E8 Consulting

Government of South Australia

Department of Planning, Transport and Infrastructure

Environmental Management Plan

(EMP)

Version 2.0

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Document History

Version	Description	Author	Reviewed	Approved	Date
1	Draft 1	TG	MF	CC	2/05/2017
1.1	Draft 2	TG	AT	CC	16/05/2017
1.2	Draft 3	TG	CC	MF	29/05/2017
2	Final Report	TG	CC,MF,AT	TG	8/06/2017

Disclaimer

The following Environmental Management Plan has been written by the Environmental team of E8 Consulting and contains all professional and technical considerations to be regarded during the construction phases of the O-Bahn City Access Project – Stage 1. This document is intended for the Department of Planning, Transport and Infrastructure and is a concurrent report to be read alongside the Detailed Design presented by E8 management. It should be noted that all information was relevant and true at the time of publication.

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Executive Summary

The purpose of this report is to identify management and mitigation strategies put in place by E8 Consulting, in order to reduce the impact on the environment influenced by the O-Bahn City Access Project – Stage 1. Conditions surrounding the environment in the affected project area have been referenced from the Environmental Impact Statement (EIS) compiled in the feasibility study and condensed into this report for the reader's convenience.

Detailed design methodology has been outlined in their respective sections throughout the document. Where necessary, references have been made to schematics drawn up by the environmental team, which are included in the detailed design document submitted by E8 Consulting.

A final cost associated with implementation of environmental procedures has been calculated and is as follows:

Final Cost:

$ 6,935,846.00

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1. ABBREVIATIONS

- EMP – Environmental Management Plan
- DPTI – Department of Planning, Transport and Infrastructure
- WSUD – Water Sensitive Urban Design
- BOM – Bureau Of Meteorology
- EIS – Environmental Impact Statement
- RHS – Rectangular Hollow Section
- EPR – Environmental Protection Regulations (2009)
- PAH - Polycyclic Aromatic Hydrocarbons
- PLMS – Park Land Management Strategy
- EPBC – Environmental Protection and Biodiversity Conservation

2. INTRODUCTION

2.1. OUR MISSION

The Environmental team at E8 Consulting strives to deliver the best possible results to an industry standard, whilst at the same time minimizing impact to the environment and the associated surrounding areas. All designs, mitigation and control principles are carefully considered throughout the design and construction process and are established accordingly to correlate with the necessary legislative acts and relevant Australian Standards. Stakeholder satisfaction is highly regarded amongst us, and we continually endeavour to meet all expectations whilst delivering innovative, sustainable and eco-friendly solutions.

2.2. OUR POLICY

E8 Consulting has devised this document in collaboration with DPTI to ensure that appropriate management of the effected environment is regulated in accordance with all relevant legislation, standards and guidelines. EMP and environmental objectives are listed in the following section. It should be noted that quarterly assessments are conducted within E8 Consulting to ensure that the aforementioned targets are acquired in all of our projects. These updates are made regularly to keep us up to date and improve outdated techniques. E8 is proud to acknowledge certifications from SAI Global in the following disciplines:

- Environmental Management System certification to AS/NZS: 14001:2008
- Quality Management System certification to AS/NZS: 9001:2008

Figure 1: SAI Global accreditations

2.3. EMP OBJECTIVES

This report aims to:

- Minimise impact on the environment through adequate planning and continual improvement
- Provide sustainable and innovative environmental design solutions in order to achieve green star ratings
- Maintain primary stakeholder satisfaction to the highest possible standards
- Comply with all relevant Australian Standards, guidelines and legislative procedures
- Establish appropriate monitoring and auditing programs
- Reduce, reuse, recycle
- Ensure the longevity of the Adelaide Parklands and River Torrens
- Respectfully honour indigenous land rights and sacred sites
- Provide sufficient handover information to external contractors to ensure all environmental policies are upheld and practiced
- Identify environmental hazards and implement appropriate mitigation strategies
- Outline environmental training policies to be provided to sub-contractors and employees
- Reduce greenhouse gas emissions and pollution from all our operations

2.4. ENVIRONMENTAL OBJECTIVES

Key objectives to be achieved through the implementation of this EMP are as follows:

Objective 1: Remove contaminated top soil from the project area (Target >90%)

Objective 2: Minimise amount of generated waste being transported to landfill

Objective 3: Minimise impact on the environment and adhere to all relevant environmental legislative procedures

Objective 4: Reduce greenhouse gas emissions through incorporation of green design solutions

3. EMP STRUCTURE

The following report outlines in detail all aspects surrounding environmental protection for the proposed project. This document is separated into 3 main sectors, which are defined below:

Section 4-10: Overview

Sections 4-7 cover all preliminaries associated within the project scope that are deemed necessary for successful implementation.

Section 11-12: Environmental mitigation and design

E8 Consulting's environmental team has identified the main areas of concern and have categorised them as follows:

- Flora
- Fauna
- Creek conditions
- Soil
- Water

- Noise & vibrations
- Air quality
- Waste & hazardous materials
- Energy

In this section, a general overview of the existing site conditions has been made. Observations were made during the feasibility section of this project and have since been updated to remain relevant to the final scope selected by DPTI. Environmental impacts are then addressed and outline all issues and offsets that have been forecasted to occur during the construction phases. Mitigation strategies are then discussed, and include key objectives to be ascertained over the life of the project. Tables summarizing these strategies have also been supplied, as well as relevant costing schedules, and can be viewed at the end of each section. Environmental design elements, along with their reasoning, location and specifications are also included within this section. For a plan view of the project area and locations of all design elements, refer to **drawing 0001-EN-2017** in the Detailed Design document.

Section 13: Final costing

A detailed final costing has been included towards the end of this document and has been summarised in the executive summary.

4. LEGISLATION

Throughout the entirety of the construction phase for stage 1, various legislation acts must be taken into consideration. The following acts have been identified by E8 consulting and must be adhered to at all times to ensure all laws are taken into consideration and minimal environmental impact results:

- Native Vegetation Act, 1991
- Development Act, 1993
- Environment Protection and Biodiversity Conservation Act, 1999
- Environmental Protection Act, 1993
- Environmental Protection Regulations, 2009
- Highways Act, 1926

- Adelaide Parklands Act, 2005
- Local Government Act, 1993
- City of Adelaide Act, 1998
- Road Traffic Act, 1961
- Crown Land Management Act, 2009
- Natural Resources and Management Act, 2004
- National Environmental Protection (Ambient Air Quality) Measure
- Disability Discrimination Act, 1992 (Commonwealth)
- Heritage Places Act, 1993

It is in accordance with E8's internal policies to practice all mitigation and design strategies in compliance with the aforementioned legislation and regulations.

It should be noted that all contractors involved must comply with the above guidelines and legislations for the entirety of this project. When necessary, it is their responsibility to ascertain all necessary licenses, permits, registrations and approvals from all relevant authorities prior to undertaking their tasks.

5. PROJECT OVERVIEW

Option 3 entails the existing O-Bahn infrastructure to be incorporated into an underground tunnel that begins at the North-Eastern side of Park Road and emerges on the Southern side of Bundeys Road. An external concrete tunnel will be constructed across the River Torrens on the Western side of the Hackney Road Bridges, which will merge into a third tunnel running underneath Hackney Road and then eventually returning to grade South of Richmond Street.

Road realignments of outbound city traffic will also be undertaken on Hackney Road, as well as a one lane width realignment of Park Road on the Eastern side. Dedicated bus lanes for North and Southbound traffic along Hackney Road will be constructed, which will be separated by a central divider. Horizontal alignment for the O-Bahn tunnel can be viewed in

Appendix A, whereas Figure 2 represents a plan view for the entire project area.

Figure 2: Plan view of project area

6. STAKEHOLDERS

It is within E8 Consulting's best interests to maintain excellent relationships with our clients and key stakeholders during each and every project that is undertaken. We endeavour to keep the stakeholders informed and happy with our scope of operations and methodology, as well as keeping the public informed of any major changes or discrepancies in our work. The following list of primary and secondary stakeholders have been identified:

Primary stakeholders

- DPTI
- Adelaide City Council
- City of Norwood, Payneham and St. Peters
- St Peters College
- Kaurna Aboriginal Community & Heritage Association Inc.
- Adelaide Botanic Gardens
- Adelaide Parklands Preservation Society

Secondary stakeholders

- Local homeowners
- Local businesses
- Pedestrians and cyclists
- Commuters
- Parkland users

7. ON-SITE MANAGEMENT

7.1. INSPECTIONS & AUDITS

On site monitoring will be undertaken at regular intervals to ensure that the EMP is being followed correctly. Compliance with the supplied checklist will ensure that all mitigation principles are being adhered to accordingly, and environmental impact will be kept to within the desired limits as outlined in the EMP. Responsibilities for this monitoring process will fall onto the site foreman and any subsequent contractors. Table 1 outlines in detail the checklist that will need to be followed:

Table 1: Monitoring checklist

Area	Description of task	Interval
Flora & fauna	Assess impact to local wildlife and vegetative species	Prior to excavation
Soil	Testing for contaminants	During excavation
Noise & vibrations	Minimalizing noisy night works	When deemed necessary
	Secondary stakeholder meetings	Fortnightly
Waste	Regular removal of waste and hazardous materials	Weekly
Air quality	Regular testing for harmful emissions and dust particles in enclosed working spaces	During tunnel excavation
Machinery	Regular cleaning	Weekly
Chemical spills	Daily inspection of areas incorporating machinery	Upon recognition

In addition to the checklist outlined in Table 1, Safe Operating Procedure (SOP) checklists will be supplied on site and must be followed accordingly at all times.

On-site auditing must occur at regular intervals to ensure the integrity of the worksite and surrounding environment. Contractors will be responsible for conducting these audits, and submit all results and findings to E8's environmental team for analysis. Internal audits undertaken by the environmental team will take place every 2 months to ensure that all standards are being enforced and compliance with this document is met.

7.2. EMPLOYEE INDUCTIONS

All employees and contractors who are granted access to the work site will undertake mandatory on-site inductions. Necessary information will be provided which will ensure the safety of themselves, the safety of others, and individual roles and responsibilities associated within this document. Areas of high environmental concern will be highlighted, as well as mitigation techniques and principles that must be adhered to at all times. Persons undertaking this induction will need to sign off with the relevant foreman to ensure understanding the compliance of this EMP has been achieved.

8. ENVIRONMENTAL IMPACT ASSESSMENT

A hierarchy of environmental assessment has been devised by E8's environmental team and is represented in Figure 3.

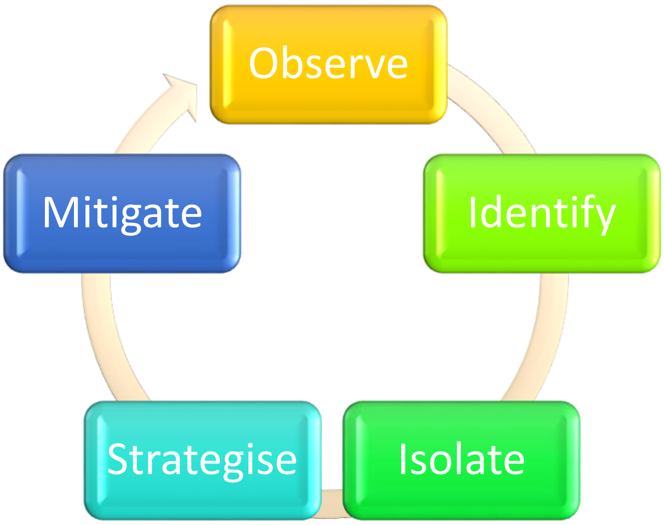

Figure 3: Environmental impact assessment hierarchy

E8's Environmental Impact Assessment is categorised into 5 main areas:

1. **Observe** – Site visits are conducted by the environmental team prior to the final design solution being put forth by the client. Existing conditions for all natural surroundings are inspected and recorded.
2. **Identify –** Areas that fall within the project scope are identified and documented.

3. **Isolate** – Issues that face environmental impact are isolated and become the main focal point of our investigation.
4. **Strategize** – Strategies are then put in place in order to reduce and/or negate any offsets that will occur due to construction.
5. **Mitigate** – Mitigation principles are brainstormed and regulated in accordance with relevant legislative procedures and Australian Standards.

9. INDIGENOUS HERITAGE SITES

In the instance of uncovering an area that has significant historical ties to the indigenous community, work within the vicinity of the discovery shall be ceased and DPTI will be contacted immediately. It is the contractor's responsibility to ensure that any archaeological findings will be properly preserved and protected from damage until proper authorities are contacted.

10. STAKEHOLDER COMMUNICATION AND COMPLAINTS

E8 Consulting will organise regular stakeholder meetings for residents, business owners and commuters associated with the Council of Norwood, Payneham and St Peters to address any issues surrounding the project scope. All communication and complaints will be respectively addressed at these meetings with minutes recorded and distributed to all attendees.

11. RAINFALL & TEMPERATURE DATA

Adelaide is considered a city with a varying climate and inconsistent rainfall. Having said this, the city often does experience extreme instances of weather in the form of rainfall and severe heat. During the hotter months of November to February, it is not uncommon to experience days that reach up to 45°C. Similarly, heavy rainfall has been known to hit Adelaide and cause major issues with flooding, as was the case with the floods of September, 2016. Historical data for mean monthly rainfall, as well as maximum and minimum temperature has been collected from the Bureau of Meteorology (BOM, 2017) for the past 3 years and collated into Table 2, 3 and 4, respectively.

Table 2: Mean Monthly Rainfall (mm), Kent Town, 2014-2016

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2014	10.2	98.2	19	50.6	64.4	104.2	99.6	20.8	31.4	5	24.4	6.4
2015	41.6	0.6	*2.4*	*57.4*	71.8	*15.4*	*73.6*	*48.4*	*52.2*	*9*	*9.8*	*13*
2016	*52.8*	*18.4*	*53.8*	*9.6*	*88*	*95.2*	*112*	*58.8*	*131.2*	*81*	*33.2*	*86.8*

Table 3: Maximum Monthly Temperature (°C), Kent Town, 2014-2016

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2014	32.5	29.8	27.3	22.9	20.6	16.3	15.3	17.4	20.9	26	26.7	27
2015	28.7	32.7	25.5	20.5	18.5	16.2	14.7	15.8	19.2	27.1	27.5	32.5
2016	31.2	29.3	28.6	24.8	19.8	16	15.3	17.7	17.4	21	24.7	28.7

Table 4: Minimum Monthly Temperature (°C), Kent Town, 2014-2016

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2014	18.6	17.8	15.2	13.4	12.2	9.3	8.2	6.8	10.8	12.1	14.6	15.4
2015	17.5	18.1	14.5	11.1	10	8.2	6.7	8.2	9	14	14.5	18.1
2016	18.1	16.4	16.8	12.6	12.4	8.9	8.1	7.7	9.1	10.6	12.1	15.4

All extremes for each table have been highlighted in red and are represented in Figure 4.

