6. Environmental Engineering

6.1. Inline Water Quality Engineering

According to the Water Sensitive Urban Design technical manual (Department of Planning and Local Government, 2010) a Gross Pollutant Trap (GPT) is a "device for the removal of solids conveyed by runoff that are typically greater than 5 millimetres." There are a number of different variations of GPTs that may be suitable for use in urban environments, these include:

- Gully baskets
- In-ground gross pollutant traps
- Trash racks
- Pipe nets
- Direct screening devices

The main function of a gross pollutant trap is to help improve water quality by the the removal of gross pollutants. Gross pollutants are defined as "debris items larger than 5mm" (Allison, 1997) and can pose a threat to the local wildlife, local water environments and aesthetics relative to the environment. They can also create unwanted smells and attract vermin.

6.1.1. Relevant Legislation

Before any design of a GPT can begin it is important to check with the appropriate legislation and regulations to see if there are any requirements that apply to GPTs in the project area. The legislations which are most applicable to the design and installation of GPTs in the Adelaide region are:

- Development Act 1993
- Development Regulations 2008
- Environmental Protection Act 1993

6.1.2. Advantages

The addition of a GPT to the existing stormwater system would be an effective way to improvement stormwater quality. Advantages of GPT include:

- Effective way of removing gross pollutants
- Some traps can be hidden from view
- They take up a relatively small area

6.1.3. Disadvantages

Limitations of GPTs include:

- Limited in the removal of fine sediments, dissolved pollutants and other materials that are less than 5mm in size
- Needs to be maintained and regularly cleaned
- High initial installation cost
- Some designs are complex to install
- May be aesthetically unpleasant in public areas

6.1.4. Cost

The cost of the GPT is largely dependent on its size and its application. To help with the decision on the appropriate GPT design to use, the life cycle cost of the trap should be considered. The life cycle cost is the combination of both maintenance and installation costs. This provides a true long term cost estimate of the infrastructure. This is done by taking into account an assumed life cycle of the project. Using simple hand calculations or the computer software MUSIC, a good estimate on the overall life cycle cost for a GPT can be calculated. The cost factors that should be considered when selecting the appropriate GPT are:

- Installation costs
- Maintenance costs
- Waste disposal costs

Installation prices of GPTs can vary anywhere between $300 and $50,000 (approximate figures based on Department of Planning and Local Government, 2010). An assumed cost of of $20,000 will be taken as conservative for the project. Maintenance and disposal costs on the other hand are dependent on a number of different factors. Factors affecting maintenance costs include:

- GPT size, based on the total area of stormwater in which the GPT is receiving
- Techniques used for maintenance, based on the unknown nature of present gross pollutants
- Time required for maintenance, i.e. hours, days needed

Factors affecting waste disposal costs include:

- Special disposal requirements for hazardous wastes
- Total volume of waste
- Implications of materials that are in a wet or dry condition

These factors should be taken into consideration as there is potential for them to have a significant effect on the lifecycle cost.

6.1.5. Recommendation

The decision on the most suitable GPT will be made with consideration of the following key areas:

- Accessibility
- Maintenance
- Aesthetics
- Lifecycle cost

Of the many GPT options available, the Environmental Team believes that a direct screening device would be best suited for the stormwater system in place at North Terrace, Kent Town. It is believed that it will be a more feasible option in comparison to other traps such as drainage entrance treatments, floating traps, sediment traps, etc. If drainage entrance treatments are installed along North Terrace, any required maintenance will disturb traffic in this area. The use of a screening device at the end of the stormwater system, will relocate the required maintenance work away from North Terrace.

In comparison to other types of GPTs, a direct screening option will be much more cost effective in the long term. The simple design will mean there is a lower installation cost, it will be easier to maintain and will have a smaller disposal of waste costs, when compared to the other types of GPTs available. In order to provide a cost effective solution, the Environmental Team believe that spending the extra money on a more efficient GPT wouldn't be feasible and a simple direct screening trap would be sufficient for this project.

The Environmental Management Team suggests the use of one of the following direct screening devices:

6.1.6. Option 1 – Litter Collection Basket at the end of the stormwater pipe

The first option is to install a littler collection basket at the end of the stormwater pipe exiting at First Creek. Any gross pollutants will be removed directly into the collection basket before they enter First Creek. For this reason, the litter collection basket would be the preferred solutions to choose. However, due to the stormwater pipe location installation and future maintenance this may be difficult. An example of a litter collection basket can be seen in Figure 131 below.

Figure 131 - Litter Collection Basket Collingwood, VIC *Source: (IEAust, 2006)*

6.1.7. Option 2 – Channel Nets in First Creek

The second option involves the screening device being submerged in First Creek, in a location that is easily accessible. Like the litter collection basket it will be an effective tool to remove gross pollutants but may be visible to the public creating aesthetic and odour problems. On the contrary, as the net will be in a visible position it will be easily accessible for installation and maintenance. An example of channel net can be seen in Figure 132 below.

