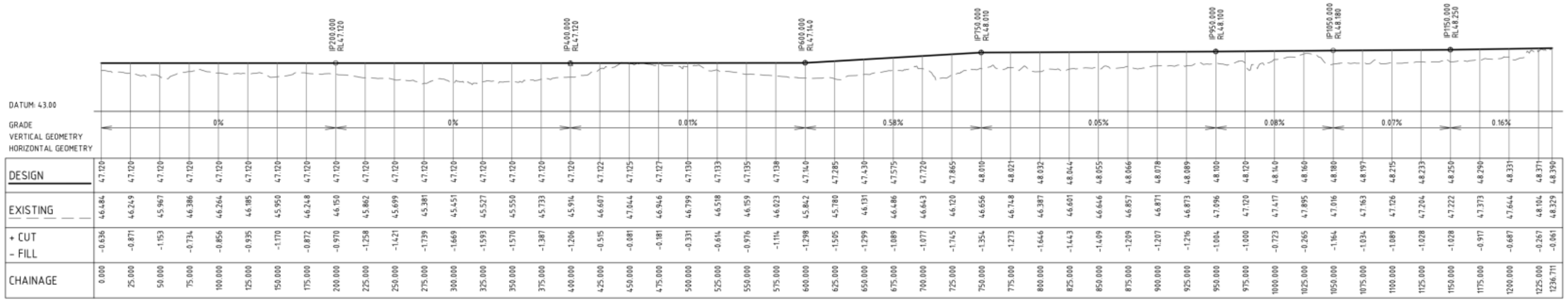

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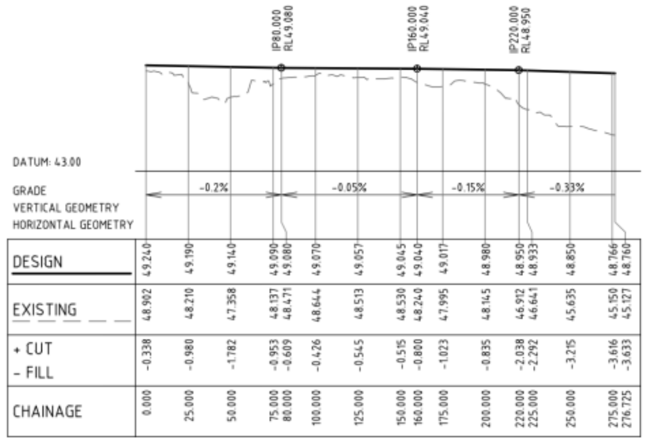

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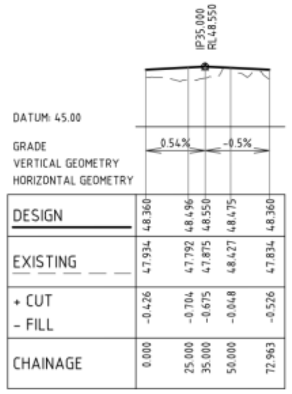

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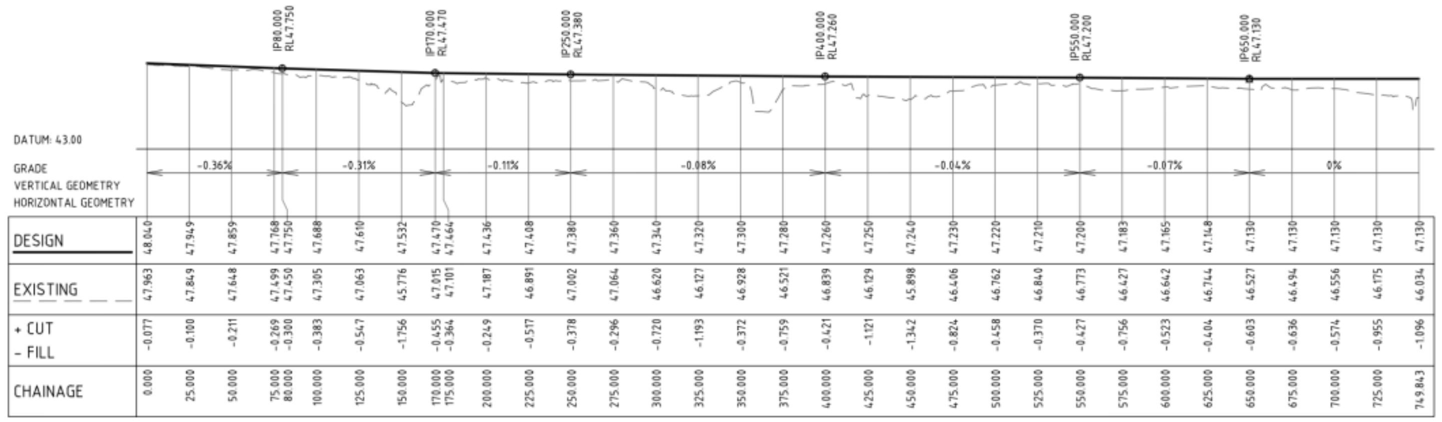