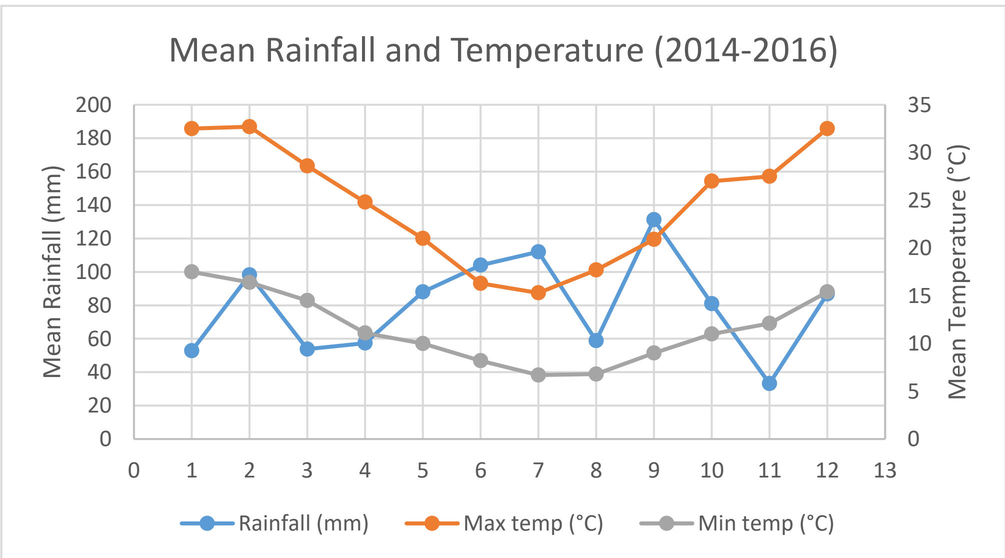

Figure 4: Mean Rainfall and Temperature Data

12. ENVIRONMENTAL MANAGEMENT

The following section will address conditions assessed in the environmental teams EIS. All conditions have been observed by E8 Consulting during the feasibility stage and must be considered and regulated during the entire construction process.

12.1. FLORA & FAUNA

The scope of this project is within close proximity to the Adelaide Botanical Gardens and Parklands, some of which will be directly affected by excavation and realignment of Hackney Road. Through collaboration with the urban planning department, the environmental team aims to conserve as mush of the native flora and fauna as possible within the project region, as well as implementing ways to rehabilitate and revegetate affected areas.

The removal or damage of trees, vegetation and negative influences on water quality can directly impact local fauna species. Environmental degradation caused by the construction stage of this project can directly contribute towards these factors, and it is important to ensure minimal impact on native fauna, in order to prevent sickness or an uninhabitable region.

12.1.1. EXISTING CONDITIONS

12.1.1.1. FLORA

On-site visits were conducted by the environmental team during the feasibility study, in order to determine which species of flora were present and how the tunnel and realignment of Hackney Road would affect them.

The Adelaide City Council stated that vegetation in the project area was removed during the first settlement of Adelaide and over time, non-native flora was replanted (AECOM 2015). The main forms of vegetation in the area included small to medium shrubs and trees, as well as larger mature trees. In 2014, DPTI carried out an investigation which analysed vegetation in the project area. Their conclusions were that no vegetation in the area was native, under the Native Vegetation Act, 1991 (DPTI 2015a). Additionally, no trees within the project area were heritage listed.

Along the Hackney Road median strip is a single row of vines and bushes of Meidiland Roses. These plants are valued by the community and are encouraged to be well looked after (DPTI 2015b). Listed below are various types of flora that are of high importance as specified by the Community Land Management Plan, the Adelaide Park Land and Squares Cultural Assessment Study, and the Botanic Gardens of Adelaide Master Plan Report (DPTI 2015a; DPTI 2015b):

- River Torrens revegetation and biodiversity plantings
- All White Cedars which date back to the mid-1870s
- Moreton Bay Fig trees dating from 1880s
- The Camphor Laurel tree near the Lions Club

It is hereby noted that these trees do not fall into the project scope, and therefore will be unaffected by construction works.

12.1.1.2. FAUNA

The project area has been deemed as a non-suitable habitat for fauna, due to the large areas of pavement, roads, high-volume traffic and human presence. The site is deemed as anthropogenic, and mainly serves as a temporary feeding and roosting spot for common bird species (DPTI 2015a). Additionally, the site is not able to deliver the requirements for suitable permanent fauna habitats. However, some common bird species, smaller mammals and even rare species have made a home in the nearby River Torrens and the Adelaide Park Lands. Therefore, this project will still endeavour to positively impact the fauna in the surrounding area. DPTI (2015a) has hold of an EPBC Protected Matters Report, which recognises ecological communities, threatened species and migratory species which may habitat within 1km of the project area, which can be viewed in Table 5.

Table 5: List of ecological communities, threatened species and migratory species (DPTI 2015a)

<table>
<tr><th colspan="2">Type</th><th>Species</th><th>Common name</th></tr>
<tr><td rowspan="3">Listed ecological communities</td><td rowspan="3">Threatened ecological communities</td><td>Grey Box (Eucalyptus microcarpa)</td><td>-</td></tr>
<tr><td>Grassy Woodlands and Derived Native</td><td>-</td></tr>
<tr><td>Grasslands of South-Eastern Australia</td><td>-</td></tr>
<tr><td rowspan="4">Listed threatened species</td><td rowspan="3">Threatened species (bird)</td><td>Botarus poiciloptilus</td><td>Australasian Bittern</td></tr>
<tr><td>Pedionomus torquatus</td><td>Plains Wanderer</td></tr>
<tr><td>Rostratula australis</td><td>Australian Painted Snipe</td></tr>
<tr><td>Threatened species (mammal)</td><td>Pteropus poliocephalus</td><td>Grey-headed Flying Fox</td></tr>
<tr><td rowspan="10">Listed migratory species</td><td>Marine</td><td>Apus pacificus</td><td>Fork-tailed Swift</td></tr>
<tr><td>Terrestrial</td><td>Haliaeetus leucogaster</td><td>White-bellied Sea Eagle</td></tr>
<tr><td>Terrestrial</td><td>Merops ornatus</td><td>Rainbow Bee-eater</td></tr>
<tr><td>Terrestrial</td><td>Myiagra cyanoleuca</td><td>Satin Flycatcher</td></tr>
<tr><td>Wetland</td><td>Adrea alba</td><td>Great Egret, White Egret</td></tr>
<tr><td>Wetland</td><td>Adrea ibis</td><td>Cattle Egret</td></tr>
<tr><td>Wetland</td><td>Gallinago hardwickii</td><td>Latham's Snipe, Japanese Snipe</td></tr>
<tr><td>Wetland</td><td>Pandion crisatus</td><td>Eastern Osprey</td></tr>
<tr><td>Wetland</td><td>Rostratula benhjalensis (sensu lato)</td><td>Painted Snipe</td></tr>
</table>

Table 6 contains information regarding species of birds located within the parklands, with their respective breeding seasons. There is a lack of data which shows where these nests are located. However, if trees are required to be relocated for the works of the project, then they shall not be removed from their current position during their respected breeding times.

Table 6: Breeding seasons of particular bird species

Bird species	Breeding season
Grey Currawong	August - December
Rare Crested Shrike Tit	August - January
Australasian Darted	August - October

12.1.2. ENVIRONMENTAL IMPACT

The events of the project will have an impact on the flora located on the Western side of Hackney Road. The alignment of the tunnel across the River Torrens will have a significantly large impact on flora in this area. The affected trees in this area are highlighted in Figure 5.

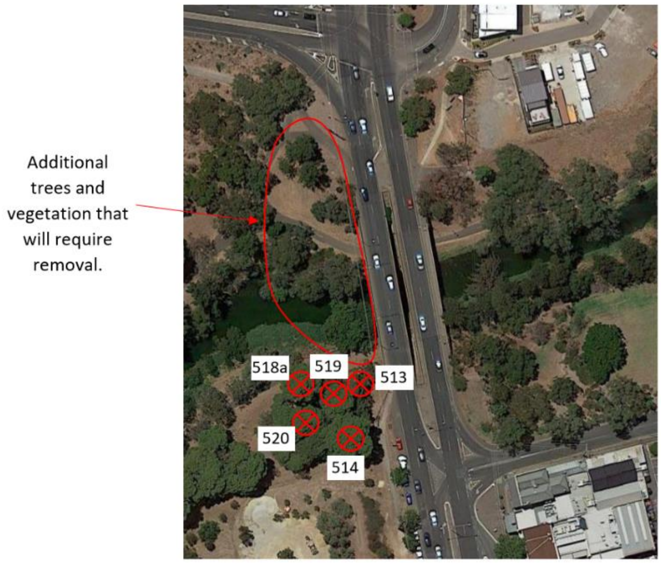

Figure 5: Impacts to trees

The regulated trees that will need to be removed include:

- Eucalyptus camaldulensis (Tree No. 513)
- Pinus halepensis (Tree No. 514, 518a, 519)
- Pinus pinea (Tree No. 520)

Although these trees are scheduled to be removed/relocated, the area is already degraded, and impacts will not be overly significant.

Fauna species outlined in Table 5 have not been observed within the project area. It is reasonable to assume that habitats for these species will not be encountered during the construction process. Furthermore, it is foreseen that the on-going outcomes from this project will not have an impact (DPTI 2015a).

12.1.3. MITIGATION AND MANAGEMENT

12.1.3.1. FLORA RELOCATION/REVEGETATION

To mitigate the impacts of tree removal, revegetation and replantation actions will take place. This will ensure that the removal of these trees will not negatively affect the environment and native fauna species. E8 has incorporated DPTI's guidelines for removing and replacing trees, and are as follows:

- 1:1 replacement for small trees
- 2:1 for regular trees
- 3:1 for significant trees

Full design of this mitigation effort was conducted by E8's Urban Planning Team, and can be viewed in the Detailed Design document.

The environmental team's mitigation proposal to offset the negative effects of the surrounding flora and fauna, will be the development of a Riparian buffer. This buffer will also be able to improve the water quality of the River Torrens.

12.1.3.2. FAUNA RELOCATION

A number of trees will need to be removed in order to cater for the widening of Hackney Road and tunnel excavations. This means that possible fauna habitats will need to be relocated. Particular species such as the state rated Vulnerable Yellow-tailed Black Cockatoo and the rare rated Common Brush-tailed Possum may be affected if habitats are discovered during the tree removable process. It is critical that these habitats are well-kept, stored and relocated suitably. Fauna Rescue SA will be contacted in the case that fauna species require organised relocation. E8 will ensure strict guidelines are put in place to relocate these animals and habitats (AECOM 2015).

Environmental developments in the project, such as the green wall and riparian buffer, can potentially serve as a new habitat for fauna. Ferns and shrubs incorporated into the green wall will be an attraction for flying species such as small birds and butterflies. The riparian buffer is located by a natural water source and will be comprised of small to large vegetation. This will attract larger fauna species and some aquatic life forms to this location.

12.1.4. RIPARIAN BUFFER

A riparian buffer is a stretch of dense vegetation alongside a water system. The main function of a riparian buffer is to improve the ecosystem surrounding a river, creek, or waterway. This includes an improvement to water quality, fauna benefits and a larger flora presence. E8 has designed a riparian buffer to be located 530 m away from the O-Bahn tunnel Bridge (figure 6). For a detailed layout of the riparian buffer, refer to ***drawing 0011-EN-2017*** in the Detailed Design document.

12.1.4.1. BENEFITS

A healthy riparian buffer is able to bring restoration to natural water systems as well as surrounding aquatic habitats. The implementation of a buffer displays great land use by incorporating dense vegetation. Fauna species take full advantage of a buffer as it provides sources of nutrients, energy, food and oxygen. The vegetation of a riparian buffer serves as a superb habitat for wildlife and keeps various parts of the affected water system at a cooler temperature. Furthermore, a riparian buffer is able to make the affected area “future proof” for migrating species of wildlife. This allows a buffer to be a beneficial habitat as well as a place for fauna to flourish.

Riparians buffers also have the ability to improve the water quality of a river or any other natural water system. Pollutants such as nitrogen, phosphorus and sediment particles can be reduced by implementing a riparian buffer. This is due to the active vegetation in the buffer (North Carolina Wildlife Resource Commission n.d).

12.1.4.2. REASONING FOR DEVELOPMENT

The environmental team acknowledges that the River Torrens is a major river for Adelaide and is within the project area. Another reason for this development is that stormwater from the tunnel catchment areas are able to overflow into the river. E8 is passionate about making sure the runoff from the tunnel alignment does not pollute the river. The current state of the river's riparian system is very poor and degraded. However E8 is concerned about the threatened species surrounding the river, and feels the need to mitigate impacts that may affect these species.

12.1.4.3. OUTCOMES

The dense vegetation associated within the buffer will emit oxygen to the surrounding region, including the botanic gardens and botanic park, and provide a resilient habitat for local wildlife. Furthermore, the riparian buffer will improve the water quality of the River Torrens by removing pollutants and ultimately aid in the recovery of the river's riparian system.

Figure 6: Riparian buffer location

12.1.4.4. DIMENSIONS

Figure 7 displays the riparian buffer project area and the lengths it will stretch along the River Torrens. The project area was separated to consume both the North and South bank of the river. The uniform starting and finishing position along each bank has been kept the same to maintain consistency. However, in reality the riparian buffer will be designed so that it merges with its natural surroundings at both ends. As water enters the buffer, the river narrows and allows the water to be affected by the buffer at a high level. The buffer terminates when it does not have a high effectiveness level, as the river widens again.

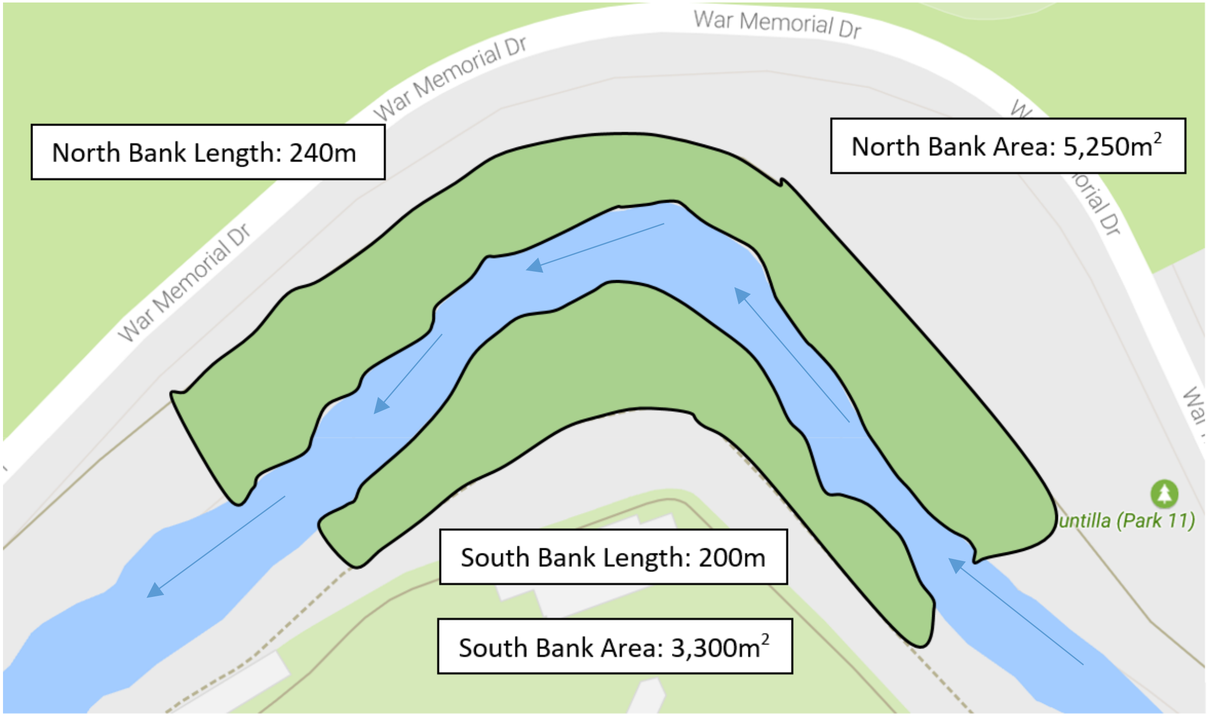

Figure 7: Riparian Buffer Project Area (River Torrens)

Areas associated with the North and South banks will vary in width along the river. These widths fall between the water's edge and the walking paths that follow the River Torrens. On the south bank, the largest and smallest widths are 33m and 14m respectively. On the north bank, the largest and smallest widths are 28m and 19m respectively. Table 7 contains information surrounding the desired widths for riparian buffer design. The table shows that based on the design widths, this project buffer can produce the following functions:

- Mitigate water temperature
- Reduce pollutants: Nitrates and Pesticides
- Reduce sediments: General, Sand, Silt
- Assist wildlife habitats and living: Edge fauna species, Aquatic and Bird Communities

These points explain why the River Torrens riparian buffer is able to achieve its goals of being an influential and effective system.