Figure 132 - Channel Nets West Torrens, SA *Source: (IEAust, 2006)*

6.2. Environmental Analysis

6.2.1. Water Quality Management

Stormwater quality will be an important consideration for each of the design options. There is particular concern during the construction phase that stormwater may be polluted. The Environmental Protection Agency (EPA) stormwater pollution prevention code of practice states: "*it is more cost effective and far more preferable to reduce, and where possible eliminate the causes and sources of stormwater pollution than to treat it downstream*" (EPA 1999). This can be managed in the construction phase by implementing the recommended mitigation strategies listed below.

The stormwater quality will also need to be considered post construction as well. The project area resides in the middle of a large catchment area, therefore any runoff from North Terrace will add pollutants to the system, such as heavy metals, oils and sediments. Through proper management and careful design the stormwater run-off can be utilised as a valuable resource rather than a waste product. The objectives of the stormwater design are listed below:

- Design for a 100 year ARI
- Maintain water quality by preventing contamination during construction
- Ensure that the natural ecosystem benefits from the chosen design

6.2.1.1. Relevant Legislation and Codes of Practice

- Environment Protection Act 1993
- Water Resources Act 1997
- EPA stormwater pollution prevention code of practice 1999

6.2.1.2. Polluted storm water runoff

With the upgrade and redesign of the stormwater drainage system, the risk of new and unwanted pollutants entering the surrounding waterways need to be minimised or eliminated. Water runoff can be and often is the primary cause of pollution in rivers, lakes and oceans. As the North Terrace redesign is within the Adelaide CBD area, the pedestrian activity areas, car traffic volumes and litter levels are expected to be higher than the South Australian average. Pollutants that can enter the waterways are listed below:

- Motor oil, petrol, diesel, fertilisers, pet waste and other toxic materials
- Sediment from construction sites and from nearby soil erosion
- Litter including bottles, cans, paper, plastic and cigarette butts

6.2.1.3. Mitigation Strategies

Construction

In order to minimise any polluted stormwater run-off, the following mitigation measures will need to be adhered to during the construction phase of this project:

- Ensure vehicles entering the construction site, are mechanically sound to minimise faults causing spills of potentially hazardous substances (e.g. oils and hydraulic fluids) to the ground
- No chemicals or products are allowed to enter the immediate environment or waterways
- Appropriate erosion and sediment control to be implemented on site
- Appropriate stormwater diversion controls will be installed and maintained to divert runoff waters around/away from potential sources of contamination

- Provision and use of spill kits, drip trays, bunding trays and lined areas to minimise pollution to the ground and/or waterways
- Provision and monitoring of temporary washout basins for concrete pumps and trucks
- Provision of sediment control structures to prevent sediment entering drainage systems particularly where surfaces are exposed or soil is stockpiled for extended periods on site

Post Construction

It will be important for each of the design options to improve water quality and protect the environment by stopping litter before it enters the water system. This can be achieved through several measures, firstly by engaging street sweepers to remove vegetation and litter that is caught in the gutters prior to it making it into the stormwater system. Further to this, if the upgrade to the existing stormwater system is selected, the installation of a gross pollutant trap prior to the wetland to remove solid waste before the stormwater enters any water ways, will be required. The use of a gross pollutant trap will ensure any downstream treatment of the water can happen more easily. The gross pollutant trap will need be cleaned out periodically.

In order to remove pollutants such as toxins and heavy metals, the use of either a wetland or bio retention system is recommended. These detention basins naturally and environmentally filter the water to remove pollutants. The water can then be reinjected into the waterways via two options: by following through to a final drain at the end of the basin or through natural infiltration entering the water table.

6.2.1.4. Impact on designs

Water quality management is very important for each of the designs. Regardless of the design option chosen, the main environmental issues occur within the construction phase, as there may be potential for water ways to be exposed to pollutants. This can be managed through the mitigation strategies listed above.

Design option 1 – upgrade existing stormwater system, post construction is the preferred option as it will produce a higher quality of stormwater through the use of the wetlands. It also moves future maintenance work from North Terrace; this will have positive social repercussions for the local residents and business owners. The wetlands will remove pollutants from the stormwater runoff prior to entering the water ways. This is desirable as the quality of water entering the waterways will be improved from the existing condition.

Design option 2 – Swale design, this design option will remove some contaminants through the swale and will improve the quality of the stormwater run-off. This design will increase maintenance in the project area in the future.

Design option 3 - WSUD with infiltration achieves the required result by increasing retention along the roadways and surrounding properties, reducing the quantity of stormwater runoff. This option has the least risk of contamination in the construction phase. Diverting stormwater from its original route using the surrounding businesses and public areas, will lower the strain that is on the system currently. The water will be diverted to newly built soakaways, leaky wells, retention basins and storage tanks. This method has little impact on the water quality.

Design Option 4 - Water harvesting achieves the required result by having the roadways lined with vegetation systems, buried infiltration pipes and an updated stormwater system with detention basin. Like option 1 this system will improve the quality of the storm water runoff into waterways but any future maintenance is likely to affect local residence and businesses.