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VERTICAL SCALE 1 : 200

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SURVEY DATE:
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TOWN OF GAWLER, LIGHT REGIONAL AND BAROSSA COUNCILS

GAWLER AND SURROUNDS SMP
GAWLER RIVER LEVEE BANK CONCEPT DESIGN
LONGITUDINAL SECTIONS (2 OF 2)

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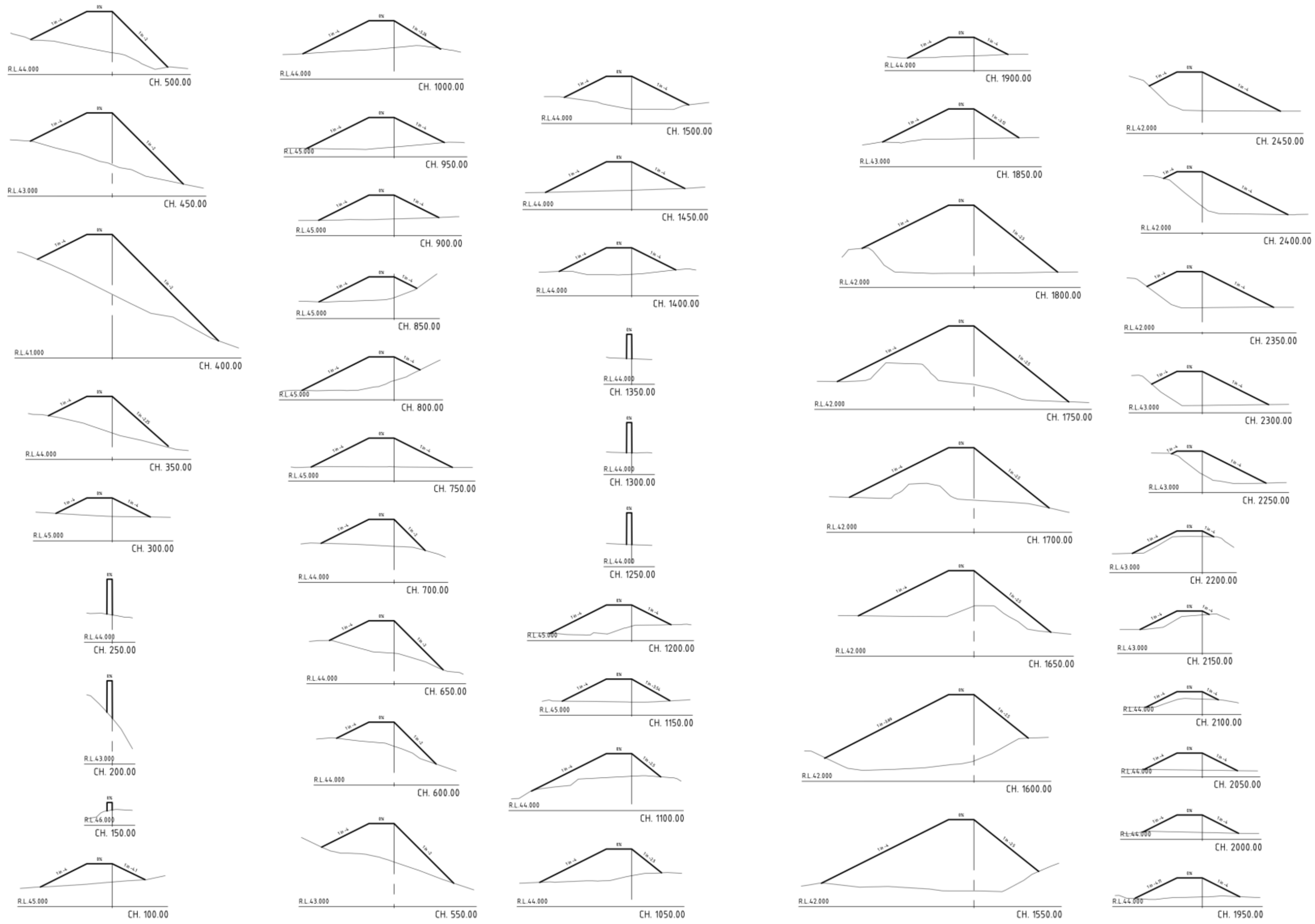