Table 7: Minimum Widths of Functional Riparian Buffers

Category	Minimum width (m)	Notes
Water quality		
Water temperature	5	Small creeks; forested
Pollutants		
Nitrates	11	
Pesticides	14	
Sediment		
General	8	On slopes <16%; expand by 2.5 m for each 1% increase in slope
Sand	3	
Silt	15	
Clay	91	
Edge species	8	
Aquatic communities	15	Dependant on river size
Bird communities	25	Includes area-sensitive species
Large mammals	30	
Semi-aquatic reptiles	127	
Semi-aquatic amphibians	159	

12.1.4.5. FLORA DESIGN

A functional riparian buffer needs to have the correct vegetation. A riparian buffer is usually split into 3 different vegetation zones (Natural Resources Conservation Service, 2011):

- Toe Zone – Plants with strong root systems (Sedges, rushes, etc.)
- Bank/Overbank Zone – Small to medium shrubs
- Transitional/Upland Zone – Large shrubs and Trees

There is little information on how wide each zone should be. However the design should be influenced by the constraints of the site and the existing flora conditions. The area that is beyond the footpaths has plenty of mature-aged, tall trees, which can act as the Upland Zone of the riparian buffer. Therefore, this zone does not need to be designed. The following dimensions have been selected for the buffers design.

Table 8: Buffer Final Dimensions

Area	Width (m)
Toezone	4
Bank/Overbank	10
Transitional	Varying

The forms of vegetation for each zone has been discussed. All plants incorporated into the buffer shall be Australian native. This will allow the buffer to blend in with its natural environment. Botanic Gardens of South Australia (2017) contains a search engine for flora used in different botanic gardens across South Australia. Each species of flora has details including height and, most importantantly, spread. The spread of the plant will ultimately determine how many plants will be able to be planted in each zone. For ease of design, the average spread of each species was considered. Furthermore, the same number of each flora species shall be used for each zone. The list of chosen flora is as follows:

Toe Zone

- Common Spike-rush (Southern Lofty) – 2.5m diameter spread
- Tall Spike-rush – 2.5m diameter spread
- Grassy Rush – 0.75m diameter spread
- Swamp Club-rush – 0.3m diameter spread

Bank/Overbank Zone

- One Sided Bottle-brush – 2.5m diameter spread
- River Bottlebrush (SA form) – 1.25m diameter spread
- Dwarf Bottlebrush – 1.75 spread

Transitional Zone

- Crimson Bottlebrush – 3.5m spread
- Bottlebrush Hakea – 1.75m spread

Full details outlining necessary calculations associated with the riparian buffer, as well as selected buffer flora can be viewed in Appendix B, Section 16.4, and Appendix D, respectively.

12.1.4.6. MAINTENANCE

Accessing the riparian buffer for maintenance will be relatively easy due to the surrounding walking paths. Adjacent to the buffer site is War Memorial Drive, which will allow maintenance vehicles to travel to the location and park. The buffer will be maintained every 3 months to keep up with the seasons. This will ensure that the riparian buffer does not get damaged and is still able to function properly.

12.1.5. PERFORMANCE OBJECTIVES

- Perform correct revegetation procedures
- Perform correct procedures to relocate fauna
- Provide a suitable habitat for fauna
- Improve water quality of the River Torrens (see section 12.4)
- Increase oxygen levels in and around project area

12.1.6. SUMMARY

Table 9: Flora Action and Mitigation Summary

Activity	Mitigation
Conserving Fauna	Relocating/Providing habitats
Rehabilitate Environment	Riparian Buffer

12.2. RIVER CONDITIONS

12.2.1. EXISTING CONDITIONS

Existing flow rates for the section of the River Torrens located beneath the existing Hackney Road bridges have been observed at 0.71m^3/s, which results in a total of 890 ML of discharge downstream per year. However, most of this quantity is during months with high rainfall (April to September) as outlined in Tables 3, 4 & 5, section 11. The rivers profile is defined as a natural creek, which contains plants, boulders and tree roots, which restrict its overall flow rate. In the past, high volumes of rainfall have caused the riverbanks to overflow, the most recent of which occurred in 2016, where the flow rate reached a high of 140m^3/s, exceeding its maximum allowable flow rate of 87.2m^3/s.

12.2.2. ENVIRONMENTAL IMPACT

Floods can have a severe impact on the surrounding environment. This includes damage to property, erosion of the embankment and death of hydrophobic flora species. This being said, various ecosystems benefit from flood events due to new food sources being created from nutrients which is washed downstream. Floods also recharge the surrounding groundwater, allowing tree roots that have extended into water tables to have a continual water source, which promotes new growth and healthy root systems. Contaminants in the river system can have the ability to cause sickness in fauna and potentially result in poisoning of trees. These impacts can cause the ecosystem linked to the River Torrens to suffer which could lead to uninhabitable areas.

12.2.3. MITIGATION AND MANAGEMENT

In the instance of a flood refreshing the surrounding groundwater, the risk of the water table rising and seeping into the submerged tunnel through cracks and joints will increase. Flooding of the tunnel would not only have severe structural consequences, but also inhibit a high level of danger to users of the O-Bahn network. In order to prevent the groundwater affecting the tunnel, a concrete channel matching the creeks profile will be constructed, starting 20m East of the Hackney Road Heritage bridge and finishing 20m West of the newly constructed O-Bahn tunnel bridge. The channel will be constructed from 50 MPa concrete with a thickness of 150 mm, and will run for a total length of 80m. Its implementation will ensure a uniform flow of floodwaters from its beginning to end. Furthermore, as concrete is a completely impermeable material, floodwaters will not be able to seep into the surrounding groundwater and hence lower the risk of tunnel flooding. Flow rate for this channel has been calculated to reach a maximum of 256 m^3/s without flooding, which is almost doubles the flow rate recorded during the flooding of September, 2016. Refer to **drawings 0014-EN-2017 and 0015-EN-2017** for detailed design of the concrete channel.

To ensure that the channel is visually appealing to the community, it will have a variety of mixed polished river pebbles incorporated onto its exposed surfaces. This will add a feature to the channel which only slightly decreases the channels ability to mitigate floods. Calculations for the detailed design of the channel, as well as design flows can be viewed in Appendix B, section 16.3.

12.2.4. PERFORMANCE OBJECTIVES

- Reduce impact caused by floods
- Maintain safe groundwater levels surrounding the tunnel

12.2.5. SUMMARY

Table 10: River Conditions Action and Mitigation Summary

Activity	Mitigation
Flood mitigation	Construction of concrete channel to guide floodwaters uniformly underneath structures

12.3. SOIL

12.3.1. EXISTING CONDITIONS

Boreholes taken within the vicinity of the existing Hackney Road Bridges have indicated that the top layers of soil consist predominantly of red/brown earth, which is common throughout the CBD, underlain mainly with silty/sandy clay. Additional borehole logs were taken along the stretch of Hackney Road and exhibited various results. Observations of the soil profiles from Hackney Road indicated inconsistencies in soil layers, with some boreholes returning only layers of fill as well as broken up asphalt, which is unsuitable for reuse.

It has been observed in past projects based around the Adelaide CBD that large amounts of contaminants are present in the top layers of soil. AECOM (2015) suggests that the presence of these various contaminants may be due to the Adelaide Parklands being used historically as a dumping ground for much of the 1850's, and/or the high levels of naturally occurring hydrocarbons which can result from the extended presence of various vegetative species. Projects undertaken within the Parklands, the Adelaide Oval Extension, the Brittania Roundabout Upgrade and the Adelaide Oval Footbridge all documented contaminants being identified within the top 600mm of soil. It is assumed that similar results will be ascertained during the excavation process and testing methods will need to be conducted.

12.3.2. ENVIRONMENTAL IMPACT

A large scope of this project surrounds deep excavation of the O-Bahn tunnel, as well as reconditioning and widening of Hackney Road South. Environmental impact due to these operations is inevitable, but will be minimised through strategic mitigation techniques. Relocation and revegetation of affected flora species has been considered and is outlined in section 12.1.31. Long term environmental conditions have also been considered in the form of remediating contaminated top soil, to provide a healthy environment for the habitats that will be present after the project's completion.

12.3.3. MITIGATION AND MANAGEMENT

12.3.3.1. CONTAMINATION MANAGEMENT

Figure 8 outlines guidelines stated in the Environmental Protection Regulations (EPR), 2009, which determine the allowable levels of materials present in soils before they are deemed contaminated:

Chemical substance	Concentration (milligrams per kilogram of waste fill)	Chemical substance	Concentration (milligrams per kilogram of waste fill)
Aldrin/dieldrin (total)	2	Ethylbenzene	3.1
Arsenic	20	Heptachlor	2
Barium	300	Lead	300
Benzene	1	Manganese	500
Benzo(a)pyrene	1	Mercury	1
Beryllium	20	Nickel	60
Cadmium	3	Petroleum hydrocarbons TPH C6-C9 (total)	65
Chlordane	2	Phenolic compounds (total)	0.5
Chromium (III)	400	Polychlorinated biphenyls (PCBs)	2
Chromium (VI)	1	Polycyclic aromatic hydrocarbons (PAH) (total)	5
Cobalt	170	Petroleum hydrocarbons TPH>C9	1000
Copper	60	Toluene	1.4
Cyanides (total)	500	Xylene (total)	14
DDT	2	Zinc	200

Figure 8: Allowable chemical concentrations in soils (Environmental Protection Regulations, 2009)

Analysis undertaken in the feasibility study established concentrations of the following 4 chemicals:

- Copper
- Hexavalent chromium
- Benzo-a-pyrene
- Zinc

To determine the total amount of these chemicals located in the topsoil, samples will be taken for every 250m^3 excavated on site and tested in accordance to the Waste Derived Fill (WDF) standards. If the soil is found to be contaminated, it is prohibited to be reused on site or anywhere else, and must be dealt with in accordance with the EPR. In the instance that soil samples are tested, and return results which exceed quantities outlined in Figure 8, the soil will be deemed contaminated and mitigation techniques will need to be exercised.

E8's geotechnical team has calculated a total of 76,217.7 m^3 of soil to be excavated from the site. An estimated 4,582.8 m^3 from the tunnel excavation, and 9,836.7 m^3 from the road widening and median strip excavation along Hackney Road, are expected to contain contamination which exceeds guidelines outlined in Figure 8. Calculations verifying these amounts can be viewed in Appendix B, section 16.1.

From an environmental perspective, an ideal solution to counteract issues concerning soil contamination would be the process of soil remediation (soil washing). Although there are various technologies available for this solution in South Australia, the process of soil remediation is extremely time consuming (generally 1-3 years) and requires large quantities of vacant land to store the soil. Unfortunately, soil flushing falls outside the project scope and will not be considered for on-site remediation. Instead, contaminated soil will be transported off site to an EPA approved landfill location. Locations for contaminated soil deposition require geo-fabric liners of low permeability to reduce the chances of contaminants seeping into surrounding groundwater. Soil deposits delivered to this site will undergo soil washing in order to be reused for future projects.

Excavated contaminated soil will be deposited directly onto transport vehicles and taken offsite immediately. This process reduces the chance of contaminated soil deposits being mistaken for clean fill, or releasing stored contaminants back into the environment. To minimise the risk of potentially harmful dust particles, loads will be sprayed with water and covered with tarpaulin prior to transportation. Additionally, all persons involved in the excavation or transport of contaminated soils will be required to wear PPE and be trained in industrial hygiene procedures. Vehicles that are associated with hauling contaminated soils, or are used on site within close proximity to the soils will require tyre cleaning prior to leaving the site.

Soil testing will also occur on a monthly basis, in areas where construction materials are stored for longer than 24 hour periods and are exposed to the environment.

12.3.3.2. BACKFILL & EROSION

Soil excavated below the estimated contaminated layers will be used as backfill once the tunnel has been constructed. Park 8 has been assigned as a temporary deposition point for this backfill as it is close to the main excavation site.

Figure 9: Backfill storage area (Park 8)

Reusable soil stockpiles will be immediately covered to prevent soil erosion due to wind and rain. Sediment fences will be temporarily set up surrounding these stockpiles with sand bags placed around perimeters to minimise silt seepage to surrounding areas.

12.3.4. PERFORMANCE OBJECTIVES

- Appropriate management of contaminated top soil
- Transport all contaminated soil off-site to EPA approved landfill (>90%)
- Re-use of uncontaminated soil as backfill for excavation
- Protection of reusable soil from wind and water erosion
- Minimise soil wastage

12.3.5. SUMMARY

Table 11: Soil Action and Mitigation Summary

Activity	Mitigation
Soil Testing	WDF guidelines to be followed accordingly
	Unexpected toxins encountered on site to be reported to the EPA immediately
	Soil testing to be conducted for every 250m^3 of soil excavated
Contaminated Soil Removal	Soil deemed contaminated to be transported to EPA approved landfill during off-peak travel times for soil remediation
	Tyres of haulage trucks to be washed prior to leaving contaminated area
	Employees to be trained in industrial hygiene procedures
	Contaminated deposits to be sprayed with water and covered with tarpaulin prior to transportation
Reusable Soil	Soil to be reused as backfill to be deposited to designated storage site (Park 8)
	Excess clean fill to be transported to Northern Connector project
Soil Erosion	Reusable soil stored in Park 8 to be covered with tarpaulin immediately after drop off
	Sediment fences and sand bags to be placed around soil stockpiles

12.4. WATER

12.4.1. EXISTING CONDITIONS

The existing condition of the stormwater drainage design system along Hackney Road and Park Terrace is quite poor. There is no water treatment or filtration incorporated before it is discharged into the River Torrens. Water runoff from the road collects a range of harmful chemicals which have been leaked from motor vehicles and can be damaging to living organisms that are dependent on the river system. This includes vegetation, fish, insects, birds and marine life, once the water flows out to the ocean. This pollution has a significant impact on the dependent ecosystem and has a great need for improvement from an environmental perspective.

Information provided by the Australian Government shows that a variety of algae and bacteria such as enterococci are present in the River Torrens area (Adelaide City Council 2016). The Australian Government data also shows that this bacteria is being transported to the river outlet and ocean. The input water quality needs to be improved in order to positively impact river water quality and stop problems from escalating further downstream.

12.4.2. ENVIRONMENTAL IMPACT

The quality of water affects all animals and living organisms that come in contact with the river water. Using water which is contaminated can lead to various health issues, as well as destroying natural habitats and environments. The most common harmful chemicals which are present in stormwater runoff are polycyclic aromatic hydrocarbons (Environmental Resources Centre). This is a large group, which contain around ten-thousand different compounds. These PAH's are by-products of incomplete combustion from vehicles which are washed away with stormwater during a rain event. PAH's that most often surpass ground or surface water standards include:

- Benzo-a-pyrene
- Fluoranthene
- Benzo-ghi-perylene
- Phenanthrene
- Chrysene
- Pyrene

Without the WSUD systems in place, these harmful chemicals will be directly discharged into the River Torrens having detrimental effects on the ecosystem.

12.4.3. MITIGATION AND MANAGEMENT

Once completed and operating, the water quality and stormwater drainage systems must comply with the Natural Resources Management Act, 2004 and the Environmental Protection Act, 1993. This is to ensure there will be no harm to the environment or the River Torrens through contamination or polluted stormwater runoff. Additionally, this design will also comply with the South Australian Water Sensitive and Urban Design Policy. The implementation of this policy will ensure each solution will not only have minimal environmental impact but also improve the system that is currently in place. More specifically, it will aid in improving the water quality conditions rather than just maintaining the current state.