Design Option 5 - Combined WSUD is a combination of WSUD with infiltration and water harvesting. This system will improve the quality and reduce the quantity of stormwater runoff in in the future. Future maintenance is still likely to affect local residence and businesses.

6.2.2. Heritage

Before any construction can begin it will be important to consider any existing heritage listed areas within the project site. Any alterations that are needed to be made on aboriginal land will first need the approval from the Minister for Aboriginal Affairs and Reconciliation. Any works conducted that can effect a heritage area will need to be in accordance with the Heritage Places Act 1993.

An issue that was outlined within the tender report is the existing 150 year old heritage arch culvert that has an existing stormwater pipe running through it. Before the construction can commence an overview of the current condition of the culvert is needed, in order to determine if it will be safe to increase flows through the structure. Further consideration will be needed for design options 1 – existing stormwater upgrade and design option 3 – WSUD with infiltration that call for the construction of a bio retention system or wetland. These design options may impact upon existing heritage trees through processes such as soil degradation and the flooding of roots caused by pooled stormwater.

6.2.2.1. Relevant legislation

- Development Act 1993 (SA)
- Native Title Act 1993
- Heritage Places Act 1993 (SA)
- Aboriginal Heritage Act 1988 (SA)
- Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)
- National Trust of South Australia Act 1955 (SA)

6.2.2.2. Mitigation Strategies

The mitigation strategies for dealing with Heritage sites and Aboriginal Heritage sites are listed below:

Heritage

- Check the quality of the arch culvert in its current state and with the help of the SA Heritage Register make a decision on whether to reuse/upgrade the stormwater drains running through the bridge.
- Investigate alternatives i.e. divert the stormwater around the bridge. Heritage listed trees will need to be surveyed to allow enough room to ensure there is no damage.

Aboriginal heritage

- Hydro-Future will not disturb or remove any material of potential archaeological or historic significance from any work site.
- Hydro-Future will take every precaution to prevent the loss, damage or removal of any item of anthropological or archaeological interest. Strategies include:
- Under the *Aboriginal Heritage Act 1988* Hydro-Future has an obligation not to damage or disturb sites or objects of Aboriginal Significance. If at any time during the works, a suspected Aboriginal site or a site containing items associated with Aboriginal occupation is uncovered, work must stop immediately and the appropriate authority will be notified immediately. Work must not recommence in

the affected area until direction is provided by the Minister for Aboriginal Affairs and Reconciliation as per the *Aboriginal Heritage Act 1988*.

6.2.2.3. *Impact on designs*

The capacity to affect any aboriginal heritage in the area is highly unlikely, this is due to the project area already having an established infrastructure and dense population. The works that are proposed for any of the designs should have no adverse effect on aboriginal heritage.

6.2.3. Air Quality and Greenhouse Gas Emissions

The Environment Protection (Air Quality) Policy 1994 states that "*air pollution means the emission into the air of any pollutant*". All aspects of this project that have the potential to have a negative impact on air quality need to be investigated by Hydro-Future. As this project will require earth works, a large consideration will be the control of dust from the work site and the mechanical condition of the earth moving equipment.

6.2.3.1. *Relevant Legislation and Policy*

- Environment Protection Act 1993
- Environment Protection (Air Quality) Policy 1994

6.2.3.2. *Construction Impacts*

Activities which may produce unacceptable or harmful levels of dust or fumes during the construction phase of this project may include:

- Transport of waste materials from site
- Excavation
- Use of solvents
- Welding, cutting, grinding
- Plant vehicles
- Wind affecting disturbed soils

6.2.3.3. *Recommended Mitigation Strategies*

The recommended mitigation strategies for the control of air quality during the construction phase are listed below:

- Construction areas, in particular exposed areas and stockpiles, should be wetted down frequently during the project
- Stockpiled soils will be excavated and placed in order to minimise dust generation
- Disturbed areas will be stabilised as soon as practical
- Rehabilitation/remediation of construction areas to be undertaken as soon as practical
- Waste materials, excess soil being carted from site, soils being carted to site, and any other dust-generating materials are to be sufficiently covered during transport
- Equipment and machinery will be maintained to ensure optimal operation
- The use of solvents will be in accordance with manufacturers' recommendations with due consideration given to environmental impacts

6.2.3.4. *Impact on Designs*

There have been five options proposed for this feasibility study; existing stormwater system upgrade, swale design, water sensitive urban design with infiltration, water harvesting and a combined water sensitive urban design. The main concern with regard to air quality will be the production of dust during the construction phase. The largest contributing factor to greenhouse gas emissions will be the use of plant and equipment during construction. In terms of air quality and greenhouse gas emissions the most desirable design is option 1 – existing stormwater upgrade. This design option places a reduced demand on construction activity, as all of the options will require some level of stormwater system to direct flows and capture overflows. However this design option will still require construction works and the mitigation strategies listed above will need to be adhered to, this will reduce the effects on local residence/businesses and the environment.