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TOWN OF GAWLER, LIGHT REGIONAL AND BAROSSA COUNCILS

GAWLER AND SURROUNDS SMP
GAWLER RIVER LEVEE BANK CONCEPT DESIGN
CROSS SECTIONS (1 OF 2)

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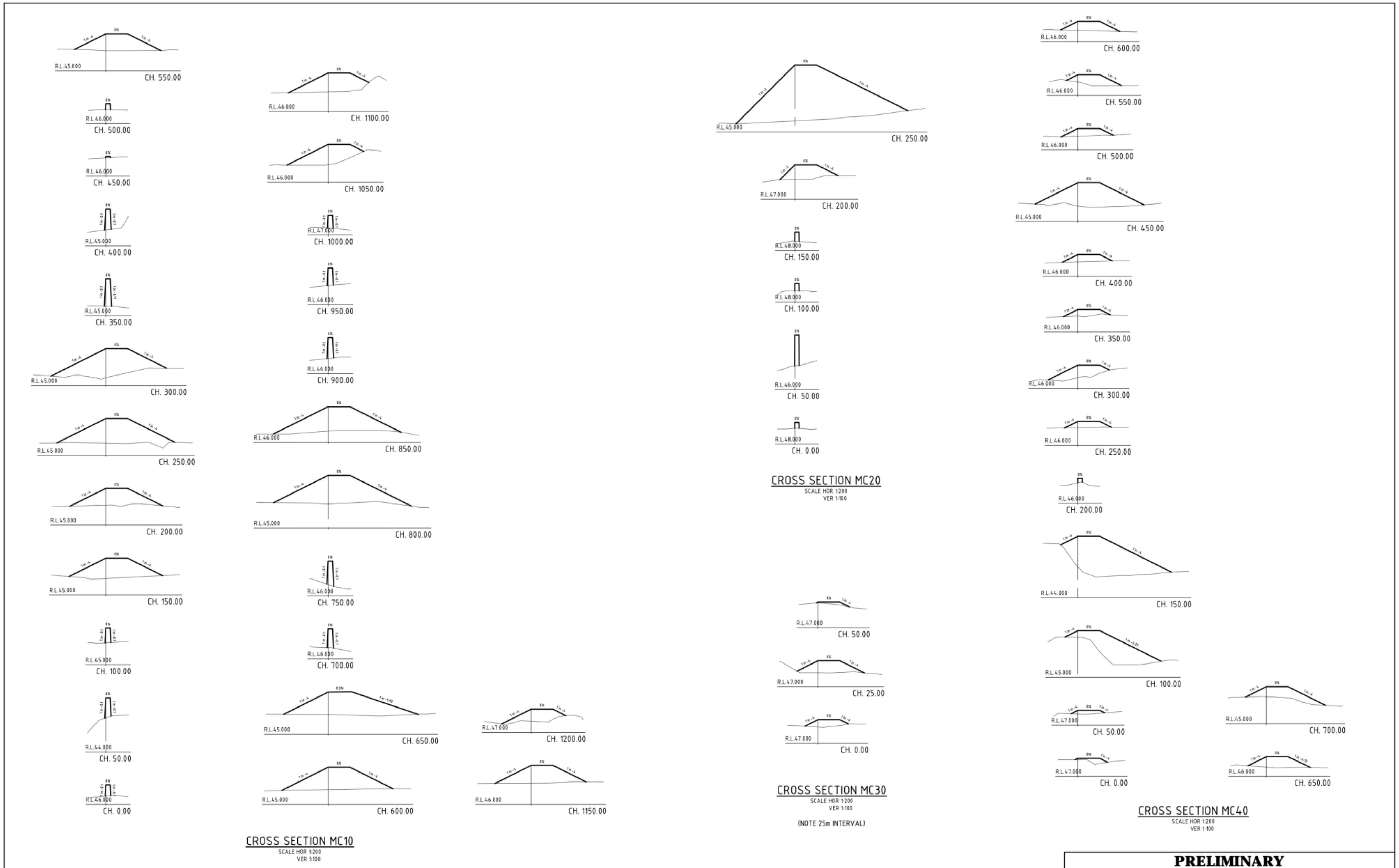

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SURVEY DATE:
COORDS & DATUM: COORDS TO (MGA94 ZONE54) ALL LEVELS TO A.H.D.

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CROSS SECTIONS (2 OF 2)

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