Reducing the pollution levels of the stormwater runoff is possible through a range of techniques and practices. The first technique is using the method of infiltration. This directs the water into the soil to be absorbed rather than into the river. Infiltrating stormwater into the soil will not only keep chemicals out of harm's way, but also give the chemicals a chance to break down over time. The second method is filtration, which is simply separating rubbish, litter and harmful chemicals from the water that is being discharged into the river. And finally, the use of appropriate vegetation placed around the area of infiltration to absorb and additionally break down the chemicals present in the soil from contaminated stormwater.

12.4.4. WSUD

12.4.4.1. INTRODUCTION

The alteration of the road alignment has resulted in an increase of road pavement surface area. This surface area is considered to be impermeable to water, which will produce a significant amount of stormwater runoff in a storm event. Additionally, this faster route will increase the level of traffic and proportionally increase the levels of chemical waste pollutant from motor vehicles. This stormwater runoff will flow downstream into the River Torrens.

Without the correct WSUD systems in place, this increase in chemical waste will have a significant impact on the river's water quality and all aspects of life dependent on the system.

12.4.4.2. WATER QUALITY

Infiltration trenches are becoming a more commonly used method to treat stormwater runoff due to being cheap, effective and aesthetically pleasing. With the right landscaping techniques, infiltration trenches can add visual attractiveness to the surrounding area (figure 10). Infiltration trenches use a natural filtration method to separate unwanted waste particles from water. Stormwater is directed to the surface of the infiltration trench where it is adsorbed into the ground firstly through larger aggregates, and then through gradually smaller, porous soil particles. Small ferns and shrubs are often incorporated into these trenches to absorb organic pollutants in the water.

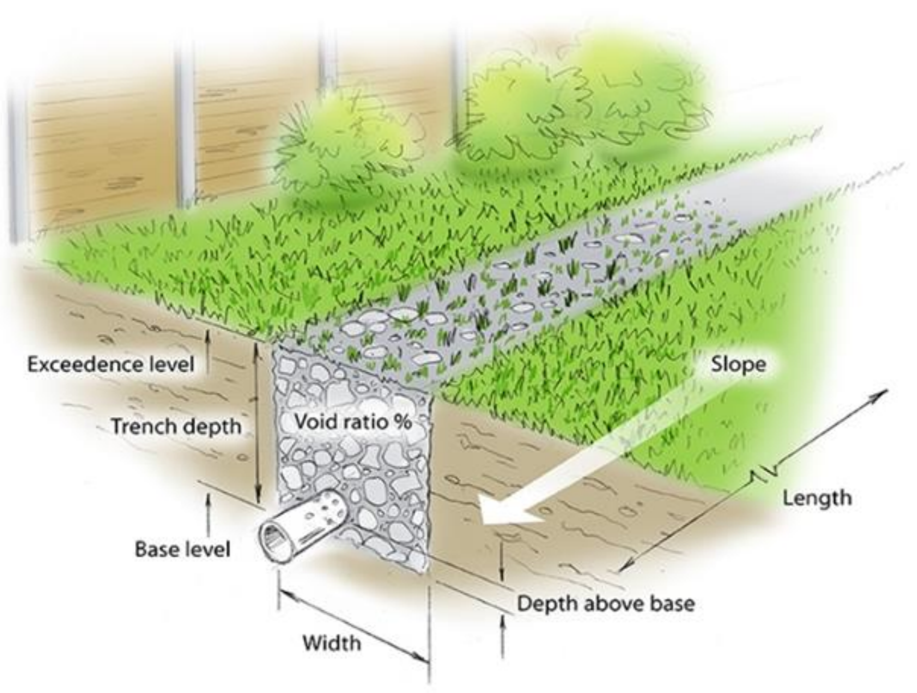

Figure 10: Infiltration Trench functional Diagram (XPDrainage 2017)

Gross pollutant traps are a built-in system which separates solid waste from water easily, due to the different relative densities of foreign matter. Waste less dense than water such as plastic and organic waste matter floats and is separated by the gross pollutant trap. Waste denser than water like glass, aluminium and other heavy waste particles will sink and be separated from the water flow. The limitations of this feature are that it doesn't separate dissolved matter and some smaller particles and waste with a density the same as or similar to water. This waste will wash through freely. Fortunately, this amount of passing waste is a small portion of the total waste. A standard gross pollutant trap diagram can be observed in Figure 11.

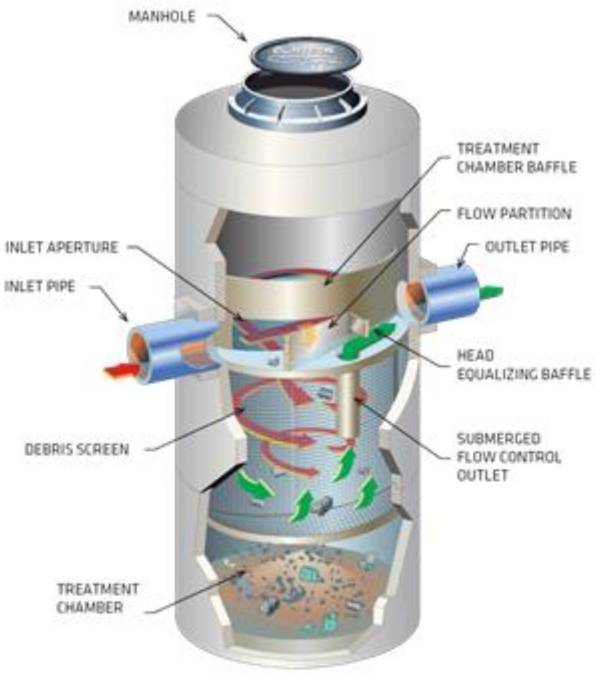

Figure 11: Gross Pollutant Trap Internal Diagram (VortSentry HS™ 2015)

Both forms of WSUD will be incorporated into the mitigation scope for the overall water quality associated within this area. Infiltration trenches are the most natural way to filter, therefore they will be the primary system used. In storm events, initial water run-off will flow into the trenches. When a storm event is large enough to result in overflow of the trenches, the excess water will be directed back into the stormwater system and eventually pass through the gross pollutant traps. After the water passes through the gross pollutant traps, the filtered water will be discharged into the river. Due to their function, gross pollutant traps will require a larger amount of cleaning maintenance than the infiltration trenches.

In total, there will be three infiltration trenches and two gross pollutant traps incorporated into this design. The infiltration trenches have been designed to fit on the Western side of

Hackney Road, to collect initial water run-off. Hackney Road, South of the river, has a significantly larger surface area than the catchment area North of the River. Therefore, there will be two trenches on the Southern side of the river, and one trench on the Northern side. The two gross pollutant traps will be on opposite sides of the river. Each trap is responsible for filtering stormwater for the major North and South catchment areas. For detailed drawings outlining locations and cross sections of the WSUD elements, refer to **drawings 0004-EN-2017 to 0010-EN-2017.**

Two storm water pipes leading into the river have not been designed to have a gross pollutant trap installed. This is due to the existing stormwater pipes are located under a number of private properties and buildings, and all locations will be difficult to access. However, the sub-catchment area is quite small and there would be little environmental improvement with the addition of gross pollutant traps. Therefore, the gross pollutant traps have only been incorporated with the pipes that are discharging the majority of the catchment area.

Another major benefit of having the infiltration trench as the primary WSUD is that the critical pollution runoff will not go into the river. During dry weather, motor vehicle leaks and other pollutants build up on the surface layer. These harmful waste chemicals will stay on the road until a storm event occurs. Most of these chemicals will wash off the surface of the road within the first 5 to 10 minutes of the storm event. This initial, highly contaminated water will runoff directly into the infiltration trench and be absorbed into the ground. This is a major benefit of having the infiltration trench as a primary WSUD feature since the traps do not filter dissolved chemicals or waste with similar densities to water.

Each trench will have identical cross-sectional geometry of 1 metre width and 1.1m depth. Each of the three units are responsible for 3 different sub-catchment areas. These areas vary in size, and therefore the trenches will vary in length which will ultimately give each trench a different storm water volume capacity. The dimensions and volumes of each infiltration trench can be observed in Table 12.

Table 12: Infiltration Trenches – Dimensions, Length and Volume

	Width (m)	Depth (m)	Length (m)	Volume (m^3)
Trench 1	1	1.1	26	28.6
Trench 2	1	1.1	28	30.8
Trench 3	1	1.1	42	46.2

The location of the WSUD units will be 1.5 metres perpendicular from the edge of a kerb or footpath. For Hackney Road, This means the units are located between the road and the footpath. The positioning of these units will provide a greater safety distance for pedestrians.

12.4.4.3. INFILTRATION TRENCH VEGETATION

Infiltration trenches installed along Hackney Road will be accompanied by a number of Carex appresa plants, more commonly referred to as a Tall Sedge. This native Australian plant has been selected due to its ability to withstand flooding conditions, since it will encounter large amounts of water during storm events. The Tall Sedge can grow up to 1m tall and requires little to no maintenance over its lifetime.

Figure 12: Carex Appresa Plant (Canberra Nature Maps)

12.4.4.4. TREE REMOVAL

Twelve trees will need to be removed in order for sufficient space to be acquired for the WSUD elements. Fortunately these trees are all medium to small in size and no large trees need to be removed. Locations for the removal of these trees are outlined in Figures 13, 14 and 15.

From and environmental perspective, the removal of these twelve trees will be a small compromise compared to the major improvement of water quality and reduction of polluted water from the infiltration trenches. For mitigation strategies implemented by E8 for the removal of local flora species, refer to section 12.1.3.1 and urban planning's section in the Detailed Design document.

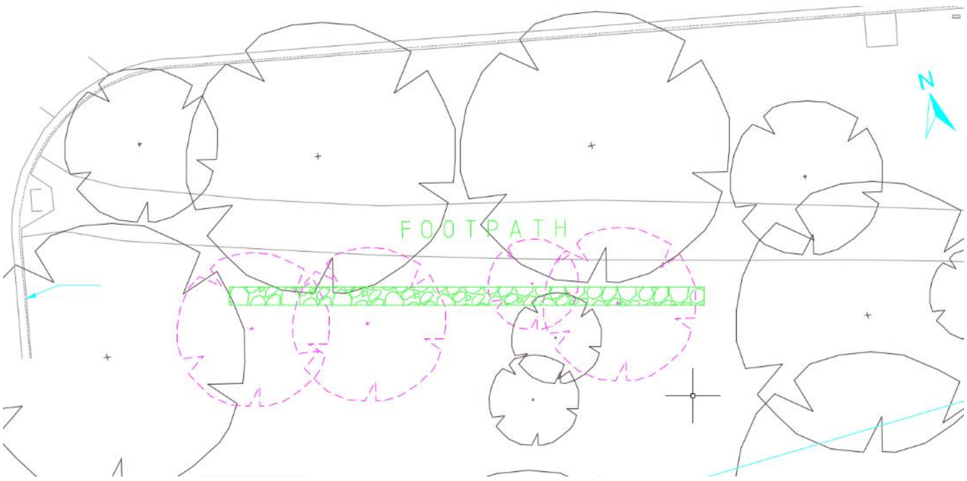

Figure 13: Tree Removal - Infiltration Trench 1

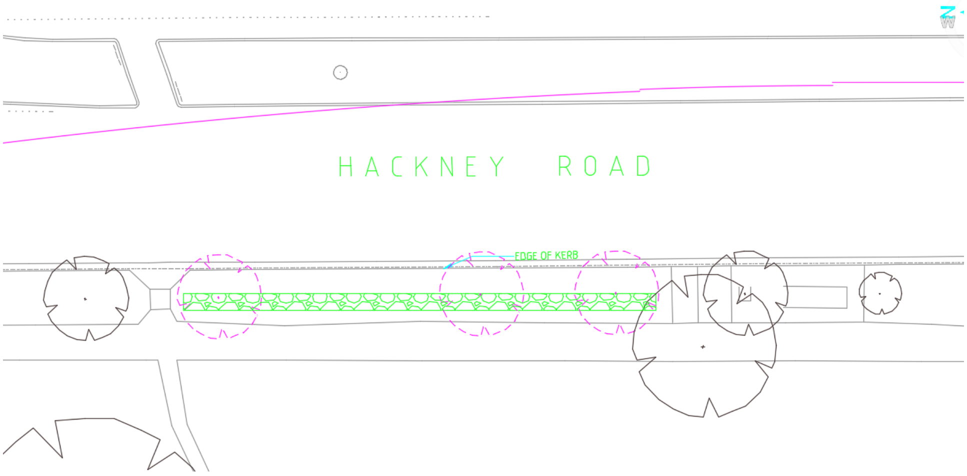

Figure 14: Tree Removal - Infiltration Trench 2

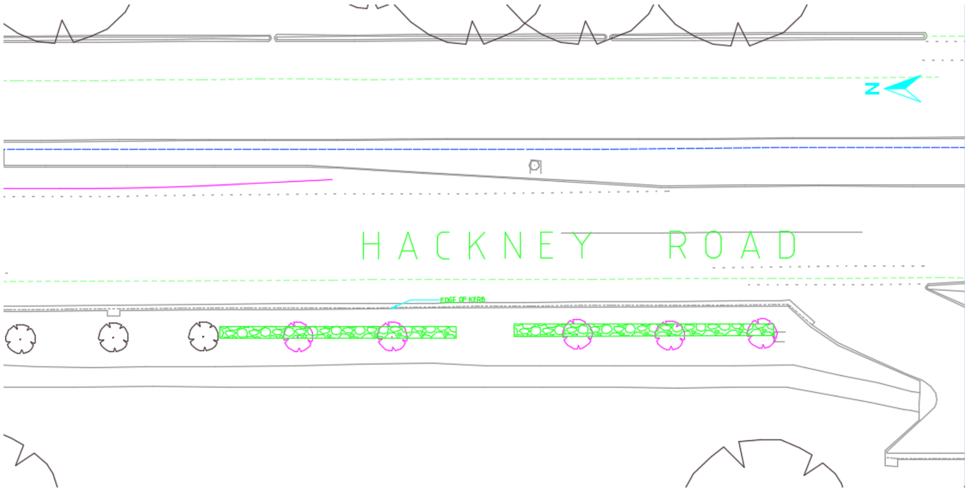

Figure 15: Tree Removal - Infiltration Trench 3

12.4.4.5. MAINTENANCE

Under normal conditions where a gross pollutant trap is used as the primary WSUD, it is estimated that the traps will need to be emptied every 3 months. (Department of the Environment, Water, Heritage and the Arts 2010a). However, due to the fact that the traps are being utilised as a secondary stormwater collection point, scheduled emptying will be slightly less.

The infiltration trenches will require significantly less maintenance. However, litter and other large waste is likely to build up on the surface of the trench, which will restrict the rate of water infiltration. This build up process is significantly slower and less impacting than the gross pollutant trap's waste build up. It is estimated that the infiltration trenches will require cleaning maintenance every 6 months, or when deemed necessary after inspection.

12.4.5. PERFORMANCE OBJECTIVES

- Remove unsightly rubbish and litter from entering the River Torrens
- Reduce harmful chemicals from flowing into the river via the stormwater system
- Construct effective WSUD units for stormwater to bypass
- Improve current stormwater quality discharging into the river
- Improve the ecosystem that is dependent on the river.
- Improve the river's riparian system (refer to 12.1.4)

12.4.6. SUMMARY

Table 13: Water quality action and mitigation summary

Activity	Mitigation
Infiltration	Infiltrate stormwater into the ground rather than discharge into River Torrens through infiltration trenches
Filtration	Separate unwanted litter and chemical waste with gross pollutant traps
Removal	Remove waste and pollutants collected in the gross pollutant traps
Chemical Breakdown	Use vegetation on top of the infiltration trenches to absorb and break down chemicals
Improve river water quality	Implementation of downstream riparian buffer to improve water quality refer to section 12.1.4)

12.5. NOISE & VIBRATIONS

12.5.1. EXISTING CONDITIONS

Hackney Road is a vital sub-arterial road which carries high volumes of daily traffic. Consequently, there is a significant amount of noise pollution that accompanies this major traffic flow. According to DPTI, Noise Pollution is defined as an unwanted sound that can be potentially disruptive to the surrounding environment and individuals. The existing noise levels on Hackney Road were recorded and formulated in a report prepared by AECOM

(2015). The report displays results of a noise level assessment which was recorded using noise loggers which were placed along Hackney Road (Figure 13). Note that only locations 1 and 3 are relevant test locations for this project.