6.2.4. Noise and Vibration

The Environment Protection Act 1993 requires that all reasonable and practicable measures are taken, in relation to construction activities to minimise noise and vibration at all times. Noise and vibration pollution can have adverse health effects on humans; including stress related illnesses, high blood pressure, speech interference, hearing loss, sleep disruption, and lost productivity (EPA 2012). Due to this, it is of the utmost importance that any construction activities undertaken in relation to this project, need to be managed with care, to minimise any impacts on local residence and businesses.

EPA Information sheet *Construction Noise 2014,* states that noise includes vibration, and defines construction noise that will have an adverse impact on amenities as; the source noise level is continuous and exceeds 45 dB, or the source noise level at its maximum exceeds 60dB.Any construction activity that will exceed these noise limits needs to be conducted using the mitigation strategies below.

6.2.4.1. Relevant Legislation and Policy

- Management of Noise and Vibration: Construction and Maintenance Activities DPTI
- Environment Protection Act 1993
- EPA information sheet *Construction Noise 2014*
- Environment Protection (Noise) Policy 2007

6.2.4.2. Construction Impacts

Due to the existing traffic condition in the project area the majority of the work will take place between the hours of 9pm and 5am. Activities, which may produce unacceptable noise levels during the construction phase of this project are:

- Engine driven equipment
- Rock breaking
- Jackhammers
- Hammering
- Friction sawing and grinding
- Vehicles entering and exiting site
- Excavations
- Compaction
- Cranes and their operations
- Warning alarms/sirens

6.2.4.3. Recommended Mitigation Strategies

Hydro-Future's recommended mitigation strategies for construction activities are:

- Engine driven equipment is to be fitted with noise suppression enclosures/devices
- Jackhammers are to be silenced and jack hammering operations are to be undertaken during less sensitive times of the day and kept to a minimum
- Hammering should not be continuous over long periods of time
- The use of friction sawing and grinding equipment is to be undertaken during less sensitive times of the day and kept to a minimum
- Vehicles entering and exiting the site will use pre-planned traffic routes

- All tasks that create noise exceeding 45dB (continuous) and 60dB (maximum) will require a noise exceedance permit that must be signed by the Project Manager and reviewed daily
- The use of acoustic barriers when any works are within close proximity to residential or commercial dwellings
- Regular monitoring of noise and vibration levels
- Advanced notice of the works to be conducted
- Conduct dilapidation reports on properties that have been identified as having a potential to be damaged by vibration during construction

6.2.4.4. Impact on Designs

There have been five options proposed for this feasibility study; existing stormwater system upgrade, swale design, water sensitive urban design with infiltration, water harvesting and a combined water sensitive urban design. The main concern with regard to noise and vibration will be the use of plant and equipment during the construction phase. All of the five options will require the use of heavy machinery to complete the works. In each of the designs there will be considerable disturbance to the residence/businesses and road users. It will be critical that whichever design is selected, the above mentioned mitigation measures are adhered to. The most desirable design option will be the one that reduces the amount of time that residence/businesses and road users will be disrupted. Option 1 – existing stormwater system upgrade is the preferred option for reducing the length of time, that noise and vibration will be an issue.

6.2.5. Fire

Hydro-Future considers the possibility of fire, a serious risk. Taking this into consideration any activities that may result in a fire, will be carefully considered and planned. There are several construction activities that pose a risk of fire, especially when performed in conjunction with high risk weather.

6.2.5.1. Relevant Legislation and Policy

- Fire and Emergency Services Act 2005

6.2.5.2. Construction Impacts

Activities which may pose a risk of fire during the construction phase of this project include:

- Welding
- Grinding
- Friction and flame cutting

6.2.5.3. Mitigation Strategies

The recommended mitigation strategies for the control of the risk of fire during the construction phase are listed below:

- Compliance with the South Australian Fire and Emergency Services Act 2005
- Monitoring of fire risk reporting and where days of acute fire risk are possible, Hydro-Future will abide by the State Fire Authority ruling
- All possible measures will be implemented for the avoidance of ignition sources on site and for the accidental lighting of fires
- Requirement of a hot work permit issued by the Project Manager for all tasks that have the potential to cause a fire, reviewed on a minimum daily basis
- Fire extinguishers to be located on site at all time
- Enforce no smoking policies on site

6.2.5.4. *Impact on Designs*

There have been five options proposed for this feasibility study; existing stormwater system upgrade, swale design, water sensitive urban design with infiltration, water harvesting and a combined water sensitive urban design. The main concern with regard to fire, will be the need to perform any; welding, grinding or friction and flame cutting. All of the proposed options may require these tasks to be performed and there is no preferred option. Each design will need to consider the mitigation strategies listed above.

6.2.6. Dangerous Goods

The Environment Protection Act 1993 states that "all persons undertaking an activity that may pollute, need to take all reasonable and practicable measures to prevent or minimise any resulting environmental harm". Hydro-Future recognises that when it is necessary to use a dangerous good on site there is potential to cause harm, and whenever a dangerous good is used steps will be taken to minimise this risk.

6.2.6.1. *Relevant Legislation and Policy*

- Environment Protection Act 1993
- Environment Protection (Water Quality) Policy 2003
- EPA information sheet *Bunding and spill management 2012*

6.2.6.2. *Construction Impacts*

Dangerous goods forecast for use on site which may cause harm include:

- Paints
- Cleaning solvents
- Oils
- Excavated soils

6.2.6.3. *Mitigation Strategies*

The recommended mitigation strategies for the handling of dangerous goods forecast for use on site during the construction phase are listed below:

- Storage and use of all chemicals including dangerous goods will be in compliance with EPA Guideline: *Bunding and spill management 2012,* and the manufacturer's recommendations
- MSDS's will be available for all chemicals that are used and stored on site
- Maintain a MSDS register
- Appropriate storage and signage to be provided for all dangerous goods (and potentially hazardous materials)
- Management of hazardous wastes to be in accordance with EPA's requirements
- Vessels/containers containing potentially hazardous substances or dangerous goods will not be left unsealed for extended periods of time
- Spill kits and procedures will be in place for activities that may cause a spill

6.2.6.4. *Impact on Designs*

There have been five options proposed for this feasibility study; existing stormwater system upgrade, swale design, water sensitive urban design with infiltration, water harvesting and a combined water sensitive urban design. There are several instances during the construction of this project where it may be necessary to use dangerous goods. It is predicted that any of the designs may require the use of dangerous goods such as paints, oils or solvents. All of the proposed options may require use of these dangerous goods so there is no preferred option. Each design will need to consider the mitigation strategies listed above.

6.2.7. Earthworks

This project involves a large amount of excavation and earthworks to the drainage system. Drainage excavations are carried out primarily to allow fitting or repair of public utilities and services, drains and sewers to serve populated areas. Damage to underground utilities and services can cause fatal or severe injuries as well as significant service disruption and environmental damage. This can also postpone the project and incur considerable costs. Hence, these services need to have their exact location confirmed prior to excavation, via potholing. The detailed design will need to take into consideration minimum distances from the particular utilities.

The surrounding environment of the site should also be examined. This includes traffic volume, stability and condition of nearby buildings, groundwater table, and flooding conditions in the vicinity of the site.

6.2.7.1. Recommended Mitigation Strategies

The location of the site has been observed to have a high risk of flooding, an emergency plan is essential; this will consist of emergency contact numbers and other emergency measures such as, fencing off possibly risky zones and provision for pumping out water from trenches. Awareness programmes should be conducted for all site personnel regarding the emergency plan. In the event of an emergency it is everybody's responsibility to take action.

6.2.8. Utilities & Services

Most of the underground utilities & services are live systems including; electricity, gas, sewer storm water and water supply. These can be hazardous to personnel when damaged or ruptured. Predominantly for water mains and sewage rising mains, ground movement resulting from excavation may be sufficient to cause a failure.

By identifying and managing the dangers that are associated with the disruption of services, the construction teams are able to avoid the negative impacts associated with earthworks. Utility companies should be consulted to determine the locations of their existing services in the vicinity of the planned upgrade, prior to commencement of excavation.

The utilities & services mentioned are:

- ***Electricity cables***
    - If disrupted, could cause the area to black out.
- ***Gas pipes***
- ***Water pipes and sewers***
- ***Telecommunication cables***
    - Damage to gas pipes and connections can cause leaks that may lead to fire or explosion.
    - Leaks of water from underground pipes can affect adjacent services and reduce support for other structures.

- Damage to mains pipes can result in flooding, leading to subsequent risks from drowning or the rapid collapse of support to the sides of an excavation; water can enter gas pipes if they are also damaged.
- Damage to telecommunication and TV cables may require expensive repairs and can cause considerable disruption to those relying on the system.

Figure 2 below demonstrates the process to start work near underground services.