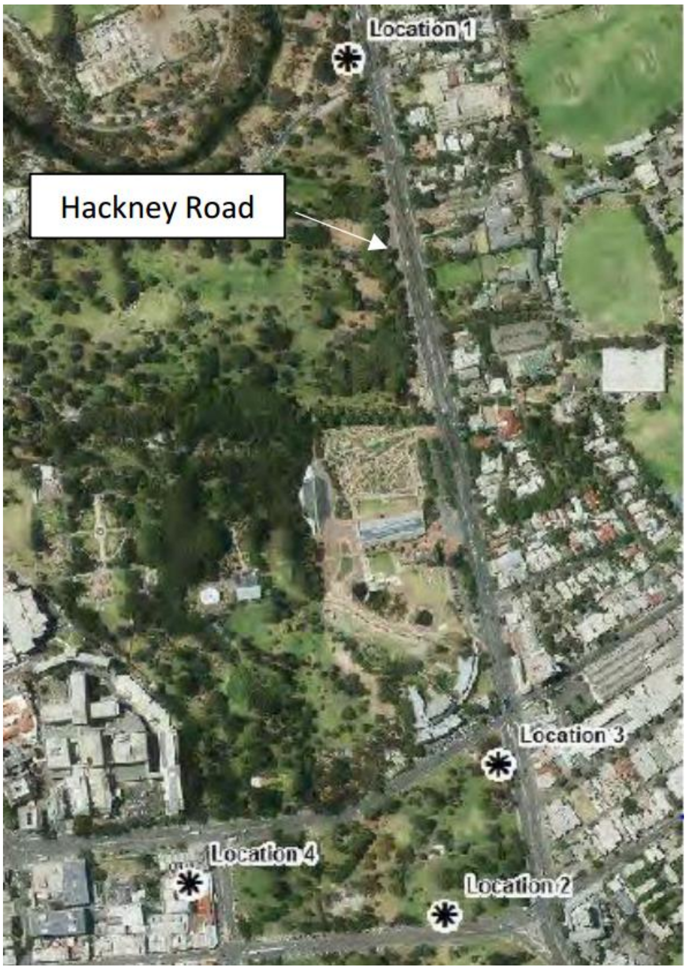

Figure 13: Noise logger test recording locations. (AECOM 2015)

Test results are displayed in Table 14. The daytime hours were recorded over a period of 15 hours (7am to 10pm) and night-time hours are recorded over a 9-hour period (10pm to 7am).

Table 14: Noise pollution statistics

Location	Day, dBA	Night, dBA
Location 1	62.7	57.9
Location 3	63.8	60.1
Average	63.3	59

Using the flowchart assessment process in section 8, the target noise levels after project completion can be predicted. The existing levels are slightly above 63 dBA and 58 dBA for day and night respectively. Hence, the outdoor target is 65 dBA during the day and 60 dBA at night.

12.5.2. MITIGATION AND MANAGEMENT

In order to maintain air quality within the tunnel, its ventilation system will produce noise that could be potentially considered noise pollution. This noise could be quite observable for pedestrians and cyclists walking across the tunnel bridge. In order to mitigate this, rather than having a fan/vent outlet, the system will consist of four internal fans along the tunnel which will direct air flow in one direction, as outlined in the services section of the Detailed Design document. This internal air flow design allows air circulation whilst keeping the noise within the tunnel. This will reduce the noise whilst still producing the same level of air quality inside the tunnel space.

Despite buses generating large volumes of noise due to their increased speeds, there will still be low noise levels observed from the outside of the tunnel. This is due to the tunnel being constructed primarily out of concrete. As a material, concrete is an excellent acoustic barrier against sound and vibration. This means that the additional noise levels will be minimal and therefore no extra noise controls will need to be implemented. Vibration levels for the bicycle and pedestrian path which will be directly above the tunnel will also be more than adequate due to the primarily concrete structure.

It should be noted that due to the design of the tunnel providing adequate noise dampening, there are no mitigation strategies or costs associated with this area.

12.6. AIR QUALITY

12.6.1. EXISTING CONDITIONS

Air pollution occurs when foreign and potentially harmful substances are emitted into the environment and change the composition of the air. This can usually result from sources such as:

- Industrial factories
- Motor vehicles
- Paints and other chemicals

Currently along Hackney Road the air pollution consists of the following pollutants:

- Carbon Monoxide (CO)
- Nitrogen Dioxide (NO2)
- Particulate Matter (both PM10 and PM2.5)
- Volatile Organic Compounds (VOC)

Which are primarily released from vehicles exhaust systems.

12.6.2. ENVIRONMENTAL IMPACT

During construction, there will be an increase of all pollutants due to operation of machinery during road works. Changed traffic conditions will result in an increase in exhaust fumes from commuters, due to changed speed limits resulting in greater rates of acceleration as they are leaving the affected areas. Furthermore, throughout construction there will be several trees removed, which in turn will decrease the amount of CO_2 absorbed from local flora species.

12.6.3. MITIGATION AND MANAGEMENT

In order to maintain an adequate level of air pollutants, E8 will be following EPA SA's pollutant criteria which is displayed in Table 16.

Table 15: Allowable air pollutants

Pollutant	Concentrations (µg/m3)
PM10 (24-hour period)	50
PM2.5 (24-hour period)	25
NO2 (1-hour period)	113
CO (1-hour period)	29,000
VOC (3-minute period)	53

By maintaining a level of each pollutant below the maximum concentration, it will ensure minimal impact on the environment. In order to help reduce the level of CO_2 in the atmosphere, a feature wall will be added to both sides of the tunnel incorporating a green wall and green façade. The plants used for the feature walls will convert CO_2 into oxygen providing cleaner air conditions for the area. Furthermore, mitigation strategies outlined in section 12.1 will enhance these effects.

12.6.4. GREEN WALL/FAÇADE

12.6.4.1. INTRODUCTION

Green walls are often incorporated vertically onto the sides of buildings or structures in the place of an architectural façade, and are biological habitats that can provide a home for several species of flora and fauna.

Figure 14: The Tryptych Green Wall located in Southbank, Melbourne (Growing Green Guide, 2016)

In the absence of any Australian Standards outlining construction guidelines for vertical green walls, E8 has based their design on an interior green wall located in the Land Services and Land Titles office on Grenfell Street in Adelaide, and an exterior wall located at Southbank in Melbourne (Figure 14). Two 3 m tall modular green walls will be constructed on each side of the exterior Western and Eastern walls situated on the bus tunnel bridge, which will be built over the River Torrens. They will take the shape of a parabolic curve and occupy 237 m^2 of the 553 m^2 surfaces. The green wall component has been designed to run for the entire length of the 78 m span between each construction joint. An additional 1 m of tunnel will be exposed between these joints and the abutments designed by E8's geotechnical team. These additional areas will also exhibit a 3 m tall horizontal strip of green wall, similarly structured to the main wall, which will run from the construction joint to the abutment. However, due to spacing between each component, the module closest to the abutment will have slightly different dimensions to the rest of the wall.

A green façade, which incorporates the use of creepers planted in a single module, has been designed to run along the top of the green wall and will be home to two breeds of native creeping vines. Below the green wall, a structural façade constructed from acrylic tiles, and designed by E8's Urban Planning Team will be incorporated to complete the feature. The presence of this element will aid in improving air quality in the area and ultimately reduce the CO_2 emissions produced from the construction process.

E8's environmental team has been delegated the task of designing the green wall and green façade in its entirety, and includes the design of:

- Design of structural elements and modules
- Flora and soil
- Dead load calculations
- Automated drip irrigation system
- Maintenance access requirements and lighting.

For full schematics of the green wall, green façade and structural elements, refer to **drawings 0002-EN-2017, 0003-EN-2017, 0012-EN-2017 and 0013-EN-2017** in the detailed design document.

12.6.4.2. MODULE AND SOIL DESIGN

E8's structural team has designed the exterior walls to withstand an additional dead load for the vertical garden of 102 kg/m^2 (1 kPa). The combination of structural elements and green wall modules have returned a dead load of 101.3 kg/m^2. These modules will be built early on in the construction phase and set aside in a nearby greenhouse located in the Adelaide Botanic Gardens, for approximately four months in order to allow the plants to grow to their allowable sizes. A total of two plants will be selected per module, each of which will be numbered accordingly to allow easy installation into their designated wall space. Welded structural galvanised steel mesh with a design capacity of 45 kg/m^2 at each weld using 4 mm bars will be used to construct the frame for each of the modules, which will have dimensions of 1 m width x 0.5 m height x 0.15 m depth.

The bottom faces of the modules frames will act as anchor points to be connected to the green wall. This method of anchoring will ensure that each plant grows horizontally outward from its module rather than upwards. Furthermore, as the plants reach maturity, their foliage will sag downwards and cover up gaps and irrigation which will be visible between each module. As they are slotted into their designated locations, their dead weight will hold them in place.

The green façade modules will be designed using the same grade of mesh. Each façade module will carry dimensions of 1 m width x 0.2 m height x 0.15 m depth. Mesh will also be incorporated into the façade modules which will climb vertically to the top of the tunnel structure to provide a lattice for creeper vines to be trained.

Soil in each module will be wrapped in a root-pot geo-fabric material. This will ensure that when the modules are hung from the wall, the soil will be held in place securely and experience minimum deformation. The material that has been sourced for these modules is made from 100% recycled and biodegradable material and has a life span of up to five years. Using this root-pot fabric promotes the process of air pruning, in which roots that come into contact with a pervious growing medium, or are exposed to air with little or no humidity, are burned off. This method of natural pruning ensures new growth of roots and in turn promotes a healthier habitat for the plant species.

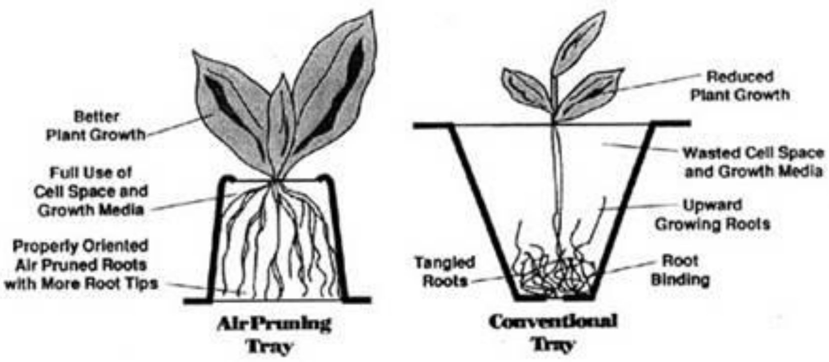

Figure 15: Benefits of air pruning vs conventional growth (Walker, 2005)

When considering the walls final design, it was established that soil contained in the individual modules would be assumed completely saturated to accommodate for the full 60 minute duration of a 1/500 year storm. Soil containing mostly organic material has been selected for the green wall, which results in a fully saturated soil unit weight of 500 kg/m^3. Furthermore, any excess water which is not initially absorbed by the plants root system will not be overly harmful to the River Torrens if it seeps out of the modules. To counteract the issue of water seepage into the Torrens, catchment trays constructed from polyethylene have been designed and will be fitted underneath the bottom row of modules to collect excess water.

12.6.4.3. STRUCTURAL CONSIDERATIONS

Prior to structural elements being fastened to the walls, cementitious waterproofing will be applied to prevent ingress of moisture into any cracks or voids. Following this procedure, Rectangular Hollow Sections (RHS) with dimensions of 150 mm x 100 mm x 5 mm will be connected to the walls using zinc plated hexagonal head dynabolts with sleeve anchors, and will provide anchor points for the green wall modules. Spacing of 75 mm from the edge of the structure to the outside edge of the first RHS will be incorporated into the design at the Northern and Southern construction joints only. Every other vertical component will be spaced at 1000 mm ctrs and grouped in pairs with a 50 mm spacing between each edge. This spacing ensures that there is a 25 mm tolerance for each module at each end to negate any indiscrepancies experienced in the modular fabrication, and to allow for thermal expansion of the mesh frames in the warmer months. 100 mm gaps will also be incorporated between the top and bottom edges of each module for the same reasoning. Each RHS member will be 3 m in length and be bolted to the exterior of the wall in a vertical orientation.

High tensile strength 8.8 Z/P M16 hex bolts have been chosen to connect the structural hooks to the exterior of the RHS, which will provide areas for the modules to be hung.

Finally, green façade modules, which will maintain an overall dead load of 22.25 kg, will be held in place by industrial graded steel shelving tracks and aluminium brackets, which will be fastened to the exterior of the wall 200 mm above the tops of the individual RHS. Each bracket will be placed along the track at 1000 mm ctrs and carry half the load of each façade module. Calculations surrounding the weights of each module, as well as structural elements can be viewed in Appendix B, section 16.2.

12.6.4.4. FLORA SELECTION

The green wall will consist of native Australian plants in order to reduce the required water and maintenance. Benefits to using Australian native plants include the similarities in growing conditions, and removes the need to adopt different soils and fertilizers for individual plants which will reduce total cost and time spent on maintenance.

In order to incorporate a variety of colours and leaf types in the green wall, three plant types were chosen including grass, shrubs and ferns. Two plants from each category were chosen based on their durability, water requirements and shade requirements to ensure they would suit the location and conditions of the green wall.

The selected plants for the green wall are displayed in figures 16-21, with details of each in Appendix C, section 17.1:

Figure 16: Lomandra longifolia 'Nyalla' (Australian Native Plants 2017)

Figure 17: Isolepis Nodosa (Australian Native Plants 2017)

Figure 18: Asplenium Bulbiferum (Kojian 2011)

Figure 19: Asplenium Australasicum (Andreasens Green 2017)

Figure 20: Acacia Cognata Bower Beauty (Bunnings 2017)

Figure 21: Acacia Cognata Dwarf Bush (Magik 2017)

Although the ferns and shrubs have a greater fully grown height, they will be pruned at annual intervals to ensure they don't shade the grass completely.

The flora for the green façade were limited to climbing plants to be suitable with the preference of native Australian plants for the same reasons as the green wall. The selected plants for the green facade are displayed in Figures 22 and 23, with details of each of in Appendix C, section 17.2:

Figure 22: Pandorea Jasminoides 'Charisma' Pandorea (Stewart n.d.)

Figure 23: Cissus antarctica (Kangaroo Vine) (Stewart n.d.)

12.6.4.5. WATER AND IRRIGATION

For the type of plants being used for the green wall and green façade the average amount of water required is 4 mm weekly. To achieve this cover, the total water required is equal to 2060 L of water, weekly. This water will be sourced by utilising the "Glenelg to Adelaide Parklands Recycled Water Project" which uses recycled grey water to provide an adequate water source for the Adelaide park lands. A tap-in point will be constructed approximately 100m south of the green wall (Figure 24). This tap-in point will feed a customised drip irrigation system which will regulate the flow to individual modules using remote telemetry. However, a backup pump will be installed at the mains water to cover the possibility of the recycled water network malfunctioning.

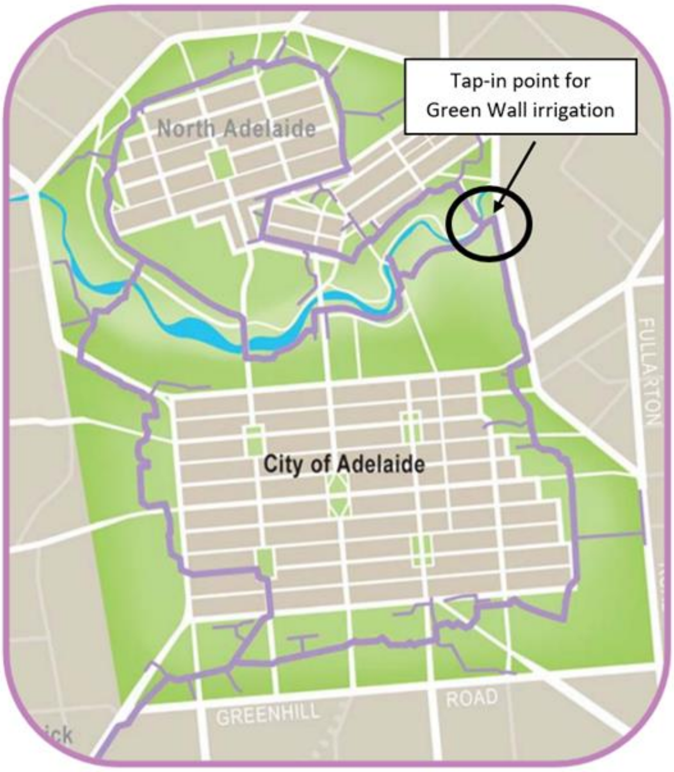

Figure 24: Adelaide Recycled Water Project

To ensure there is no wastage in water, smart irrigation systems that utilise moisture probes will dictate the amount of water supplied to the system. By setting the moisture sensor to 40%, it will ensure that once the moisture content drops below this value, irrigation controllers will pump water through the system. This will allow the soil to become saturated and regain its designed moisture content.

12.6.4.5.1. IRRIGATION MATERIALS

A 50mm diameter PVC pipe will run from the tap-in point to the green wall. The pipework will need several 90^{o} and 45^{o} bends to accommodate the design. One 90^{o} bend will be placed at the Southern, bottom corner of the green wall so the pipe is able to go along the side. Connected to the side of the pipe will be six irrigation pipes. One over the top of the green façade modules, and one for each row of green wall modules. These pipes will be 13 mm in diameter, polyethylene pipes with a burst pressure capacity of 1000 kPa. Three drippers will be placed for each box for the entire length of the wall. These drippers will be made of polypropylene and have a flow rate capacity of 4 L/hr @100 kPa. Incorporating the use of these drippers will reduce wastage of water and ensure all plants desired moisture content is achieved. The same design for the drip irrigation system will be used for each of the green walls.

12.6.4.6. SOIL

It was decided that the use of chemical fertilizer soils was a poor choice, as water runoff could drain into the River Torrens potentially causing algae blooms, which can have major impacts on the existing flora and fauna. The chosen soil is a light weight compost mix with a density of 0.5 t/m^3, which is described as free draining, high in organic nutrients, reduces watering and has a lifespan of 3 years. Compared to other organic soils, this was the suitable choice as the better option due to its reduction in watering and its long lifespan which can be expanded by topping up the boxes as part of the maintenance schedule.

12.6.4.7. MAINTENANCE

The key requirements in regards to maintenance for the green wall and green façade are listed in table 1:

Table 16: Green wall maintenance frequencies

Maintenance	Frequency
Trimming of plants	6 months
Inspection of module integrity	12 months
Inspection of module supports integrity	3 years
Fertilization	2 years

All of these tasks require access to all of the green wall which, being suspended over a creek, has limited the potential of ways to gain access to its elements. E8's structural team has designed the shared pedestrian pathway to be able to withstand the weight of a medium size maintenance truck, equipped with a crane and platform to be lowered over the edge to perform maintenance on the green wall's modules. Sub-contractors responsible for green wall maintenance will be required to hold a current working at heights qualification.

The total duration of trimming the plants is estimated to be eight hours on the green wall and four hours on the green façade per side. Therefore, this process would take approximately four working days to complete both sides of the tunnel. The inspections of both the modules and supports integrity is of high importance to ensure that none of the plants or even modules were to fall from the bridge. By checking both components for signs of failure on a twelve-month basis, this will help eliminate the chance of green wall structural failure.

12.6.4.8. FEATURE LIGHTS

The green wall will be designed to incorporate multicolour solar powered LED's which will provide a mesmerising lighting effect to both the green wall and green façade. The LED's will be controlled using built in sensors, so that the lights only come on at night. Due to the method of using solar power to charge the battery, little to no maintenance is required.

12.6.5. PERFORMANCE OBJECTIVES

- Not exceed EPA SA guidelines on pollutant concentrations
- Reduce CO_2 emissions with the addition of a green feature wall, and revegetation plan (refer to section 12.1.3.1)

12.6.6. SUMMARY

Table 17: Air Quality Action and Mitigation Summary

Activity	Mitigation
Reduction of CO_2 emissions	Implementation of green feature wall
Reduction of other air pollutants	Adopt EPA SA guidelines

12.7. WASTE & HAZARDOUS MATERIALS

12.7.1. MITIGATION AND MANAGEMENT

Waste generated from the construction process will be stored on-site and disposed of in accordance with the Environmental Protection Act, 1993. E8 has identified several areas that will generate waste throughout the life of this project, as well as appropriate mitigation strategies in order to minimise landfill and optimise reuse and recycling. Categories of waste have been summarised in Table 19.

Table 18: Waste generation

Waste Generation	Waste Type	Environmental Impact	Notes
On site contractors and labourers	General waste	Large quantities of landfill	N/A
Construction process	Construction waste	Groundwater and soil contamination	N/A
Plant and machinery	Chemical waste	Groundwater and soil contamination	N/A
Excavation of contaminated soils	Hazardous waste	Groundwater and soil contamination	See section 12.3

12.7.2. WASTE CATEGORIES

A project of this magnitude will produce copious amounts of waste that must be managed properly. The following categories of waste have been determined:

- General waste
- Paper and cardboard
- Glass
- Metal, Aluminium and Steel
- Co-mingled recyclables
- Food and organics
- Dry materials
- Electronic waste
- Plastics
- Timber
- Construction waste
- Liquid waste
- Hazardous & Toxic waste

Considering the waste variables that have been identified, the following control measures have been put in place:

1. Appropriate waste containers will be made available to all areas where employees are most active. Each container will be appropriately labelled for easy identification and all will be fitted with lids. It is the contractor's responsibility to ensure that these containers are emptied and replaced on a weekly basis, or whenever they reach their full capacities. Dispersion of waste specific bins will aid in reducing landfill, separating hazardous and organic materials and maximising recyclables.

2. Plant and machinery maintenance, including the cleaning of cement mixers, are to take place off site prior to arrival or after leaving. If maintenance must occur on-site, it will take place on impermeable surfaces to minimise the chances of chemical infiltration into surrounding soil and groundwater. Any liquids used in this cleaning process will be collected for treatment prior to being released.

3. Orders for construction materials must be as precise as possible. Furthermore, it is advised that delivery of materials must fall within a 24 hour period of when they are required for use. By minimising storage times of materials, and ensuring that materials are placed to order, contamination to soil and groundwater is minimised by reducing the amount of time they spend exposed to the environment.

4. Weekly inspections will be undertaken by the environmental team to ensure all measures outlined in this document are being utilised. In the instance of non-compliance, disciplinary actions will be taken at the discretion of the contractor in charge.

5. Quantities of waste categories will be recorded and monitored in joint collaboration with the sub-contracted waste removal company. Monthly reports will be conducted by the environmental team to ensure all mitigation strategies are being followed and waste is properly managed.

12.7.3. PERFORMANCE OBJECTIVES

- Minimising generated waste
- Recycling, where possible
- Preventing contamination to the surrounding environment by properly disposing of waste
- Maintain a clean and sanitary worksite at all times
- Prevent contamination to topsoil and groundwater
- Advanced resource recovery
-

12.7.4. SUMMARY

Table 19: Waste & hazardous materials action and mitigation summary

Activity	Mitigation
All waste	All waste to be separated and disposed of accordingly in appropriate bins
	General waste to be compacted and deposited to landfill
	Recyclables to be transported to recycling depots
	Any materials found on-site thought to be hazardous to be reported to the EPA immediately for remediation
	All waste bins to be emptied and replaced weekly or when capacity is reached
Construction materials	Material orders to be as precise as possible
	Materials ordered to be used within 24 hours of delivery
	Leftover materials outsourced to other E8 projects
Plant and machinery	Maintenance to be performed off-site prior to arriving or after leaving worksite
	Emergency maintenance on-site to be performed on impermeable surfaces

12.8. ENERGY

12.8.1. EXISTING CONDITIONS

All energy currently consumed along hackney road is due to the illumination of street lights, as well as traffic lights throughout the day. All power associated with these functions is drawn directly from the local grid.

12.8.2. ENVIRONMENTAL IMPACT

The high use of power from the grid causes greenhouse gas emissions from the production of energy. During construction, the energy required will be primarily using fossil fuels to power machinery as well as generators for lighting for working at night, which will also contribute to greenhouse gases.

12.8.3. MITIGATION AND MANAGEMENT

In order to decrease greenhouse gas emissions, two concepts will be used. The first being the use of smart controlled LED's for the street lights along hackney road, which require significantly less power to run. Renewable energy will also be incorporated into the project using solar powered lighting for night construction, and only using a diesel generator when deemed necessary.

12.8.4. PERFORMANCE OBJECTIVES

- Reduction in energy use through incorporation of smart controlled LED street lights
- Reduction in use of diesel generators by using solar powered lighting for night works

12.8.5. SUMMARY

Table 20: Energy action and mitigation summary

Activity	Mitigation
Street light power consumption	Implementation of Smart controlled LED's
Night works power consumption	Implementation of solar powered lights

13. COSTING ANALYSIS

Detailed costing for all design processes and mitigation measures have been calculated by the environmental team and are outlined in Tables 22-27. The final costing as advised by E8's Environmental Team can be viewed in Table 28.

Table 21: Costing - Flora & Fauna

Flora & Fauna					
Item Description	**Type**	**Amount**	**Unit**	**Rate**	**Total**
Toe Zone Plants	Sedges/Hedges	704	-	$ 3	$ 2,112
Bank/Overbank Plants	Small/Medium Shrubs	1116	-	$ 5	$ 5,580
Transitional Plants	Large Shrubs/Small Trees	768	-	$ 10	$ 7,680
Machine hire	Mini Excavator	14	days	$ 150	$ 2,100
Labour	-	672	hrs	$ 50	$ 33,600
SUBTOTAL					**$ 51,072**
Allow Preliminaries				**10%**	**$ 5,107**
Contingencies				**10%**	**$ 5,107**
GST				**10%**	**$ 5,107**
TOTAL					**$ 66,394**

Table 22: Costing - River Conditions

River Conditions					
Item Description	**Type**	**Amount**	**Unit**	**Rate**	**Total**
Concrete Channel	50 Mpa	2508.8	m^3	$ 190	$ 476,672
Reinforcing mesh	RL 818	1200	m^2	$ 15	$ 18,000
Formwork	Class 1	1200	m^2	$ 180	$ 216,000
Pebbles	-	320	m^2	$ 10	$ 3,200
Excavation	-	420	m^3	$ 120	$ 50,400
Labour	-	944	hrs	$ 51	$ 48,144
SUBTOTAL					**$ 812,416**
Allow Preliminaries				**10%**	**$ 81,242**
Contingencies				**10%**	**$ 81,242**
GST				**10%**	**$ 81,242**
TOTAL					**$ 1,056,141**

Table 23: Costing - Soil

Soil					
Item Description	**Type**	**Amount**	**Unit**	**Rate**	**Total**
Transportation to landfill	Contaminated topsoil	27,252.90	t	$ 160	$ 4,360,464
Testing - excavation	Portable tubidity meter	305	-	$ 60	$ 18,300
Testing - Storage areas	Portable tubidity meter	24	-	$ 60	$ 1,440
Miscelaneous	Tarpaulin (6m x 5.5m)	6	-	$ 17	$ 102.00
	Sediment fences	60	-	$ 12	$ 720
	Sandbags	180	-	$ 1	$ 180
SUBTOTAL					**$ 4,381,206**
Contingencies				**10%**	**$ 438,121**
GST				**10%**	**$ 438,121**
TOTAL					**$ 5,257,447**

Table 24: Costing - Water Quality

Water Quality					
Item Description	**Type**	**Amount**	**Unit**	**Rate**	**Total**
Tree removal	-	12	trees	$ 440	$ 5,280
Trench excavation	-	155	t	$ 57	$ 8,835
Soil removal	-	105	t	$ 160	$ 16,800
Geo-fabric	-	700	m^2	$ 1	$ 700
Porous material	-	28.8	t	$ 99	$ 2,851
Top layer aggregate	UGM	62	t	$ 99	$ 6,138
Carex Appressa Plan	-	786	plants	$ 3	$ 2,358
Labour	-	563	hrs	$ 51	$ 28,713
Machine hire	Front end loader & bobcat	15	days	$ 165	$ 2,475
Item Total					**$ 40,604**
SUBTOTAL					**$ 114,754**
Allow Preliminaries				**10%**	**$ 11,475**
Contingencies				**10%**	**$ 11,475**
GST				**10%**	**$ 11,475**
TOTAL					**$ 149,181**

Table 25: Costing - Air Quality

Air Quality (Green wall & façade)					
Item Description	**Type**	**Amount**	**Unit**	**Rate**	**Total**
Mesh (main cage)	Galvanized steel	740	-	$ 31	$ 22,940
Mesh (top)	Galvanized steel	740	-	$ 15	$ 11,100
Geo-fabric	-	1304.4	m^2	$ 1	$ 1,304
Soil	-	61.06	t	$ 99	$ 6,045
RHS	Galvanized, steel	780	m	$ 37	$ 28,860
Hooks	Galvanized, steel	2600	-	$ 5	$ 13,000
Hook fasteners	8.8 Z/P M16 hex bolts	2600	-	$ 1	$ 2,600
RHS fasteners	DP12125 M10/70 dynabolt	1264	-	$ 1	$ 1,264
Tracks	1000 mm twintrack mount	148	-	$ 7	$ 1,036
Brackets	125 mm bracket	296	-	$ 2	$ 592
LED's	-	296	-	$ 18	$ 5,328
Plants	See Appendix C	1776	-	$ 9	$ 15,984
Greenhouse hire	-	1000	month	$ 4	$ 4,000
Cementitious water proofing	Polyurethane base	1106	m^2	$ 35	$ 38,710
Labour	-	1500	hrs	$ 51	$ 76,500
Machine hire	Truck with work platform	4	days	$ 165	$ 660
Back-up Pump	-	2	-	$ 100	$ 200
Irrigation Piping	PVC	250	m	$ 10	$ 2,500
Irrigation Fittings	90, 45 degree bends	4	-	$ 5	$ 20
Irrigation Piping	Polyethylene	1000	m	$ 1	$ 1,000
Irrigation Fittings	Polypropylene	1600	-	$ 1	$ 1,600
SUBTOTAL					**$ 235,243**
Allow Preliminaries				**10%**	**$ 23,524**
Contingencies				**10%**	**$ 23,524**
GST				**10%**	**$ 23,524**
TOTAL					**$ 305,816**

Table 26: Costing - Energy, Waste & Hazardous Materials

Energy, Waste & Hazardous Materials					
Item Description	**Type**	**Amount**	**Unit**	**Rate**	**Total**
Smart Street lights	LED's	60	-	$ 220	$ 13,200
Waste removal	Sub-contracters (SUEZ)	2	yrs	$35,000	$ 70,000
SUBTOTAL					**$ 83,200**
Contingencies				**10%**	**$ 8,320**
GST				**10%**	**$ 8,320**
TOTAL					**$ 99,840**

Table 27: Costing - Final Figure

FINAL COST	
Section	**Cost**
Flora & Fauna	$ 66,394
Water	$ 149,181
River Conditions	$ 1,056,141
Soil	$ 5,257,447
Air Quality	$ 306,843
Energy, Waste & Hazardous Materials	$ 99,840
FINAL COST	**$ 6,935,846**