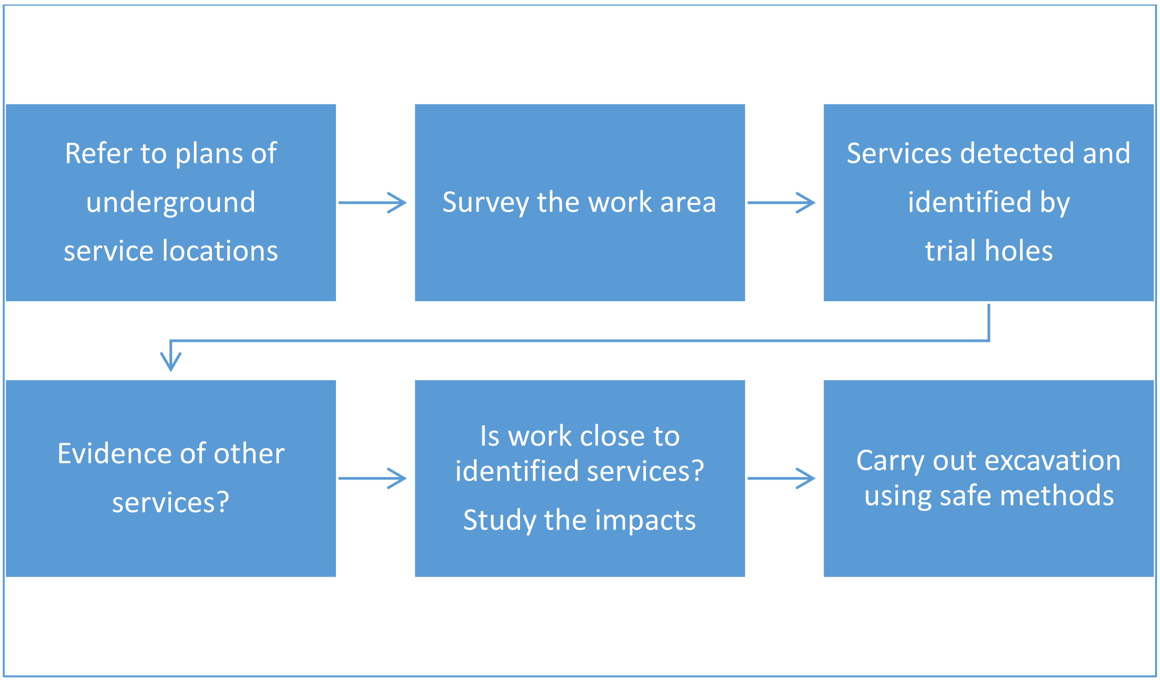


Figure 133 - Utilities & Services Safe Work Practices

6.2.8.1. Recommended Mitigation Strategies

The following are the recommended mitigation strategies that should be followed:

- Installation of fences and barriers to prevent public access to construction areas
- Safety signs and warnings to be installed around the site
- Appropriate erosion and sediment control methods to be in place
- Minimise the exposure of humans and environment to polluted soils
- Manage pollutants and waste reasonably without discharging into the environment
- Ensure all hazardous and potentially contaminated material are documented and disposed of through appropriate means
- Minimise surface runoff through drainage control
- Excavation work should be carried out carefully and follow recognised safe digging practices
- Detect underground services
- Excavation to be done alongside the service rather than directly above it, where possible
- Length of excavations kept to a minimum to reduce resulting load on services
- The routing of the utilities and services should be kept as far away from the site as possible
- Develop plans to minimise the risk of damage to services in the project area
- Ensure the teams involved in detecting and identifying services are competent in the proper use of survey tools and detecting devices as well as reading/interpreting plans
- Backfilling of excavations must properly support and protect the underground services

- All Hydro-Future employees and subcontractors to comply with WHS requirements
- All personnel to wear personal protective equipment and follow a safe system of work

6.2.8.2. Impacts on Chosen Design

There have been five options proposed for this feasibility study; existing stormwater system upgrade, swale design, water sensitive urban design with infiltration, water harvesting and a combined water sensitive urban design. For any of the design solutions, the impact will be the same in terms of earthworks and utilities & services. The project will involve large amounts of excavation and backfilling, these activities will interfere with sidewalks and roads. In addition, the utilities and services will be rerouted to another station temporarily until the project is finalised. This will affect the occupants in the area for a period of time.

6.2.9. Soil Contamination and Pollution

Soil contamination can be defined as "either solid or liquid hazardous substances mixed with the naturally occurring soil" (UEPA 2011). It is typically caused by industrial activities, construction activities, agricultural chemicals, or improper disposal of waste. Humans introduce hazardous objects, chemicals or substances, directly or indirectly into the soil environment in a way that causes harm to themselves and other living things, and destroys soil or water ecosystems.

Contaminants in the soil can impact the health of humans when they ingest, inhale, or touch contaminated soil, or when they eat plants or animals that have themselves been affected by soil contamination. Plants can be damaged when they attempt to grow in contaminated soil as they can absorb the contamination through their roots. Humans ingest and come into contact with contaminants when they come in contact with contaminated soil through a number of activities including digging in the soil as part of a construction process. When contaminants are attached to small surface soil particles they can become airborne as dust and can be inhaled.

6.2.9.1. Potential Impacts

6.2.9.1.1. Seepage and leakage

There are risks associated with any project undergoing construction. The aim is to minimise these risks and provide a safe environment. However, during construction there could be leakage of a hazardous substance. This causes the soil to become contaminated and is a threat to the surrounding environment. Chemicals present in the soil can infiltrate and pass through the soil layers, eventually coming in contact with the groundwater table. This enables the contamination to spread quickly and causes the formation of sewage sludge. Thus, it is imperative to avoid contamination of the soil layers as much as possible, as it poses a threat to the general environment.

6.2.9.1.2. Erosion

The loss of topsoil, either by removal with heavy equipment or erosion by wind and water, is the worst type of on-site damage in urban areas. This layer of soil has the highest biological activity, organic matter, and plant nutrients—all key components of healthy soil. The onsite loss of this upper layer of soil nearly eliminates the soil's natural ability to provide nutrients, regulate water flow, and combat pests and disease (USDA 2000).