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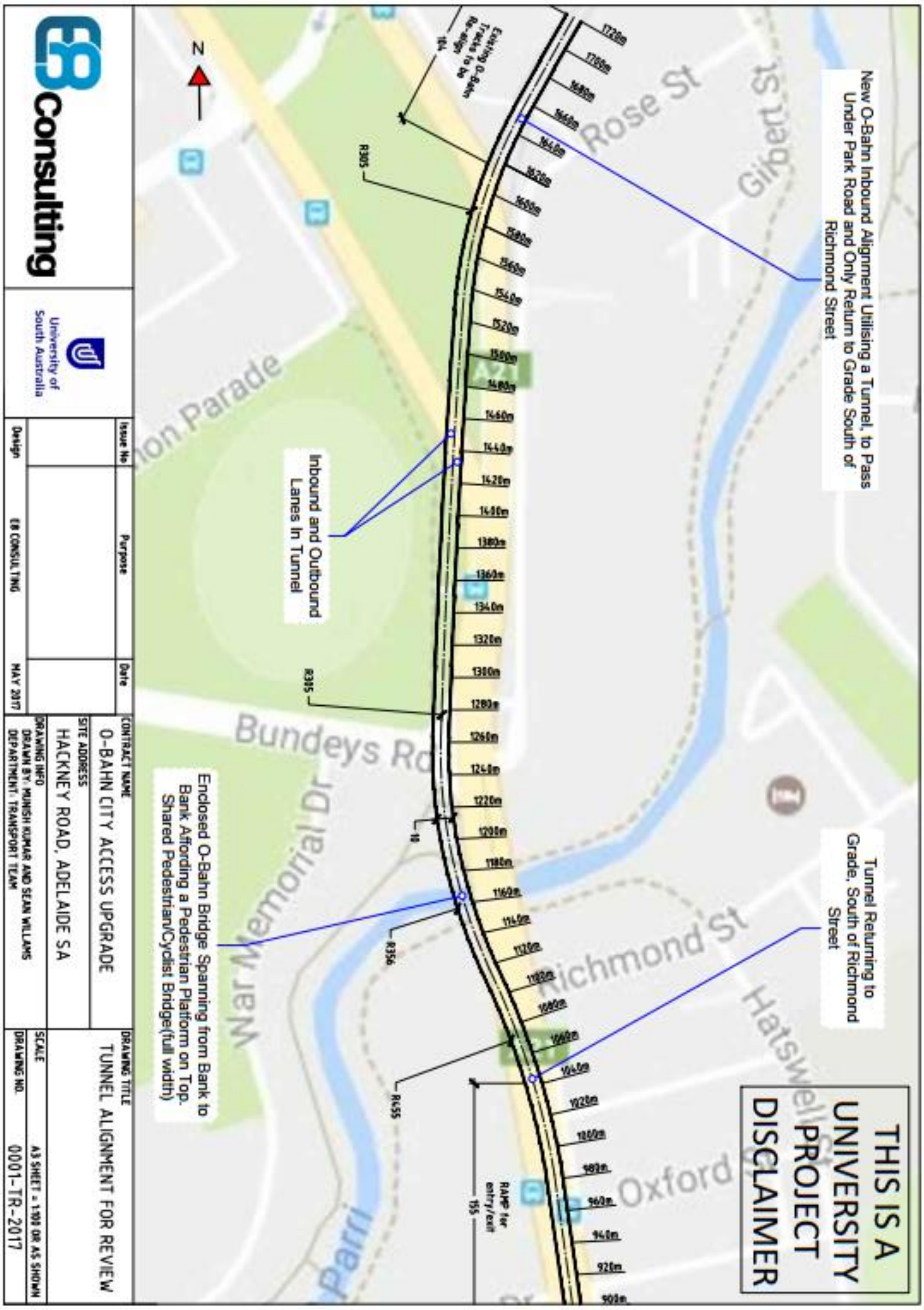
15. APPENDIX A – HORIZONTAL ALIGNMENT OF NORTHERN TUNNEL



16. APPENDIX B – DESIGN CALCULATIONS

16.1. CONTAMINATED SOIL EXCAVATION

$$\gamma_{soil} = 18.5\frac{kN}{m^3} = 1.89\ t/m^3$$

Tunnel Excavation

$$(841.8\ m - 78\ m) * 10\ m * 0.6\ m = 4{,}582.8\ m^3$$

Hackney Road median North

$$415\ m * 4\ m * 0.68\ m = 1{,}128.8\ m^3$$

Hackney Road median South

$$388\ m * 4\ m * 0.75\ m = 1{,}164\ m^3$$

Hackney Road widening (Western carparks)

$$5{,}300\ m^2 * 0.6\ m = 3{,}180 m^3$$

Hackney Road median works, incorporating 4% reuse for backfill

$$(1{,}164\ m^3 + 1{,}128.8\ m^3 + 3{,}180 m^3) - [0.04(1{,}164\ m^3 + 1{,}128.8\ m^3 + 3{,}180 m^3)]$$

$$= 9{,}836.7 m^3$$

Total expected contaminated soil to be removed

$$(9{,}836.7\ m^3 + 4{,}582.8\ m^3) * 1.89\frac{t}{m^3}$$

$$\underline{= \mathbf{27,252.9\ tonnes}}$$

16.2. GREEN WALL/FAÇADE DEAD LOAD

Structural Elements – Green wall

Axial compression for RHS

RHS sections will be fastened to the exterior tunnel wall using dynabolts and sleeves at 1000 mm ctrs. For each 1000 mm, RHS will carry half the weight of 2 full modules. N* is calculated as:

$$Module\ weight = 47.2\ kg$$

$$N^* = \frac{[2(47.2\ kg)]}{2} = 47.2\ kg = 0.46\ kN$$

For 150 mm x 100 mm x 5 mm RHS to be deemed as suitable structural members, the following must be satisfied:

$$N^* \leq \emptyset N_s, and$$

$$N^* \leq \emptyset N_c$$

[AS4100, p81, cl 6.1]

N^* = 0.46 kN

$$\emptyset N_s = \emptyset k_f A_n f_y$$

[AS4100, p81, cl 6.2.1]

Where:

k_f = 1

A_n = 2310 mm^2

f_y = 500 MPa

ϕ = 0.9

$$\emptyset N_s = 0.9(1.0)(2310)(350)(10^{-3})$$

**Note: A_n & r value taken from Table 2.1(a) of Cold Formed Structural Hollow Sections & Profiles, Onesteel Market Mills, November 2004.*

$$\emptyset N_s = 727.7\ kN$$

$$0.46\ kN < 727.7\ kN$$

$$\emptyset N_c = \emptyset \alpha_c N_s \leq N_s$$

[AS4100, p83, cl 6.3.3]

For α_c to be determined l_e, α_b and λ_n must first be established

$$l_e = k_e l$$

[AS4100, p83, cl 6.3.2]

$$k_e = 1.0\ (pinned\ connections)$$

[AS4100, p44, Figure 4.6.3.2]

$$\therefore l_e = 1m$$

$\alpha_b = -0.5$ (cold formed, non stress relieved)

[AS4100, p85, Table 6.3.3(1)]

For compression about x-axis

$$\lambda_n = \left(\frac{l_e}{r}\right)\sqrt{(k_f)}\sqrt{\frac{f_y}{250}}$$

[AS4100, p86, Table 6.3.3(3)]

$$\lambda_n = \left(\frac{1000}{40.4}\right)\sqrt{1.0}\sqrt{\frac{350}{250}}$$

$$\lambda_n = 29.3$$

$\therefore \alpha_{cx} = 0.97$ by interpolation

[AS4100, p86, Table 6.3.3(3)]

$$\emptyset N_{cx} = (0.9)(0.97)(727.7)$$

$$\emptyset N_{cx} = 635.3\ kN$$

$$0.46\ kN < 635.3\ kN$$

Therefore, 150 mm x 100 mm x 5 mm RHS is ok in axial compression.

Taking into consideration the entire 79m span of the bridge, the following applies:

Within the first and last metre of the span, 1 RHS will be incorporated at each end.

Within the remaining 77m of the span, 2 RHS per metre will be used.

Total length of RHS

$$130\ units * 3m = 390m$$

Total weight

$$390m * 14.2\frac{kg}{m} = 5{,}538\ kg$$

Amount of hooks

$$5 * 130 = 650\ hooks$$

Total weight

$$650\ hooks * [0.01m(0.04m + 0.09m + 0.05m)] * 0.09m * 8{,}000\frac{kg}{m^3} = 842.4\ kg$$

Amount of bolts

$$650\ hooks * 2\ bolts = 1{,}300\ bolts$$

Total weight

$$1{,}300\ bolts * 0.123kg = 159.9\ kg$$

Total structural elements weight

$$5{,}538\ kg + 842.4\ kg + 159.9\ kg$$

$$\underline{= \mathbf{6,540.3\ kg}}$$

Plant modules - Green wall

The final design for the green wall and façade incorporates the use of a modular system containing individual plant containers, each containing between 8 plants. The following applies:

Module volume

$$1m * 0.5m * 0.15m = 0.075m^3$$

Module cage mesh weight

$$Mesh\ custom\ made\ from\ 4mm\ diameter\ galvanized\ steel\ at\ 3.10\frac{kg}{m^2}$$

$$\therefore 3.1\frac{kg}{m^2} * [1.3m * 0.8m - 4(0.15m^2)] = 2.95\ kg\ per\ sheet$$

Module cover mesh weight

$$3.1\frac{kg}{m^2} * 1m * 0.5m = 1.55\ kg\ per\ sheet$$

<u>Soil per module:</u>

$$\gamma_{soil,saturated} = 500\frac{kg}{m^3}$$

$$0.075m^3 * 500\frac{kg}{m^3} = 37.5\ kg\ per\ module$$

<u>Plants</u>

$$Note: Average\ plant\ weight = 10.2\frac{kg}{m^2}$$

<u>Total module weight</u>

$$2.95\ kg + 1.55\ kg + 37.5\ kg + \left(\frac{10.2}{2}\right)$$

$$\underline{= \mathbf{47.2\ kg\ per\ module}}$$

Irrigation

Total green wall weight

$$\underline{370 * 47.2 + 6{,}540.3\ kg = \mathbf{24,004.3\ kg} = \mathbf{101.3\ kg/m^2}}$$

Structural elements – Green façade

<u>Horizontal steel tracks</u>

$$1m * 0.02m * 0.005m * 8{,}000\frac{kg}{m^3} = 0.8\ kg\ per\ track$$

<u>Aluminium brackets</u>

$$weight = 0.1\ kg$$

Plant modules - Green façade

<u>Module volume</u>

$$0.25m * 0.15m * 1m = 0.0375m^3$$

<u>Module cage mesh weight</u>

$$3.1\frac{kg}{m^2} * [1.6m * 0.75m - 4(0.3m^2)] = 2.6\ kg\ per\ sheet$$

<u>Soil per module</u>

$$0.0375m^3 * 500\frac{kg}{m^3} = 18.75\ kg\ per\ module$$

<u>Plants per module</u>

$$Note: Creeper\ vine\ weight\ \approx 0.9\frac{kg}{m}$$

<u>Total module weight</u>

$$2.6\ kg + 18.75\ kg + 0.9\ kg$$

$$\underline{= \mathbf{22.25\ kg\ per\ module}(+\mathbf{1kg\ for\ structural\ tracks})}$$

Total green façade weight

$$\underline{74 * 23.25 = 1{,}720.5\ kg}$$

**Note: Exterior walls have been designed by the structural team for 102 kg/m^2 (1 kPa) additional dead load for the entire 553 m^2 area.*

16.3. CONCRETE CHANNEL

Concrete design

AS 3600 Table 4.3 – Class 4(b) defines classification as category U (refer to AS 3735)

AS 3735 table 4.1 – Class 1(b) defines classification as category B2

Assuming installation won't involve intense compaction use table 4.2

To ensure a long design life 50MPA concrete will be used

AS 3735 table 4.2 states 50MPA concrete with B2 classification requires cover of 40mm

Design thickness = 150mm

Reinforcement Design

Due to channel being fully supported by the surrounding soil tensile and compressive reinforcement isn't necessary.

Crack control is required to ensure water doesn't penetrate through the cracks into the soil.

$$P_{min} \geq 0.2(\frac{D_S}{d})^2 * (\frac{f'_{ct.f}}{f_{sy}})$$

$$0.2(\frac{150}{104})^2 * \left(\frac{0.6\sqrt{50}}{500}\right) = 0.0035$$

To achieve cracking control P ≥ 75% of P_{min}

$$P \geq 0.75 * 0.0035 * \frac{150}{104} = 0.0038$$

$$Ast \geq 0.0038 * 1000 * 104 = 394mm^2$$

Adopt RL 818 Ast longitudinal = 454mm^2

Earth channel max flow without flooding				Concrete channel matched with Earth channel flow		
Parameter	**Value**	**Unit**		**Parameter**	**Value**	**Unit**
T (top width)	15	m		T (top width)	12.2084001	m
b (bottom width)	9	m		b (bottom width)	9	m
Z (bank slope)	1	m		Z (bank slope)	1	m
s (channel slope)	0.0056	%		s (channel slope)	0.0056	%
y (height of water)	3	m		y (height of water)	1.60	m
n earth (manning roughness)	0.05	m		n concrete (manning roughness)	0.017	m
A (channel area)	36.0	m^2		A (channel area)	17.0	m^2
p (chennel perimeter)	17.49	m		p (chennel perimeter)	13.54	m
R (hydraulic radius)	2.06	m		R (hydraulic radius)	1.26	m
V (velocity)	2.42	m/s		V (velocity)	5.13	m/s
Q (flow rate)	87.20	m^3/s		Q (flow rate)	87.20	m^3/s

Earth channel Average flow				Concrete channel max flow		
Parameter	**Value**	**Unit**		**Parameter**	**Value**	**Unit**
T (top width)	9.342831944	m		T (top width)	15	m
b (bottom width)	9	m		b (bottom width)	9	m
Z (bank slope)	1	m		Z (bank slope)	1	m
s (channel slope)	0.0056	%		s (channel slope)	0.0056	%
y (height of water)	0.171415972	m		y (height of water)	3	m
n earth (manning roughness)	0.05			n concrete (manning roughness)	0.017	
A (channel area)	1.6	m^2		A (channel area)	36.0	m^2
p (chennel perimeter)	9.48	m		p (chennel perimeter)	17.49	m
R (hydraulic radius)	0.17	m		R (hydraulic radius)	2.06	m
V (velocity)	0.45	m/s		V (velocity)	7.12	m/s
Q (flow rate)	0.71	m^3/s		Q (flow rate)	256.47	m^3/s

Earth channel Flood height				Concrete channel previous flood flow		
Parameter	**Value**	**Unit**		**Parameter**	**Value**	**Unit**
T (top width)	16.82706254	m		T (top width)	13.23472132	m
b (bottom width)	9	m		b (bottom width)	9	m
Z (bank slope)	1	m		Z (bank slope)	1	m
s (channel slope)	0.0056	%		s (channel slope)	0.0056	%
y (height of water)	3.913531269	m		y (height of water)	2.117360659	m
n earth (manning roughness)	0.05			n concrete (manning roughness)	0.017	
A (channel area)	50.5	m^2		A (channel area)	23.5	m^2
p (chennel perimeter)	20.07	m		p (chennel perimeter)	14.99	m
R (hydraulic radius)	2.52	m		R (hydraulic radius)	1.57	m
V (velocity)	2.77	m/s		V (velocity)	5.95	m/s
Q (flow rate)	140.00	m^3/s		Q (flow rate)	140.00	m^3/s