Erosion control practices are implemented to hold soil in place and reduce soil removal by stormwater. The most effective way to control erosion is to preserve existing vegetation and replant cleared or bare areas as soon as possible. Planning before construction is vital to conserve the topsoil, prevent costly flooding problems, conserve natural areas and native species, reduce paved areas, prevent property damage and minimise stormwater runoff. As the project area is mostly paved the risk of erosion is minimal, but careful consideration should be made in areas where any vegetation is present and when construction/excavations are ongoing.

6.2.9.1.3. Existing Slope Features

The stability condition of the slope features in the site area should be examined and taken into consideration in the design stage. These slope features consist of cut slopes, fill slopes or retaining walls. For each of the design options the slope of excavated areas needs to be considered. When the slope features are assumed to be slightly instable, or are prone to ground movement, preventative procedures will be put into place to support the slope features.

6.2.9.1.4. Groundwater control

Groundwater control is a significant issue in the majority of excavation sites to avoid migration of contaminants, control erosion, or to keep groundwater from escaping into the excavation site. If a high groundwater table is present, the cut-off wall method or the techniques of dewatering will need to be put into action to prevent groundwater from entering the project site. In reality however, the application of dewatering techniques may cause a reduction of the groundwater around the excavation area, resulting in an increase in the effective stress of the soil layers, resulting in soil and ground settlement (HBGC 2014).

Since the project area and its surroundings are rich in heritage with old sensitive buildings, an evaluation of the potentially negative effects associated with the groundwater control techniques will be mandatory, through careful management.

6.2.10. Social Impact

Under heavy rainfall conditions, North Terrace currently undergoes substantial flooding near the Royal Hotel. It is imperative to develop a solution to this problem. However, during the construction phase, this project will significantly impact the society and surrounding environment including; residents, business owners and public areas. Despite the fact that the project aims to minimise the flooding, the social impact linked with the project design should be considered thoroughly. Since the project area consists of residential and commercial dwellings, the occupants will be directly affected during the construction phase of the project.

6.2.10.1. Construction Impacts

It is typical for the surrounding area and occupants to have a sense of discomfort during the construction phase of the project. Air pollution, noise pollution, peak traffic flows, untidiness and many other drawbacks will cause social impacts. Air pollution could be a significant source of this discomfort and has the potential to cause adverse health effects. This could affect the surrounding area including residents, business owners, and the workers on site. Thus, the implementation of the recommended mitigation strategies to minimise, or eliminate this problem is critical.

North Terrace is the main arterial routes into the city centre from the North-Eastern suburbs. The road is busy from 5am until 3am most days. This project will radically affect the traffic in the area, thus increasing the build-up of vehicles and pollution concentrated in the surrounding area. This project will require extensive traffic management measures, to ensure safe travel and smooth traffic conditions. The business owners along the road including the Heart Centre, The Royal Hotel, and Clark Rubber will be provided access to their respected areas at all times.

Since the project requires deep excavation, significant underground obstructions and services could be removed or refurbished. These services include TV cables, electricity cables, telecommunication and Ethernet connections, potable water pipes, high pressure gas pipes and others. During the excavation phase of the project, these services may be temporary cut-off from the surrounding area to ensure safe excavation without damaging the existing utilities and services pipes.

6.2.10.2. Post-Construction Impacts

Post construction the flooding issue will be resolved in the project area regardless of the design option selected. This will have positive social impacts for the surrounding residence and business owners, they will no longer have to deal with the concerns associated with flooding.

6.2.10.3. Recommended Mitigation Strategies

- Informing the public about the project and how it may affect the surrounding area
- Taking precautionary measure to avoid any unnecessary disturbance to the public and the community
- Redirecting the utilities and services as soon as possible to reduce impact to the community
- Install appropriate signage

6.2.10.4. Impact on Chosen Design

Table 61 below shows the five different design options and the social impact each choice will have.

Table 61: Impact on chosen design

Design Option	Impact
Existing Stormwater upgrade	As the existing stormwater upgrade option would require the least amount of construction on North Terrace, it will have a reduced negative social impact during the construction phase. Post construction the flooding problem will have been solved this will have positive social impacts for residents and businesses.
WSUD with infiltration	The WSUD with infiltration option would require significant construction along North Terrace having a negative social impact, as it will disrupt traffic, residents and businesses. In addition, air and noise pollution would cause the area to be unfavourable until the work is complete. Post construction the flooding problem will have been solved this will have positive social impacts for residents and businesses.
Swale Design **Water Harvesting** **Combined WSUD**	All three of these options would enhance the landscape zone by integrating green ecological systems within the drainage systems. These options require large amounts of disturbance to the project area during the construction phase which will have negative social impacts for traffic, residents and businesses.

6.2.11. Aesthetics

Architectural impacts are expected with the North Terrace drainage system upgrade project from the pre-construction to operation stages. The impacts involve urban design, landscape character and views. In this project, there are businesses on the North side of North Terrace, as well as residential areas and St Peter College Junior School along the northern side of the road.

Hence, environmental strategies will need to be used to minimise the negative influence on the surrounding environment and to improve the aesthetic aspect of the environment.