Figure 25: River and Concrete Channel Flow Rates

16.4. RIPARIAN BUFFER

$$North\ bank\ area\ (land)\ =\ 5{,}250m^2$$

$$North\ bank\ length\ =\ 240m$$

$$South\ bank\ area\ (land)\ =\ 3{,}300m^2$$

$$South\ bank\ length\ =\ 200m$$

$$+\ Proposed\ submerged\ buffer\ width\ of\ 4m\ (both\ banks)$$

$$\therefore\ Extra\ submerged\ North\ bank\ area\ =\ 240\ \times 4 = 960m^2$$

$$Extra\ submerged\ South\ bank\ area\ =\ 200\ \times 4 = 800m^2$$

$$\therefore\ Total\ Northern\ design\ area\ =\ 5{,}250 + 960 = 6210m^2$$

$$Total\ Southern\ design\ area\ =\ 3{,}300 + 800 = 4{,}100m^2$$

$$Total\ design\ area\ =\ 6{,}210 + 4{,}100 = 10{,}310m^2$$

3 Zones: ***Toe Zone, Bank/Overbank Zone, Transitional Zone***

1. Toe Zone

$$Toe\ Zone\ width = 4m$$

$$Area = 4\ \times (200 + 240) = 1760m^2$$

$$Total\ diameter\ of\ combined\ Toe\ Zone\ flora = 2.5 + 2.5 + 0.75 + 0.3 = 5.05m$$

$$Area = \pi(\frac{5.05}{2})^2 = 20.03m^2$$

$$\therefore \ Number\ of\ each\ plant\ = \frac{1760}{20.03} = 87.9 \rightarrow 88$$

$$\underline{Total\ number\ of\ Toe\ Zone\ plants = 88 \times 4 = 352\ plants}$$

2. Bank/Overbank Zone

$$Bank/Overbank\ Zone\ width = 10m$$

$$Area = 10\ \times (200 + 240) = 4400m^2$$

$$Total\ diameter\ of\ combined\ Bank/Overbank\ Zone\ flora$$

$$= 2.5 + 1.25 + 1.75 = 5.5m$$

$$Area = \pi(\frac{5.5}{2})^2 = 23.76m^2$$

$$\therefore \ Number\ of\ each\ plant\ = \frac{4400}{23.76} = 185.2 \rightarrow 186$$

$$\underline{Total\ number\ of\ \frac{Bank}{Overbank}\ Zone\ plants = 186 \times 3 = 558\ plants}$$

3. Transitional Zone

$$Transitional\ Zone\ Area = Total - Toe - Bank/Overbank$$

$$= 10{,}310 - 1{,}760 - 4{,}400 = 4150m^2$$

$$Total\ diameter\ of\ combined\ Transitional\ zone\ flora = 3.5 + 1.75 = 5.25$$

$$Area = \pi(\frac{5.25}{2})^2 = 21.65m^2$$

$$\therefore \ Number\ of\ each\ plant\ = \frac{4150}{21.65} = 191.7 \rightarrow 192$$

$$\underline{Total\ number\ of\ Transitional\ Zone\ plants = 192 \times 2 = 384\ plants}$$

$$\therefore \ Total\ number\ of\ plants\ required\ for\ Riparian\ Buffer$$

$$\underline{= 352 + 558 + 384 = 1294\, plants}$$

$$\underline{Allowing\ for\ unexpected\ plant\ death \rightarrow\ Total = 1294 \times 2 = 2588}$$

17. APPENDIX C – FEATURE WALL FLORA SELECTION

17.1. GREEN WALL PLANTS

Table 28: Green wall plant varieties

Plant Name	Plant type	Fully Grown width (mm)	Fully Grown Height (mm)
Lomandra longifolia 'Nyalla'	Grass	900	900
Isolepis nodosa	Grass	600	600
ASPLENIUM BULBIFERUM	Fern	1200	1200
Asplenium australasicum	Fern	1500	1500
Acacia Cognata Compact Lime Cascade	Shrub	1500	1200
Acacia cognata dwarf	Shrub	1500	1200

17.2. GREEN FAÇADE PLANTS

Table 29: Green facade plant varieties

Plant Name	Plant type	Fully Grown width (mm)	Fully Grown Height (mm)
Pandorea jasminoides	Climbing	2000	3000
Cissus antarctica	Climbing	6000	4000

18. APPENDIX D – RIPARIAN BUFFER FLORA DETAILS

18.1. TOE ZONE FLORA

Eleocharis acuta

Common Spike-rush (Southern Lofty)

Notes

Uses: Along or around fresh watercourses, ponds and wetlands to improve the aesthetic appearance and provide habitat for water-birds, frogs and fish. Requires permanent or semi-permanent waterlogging.

Can spread rapidly.

This plant is indigenous to the following botanical regions of South Australia.

:LE: Lake Eyre
:GT: Gairdner-Torrens
:FR: Flinders Rangers
:EP: Eyre Peninsula
:NL: Northern Lofty
:MU: Murray
:YP: Yorke Peninsula
:SL: Southern Lofty
:KI: Kangaroo Island
:SE: South Eastern

For detail on these regions refer to the user guide.

Height
0.3-0.9 m

Spread
2-3 m

Position
Full Sun

Family
Cyperaceae

Botanical Name
Eleocharis acuta

Common Name
Common Spike-rush (Southern Lofty)

Origin
SA, Vic, NSW, WA, Tas, Qld

Habit
Clumping, Spreading, Vigorous

Landscape
Watercourse

Soil Texture
Clay, Loam

pH
Acidic, Neutral

Tolerates
Moderate frost

Supplementary Watering
None

Flower Colour
Brown

Flowering Time
Spring, Autumn

Flower Type
Spikes

Purpose
Habitat, Ornamental

Evergreen/Deciduous
Evergreen

Form
Grass Sedge or Flax

Indigenous to the Adelaide Region

Figure 26: Eleocharis acuta (Botanic Gardens of South Australia, 2017)

Eleocharis sphacelata

Tall Spike-rush

Notes

Uses: Along or around fresh watercourses, ponds and wetlands to improve the aesthetic appearance and provide habitat for water-birds, frogs and fish. Requires permanent or semi-permanent waterlogging.
Can spread rapidly.

This plant is indigenous to the following botanical regions of South Australia.

:FR: Flinders Rangers
:NL: Northern Lofty
:SL: Southern Lofty
:KI: Kangaroo Island
:SE: South Eastern

For detail on these regions refer to the user guide.

Height
0.5-2 m

Spread
2-3 m

Position
Full Sun

Family
Cyperaceae

Botanical Name
Eleocharis sphacelata

Common Name
Tall Spike-rush

Origin
SA, Vic, NSW, Qld,Tas, NT, New Zealand, New Guinea

Habit
Clumping, Spreading, Vigorous

Landscape
Watercourse

Soil Texture
Clay, Loam

pH
Acidic, Alkaline, Neutral

Tolerates
Moderate frost

Supplementary Watering
None

Flower Colour
White

Flowering Time
Summer, Autumn

Flower Type
Spikes

Purpose
Habitat, Ornamental

Form
Grass Sedge or Flax

Indigenous to the Adelaide Region

Figure 27: Eleocharis sphacelate (Botanic Gardens of South Australia, 2017)

Juncus australis

Grassy Rush

Notes

Uses: A useful perennial rush for growing in moist and wet soils along watercourses and wetlands. Tolerant of periods of inundation.
Valuable for bird and wildlife habitat.
Cultural uses: Indigenous peoples used the stem and leaves for fibre to make string, fishing line, woven rugs and baskets.
Appropriate in biofiltration systems and raingardens.

This plant is indigenous to the following botanical regions of South Australia.

:SL: Southern Lofty
:SE: South Eastern

For detail on these regions refer to the user guide.

Height
0.6-1.2 m

Spread
0.5-1 m

Position
Full Sun

Family
Juncaceae

Botanical Name
Juncus australis

Common Name
Grassy Rush

Origin
SA, Vic, NSW, Tas

Habit
Clumping, Spreading

Landscape
Watercourse

Soil Texture
Loam, Sand

pH
Acidic, Neutral

Tolerates
Drought, Moderate frost

Supplementary Watering
None

Flower Colour
Brown

Flowering Time
Spring, Summer, Autumn, Winter

Flower Type
Clusters

Purpose
Ornamental, Habitat

Evergreen/Deciduous
Evergreen

Form
Grass Sedge or Flax

Figure 28: Juncus australis (Botanic Gardens of South Australia, 2017)

Isolepis inundata

Swamp Club-rush

Notes

Uses: A useful tufting perennial plant for growing in moist and wet soils along watercourses and wetlands. Tolerant of periods of inundation. Habitat and food source for birds, fish, frogs and insects.

This plant is indigenous to the following botanical regions of South Australia.

:FR: Flinders Rangers
:EP: Eyre Peninsula
:MU: Murray
:SL: Southern Lofty
:KI: Kangaroo Island
:SE: South Eastern

For detail on these regions refer to the user guide.

Height
0-0.5 m

Spread
0.1-0.5 m

Family
Cyperaceae

Botanical Name
Isolepis inundata

Common Name
Swamp Club-rush

Origin
SA, Vic, NSW, WA, Tas, Qld

Habit
Tufting

Landscape
Watercourse

Soil Texture
Loam

pH
Acidic, Neutral

Tolerates
Lime, Moderate frost

Supplementary Watering
None

Flower Colour
Brown

Flowering Time
Spring, Autumn

Flower Type
Spikes

Purpose
Habitat, Ornamental

Evergreen/Deciduous
Evergreen

Form
Grass Sedge or Flax

Indigenous to the Adelaide Region

Figure 29: Isolepis inundata (Botanic Gardens of South Australia, 2017)

18.2. BANK/OVERBANK ZONE FLORA

Calothamnus quadrifidus

One Sided Bottle-brush

Notes

Uses: Highly ornamental shrub for verges, median streets, parks and reserves. Planted singly as a colourful background in mixed plantings or en-mass as a barrier or small informal hedge. Responds to pruning. Bird and insect attracting.

Note: This species is provisionally classified schedule 1, Regulation 24.2 under the Sewerage Act. Written approval is required prior to planting in streets or roads. It should not be planted closer than two metres to any sewer main or connection.

Height
2-3 m

Spread
2-3 m

Position
Full Sun

Family
Myrtaceae

Botanical Name
Calothamnus quadrifidus

Common Name
One Sided Bottle-brush

Origin
WA

Habit
Upright to spreading, Dense

Landscape
2nd line coast, Coastal footslopes, Footslopes, Hills, Plains

Soil Texture
Clay, Loam, Sand

pH
Acidic, Alkaline, Neutral

Tolerates
Drought, Heavy frost, Lime

Supplementary Watering
Minimal

Flower Colour
Red

Flowering Time
Autumn, Spring

Flower Type
Bottlebrush

Purpose
Ornamental, Habitat

Evergreen/Deciduous
Evergreen

Form
Medium Shrub (Usually between 1.2m & 3.6m)

Figure 30: Calothamnus quadrifidus (Botanic Gardens of South Australia, 2017)

Callistemon sieberi

River Bottlebrush (SA form)

Notes

Uses: For higher rainfall areas of the Adelaide Plains and hills in verges, median streets, parks and reserves. Planted singly as a background in mixed plantings or en-mass as a barrier or informal hedge. Responds to pruning.

Attracts nectar eating birds and insects.

Note: Although this species is not classified under the Sewerage Act, it is recommended that it not be planted closer than 3.5 metres to any sewer main or connection.

Height
1-2 m

Spread
1-1.5 m

Position
Full Sun

Family
Myrtaceae

Botanical Name
Callistemon sieberi

Common Name
River Bottlebrush (SA form)

Origin
SA

Habit
Upright, Open

Landscape
Footslopes, Hills, Watercourse

Soil Texture
Clay, Loam

pH
Neutral

Tolerates
Moderate frost

Supplementary Watering
Moderate

Flower Colour
Cream, Yellow

Flowering Time
Spring, Autumn

Flower Type
Bottlebrush

Purpose
Habitat, Ornamental

Evergreen/Deciduous
Evergreen

Form
Medium Shrub (Usually between 1.2m & 3.6m)

Indigenous to the Adelaide Region

Figure 31: Callistemon sieberi (Botanic Gardens of South Australia, 2017)

Callistemon 'Captain Cook'

Dwarf Bottlebrush

Notes

Uses: In verges, median streets, parks and reserves. Planted singly as a colourful background in mixed plantings or en-mass as a barrier or informal hedge. Prune after flowering for dense habit. Bird and insect attracting.

Requires well-drained soils.

Note: This species is provisionally classified schedule 1, Regulation 24.2 under the Sewerage Act. Written approval is required prior to planting in streets or roads. It should not be planted closer than two metres to any sewer main or connection.

Height
1.5-2 m

Spread
1.5-2 m

Position
Full Sun

Family
Myrtaceae

Botanical Name
Callistemon 'Captain Cook'

Common Name
Dwarf Bottlebrush

Habit
Bushy, Dense

Landscape
2nd line coast, Coastal footslopes, Footslopes, Hills, Plains

Soil Texture
Clay, Loam, Sand

pH
Acidic, Alkaline, Neutral

Tolerates
Drought, Lime, Moderate frost

Supplementary Watering
Minimal

Flower Colour
Red

Flowering Time
Autumn, Spring

Flower Type
Bottlebrush

Purpose
Ornamental, Habitat

Form
Medium Shrub (Usually between 1.2m & 3.6m)

Figure 32: Callistemon 'Captain Cook' (Botanic Gardens of South Australia, 2017)

18.3. TRANSITIONAL ZONE FLORA

Callistemon citrinus

Crimson Bottlebrush

Notes

Uses: This hardy reliable Callistemon has been the primary species in the production of a variety of cultivars including Callistemon citrinus 'White Anzac' and Callistemon citrinus 'Burgundy'. Prefers well drained soils but can tolerate wet winter conditions. Responds well to annual pruning and fertiliser.

Canopy Shape
Domed

Height
2-5 m

Spread
2-5 m

Position
Full Sun

Family
Myrtaceae

Botanical Name
Callistemon citrinus

Common Name
Crimson Bottlebrush

Origin
Qld, NSW, Vic

Habit
Rounded

Landscape
Coast, Coastal footslopes, 2nd line coast, Plains, Footslopes, Hills

Soil Texture
Clay, Loam, Sand

pH
Acidic, Alkaline, Neutral

Tolerates
Drought

Supplementary Watering
Minimal

Flower Colour
Crimson

Flowering Time
Summer, Autumn

Foliage
Green

Flower Type
Bottlebrush

Purpose
Ornamental, Shade

Evergreen/Deciduous
Evergreen

Trunk
Furrowed

Form
Small Tree (Up to 7m)

Figure 33: Callistemon citrinus (Botanic Gardens of South Australia, 2017)

Hakea francisiana

Bottlebrush Hakea

Notes

Uses: Small Hakea from Western Australia.
Has spectacular spikes of coral pink flowers in spring. For the best result it needs to be planted in full sun.
Often grafted onto hardier rootstock
Drought tolerant once established.
Flowers attract both birds and bees.

Canopy Shape
Vase

Height
2-3 m

Spread
1.5-2 m

Position
Full Sun

Family
Proteaceae

Botanical Name
Hakea francisiana

Common Name
Bottlebrush Hakea

Origin
WA

Habit
Upright

Landscape
Plains, Footslopes, Hills, Coastal footslopes, 2nd line coast

Soil Texture
Gravel, Loam, Sand

pH
Acidic, Alkaline, Neutral

Tolerates
Drought, Lime, Moderate frost, Light frost

Supplementary Watering
Minimal

Flower Colour
Orange, Pink

Flowering Time
Winter, Spring

Foliage
Green

Flower Type
Spikes

Purpose
Ornamental, Habitat

Evergreen/Deciduous
Evergreen

Trunk
Rough

Form
Small Tree (Up to 7m)

Indigenous to the Adelaide Region

Figure 34: Hakea francisiana (Botanic Gardens of South Australia, 2017)