6.2.11.1. Potential impacts

6.2.11.1.1. Operation

Once the drainage system is upgraded, it would contribute to the aesthetic values of surroundings. Through the successful completion of the project, the flooding problem will be resolved, it may also enhance the landscape by incorporating Water Sensitive Urban Design features into the landscape design. The urban design and landscape areas along the road could be maintained and made consistent with other ~~recently completed~~ sections of North Terrace and the street views of Norwood city.

6.2.11.1.2. Construction

During the construction stage, the most negative visual impact would be the destruction of existing plants around the site. The construction site, earth work, waste (liquid, solid and dust) and lighting from construction will affect the adjacent businesses and residents. The project may also cause an increased traffic delays changes in lighting and added signage with the potential blocking of doorways, entrances, and paths.

6.2.11.2. Recommended Mitigation measures

A detailed aesthetics management plan would be developed referring to the selected design option. Measures need to be taken to contribute to the overall designs appearance, and to reduce the overall impact on the environment.

Investigation is needed to keep the urban design and landscaping consistent along North Terrace in Kent Town. Measures to improve visual amenities would be undertaken as follows:

- Retain existing vegetation around the perimeter of the construction sites
- Undertake revegetation or landscaping progressively
- Implement landscape wall, artwork or project information to provide visual screening
- Implement signage displaying basic information and locations of elements within the construction site
- Organise site hoardings and maintain them within the site area
- Develop a signage strategy during detailed design
- Manage lighting locations to minimise annoyance to adjoining residential and business areas
- Carry out regular clean-up and maintenance during and after construction
- Visual evaluation to control and guarantee the impact is at an minimised level

6.2.11.3. Impact on chosen design

All of the five design options of North Terrace drainage design project would bring visual changes to the current project area. They will improve the aesthetics of the project area by resolving the flood problem.

Options 1 – Existing stormwater upgrade will require the least amount of construction, meaning during this phase of the project it will have the least negative effect on the project site aesthetics. Post construction the wetlands will provide an improvement to the existing landscape, however North Terrace will remain looking the same.

Option 2 – Swale design, involves the most construction work and will have the worst effect on aesthetics during this stage of the project. Post construction this design will greatly improve the aesthetic appearance of North Terrace.

Option 3 - WSUD with infiltration will involve large excavation works to be conducted in the construction stage, aesthetically this will be unpleasant. Post construction this will add greenery to the project site increase the areas aesthetic appeal.

Option 4 – Water harvesting, will involve a large amount of earthworks to prepare the site for underground tanks having a visual displeasing appearance. Post construction the installation of underground rainwater tanks will have little impact on the aesthetics of the area.

Option 5 – Combined WUSD, involves similar amounts of earthworks to options 3 and 4 listed above as it is a combination of the two. Post construction the addition of greenery will improve the aesthetics of the area.

Options 3, 4 and 5 listed above are the preferred design options for post construction aesthetic appeal.

6.2.12. Property Access

The study area involves the city of Norwood Payneham and St Peters' Kent Town, where a high density of business and residential areas are located. Since North Terrace is one of the main arterial roads to the city centre, there is always heavy traffic and pedestrian flow during peak hours, as well as three bus stops located within the project area. The project would further increase the traffic volume and restrict access to properties along North Terrace. The traffic capacity, intersection capacity and safety index will need to be investigated. An assessment of these impacts on the road network due to the proposed works will need to be developed and presented during different stages.

6.2.12.1. Potential impacts

6.2.12.1.1. Operation

The impacts of the project on the operation of the area are positive: it contributes to safer traffic flow for North Terrace, Kent Town as there will be no more flooding in project area.

6.2.12.1.2. Construction

Significant access issues will occur during the construction stage. The project constructions may temporarily block the entrances to the properties along the road project area, including the Royal Hotel and St Peters' College Junior School. The project will influence the traffic heading through The City of Norwood Payneham and St. Peters and the surrounding residential and business areas during the construction stage.

6.2.12.2. Recommended Mitigation Measures

Affected property owners in the project will be consulted on where temporary property access should be located, and notified of relevant project schedules, construction works and changes to access arrangements. Those affected landowners along the road sides who need to be relocated would be appropriately compensated according to Real Property Act, 1886 (SA) and Land & Business (Sale & Conveyancing) Act 1994. Community updates would be provided on changes to the local road network within the project area during construction.

Appropriate signage would be provided to ensure an understanding of how to access local businesses, how local residents can access their homes and to indicate parking areas for people stopping in the area.

6.2.12.3. *Impact on chosen design*

All design options will temporarily block access to properties at various stages of the construction phase. Option 2 – Swale design, would require the most road side construction, meaning the largest amount of disruption to property access. Option 1 – Existing stormwater upgrade and Option 4 – Water harvesting are the preferred options regarding property access, these options involve the least construction along North Terrace.

6.2.13. Land Acquisition

In the project, the acquisition of land would be required for areas adjacent to North Terrace, for Water Sensitive Urban Design options, including swale and water harvesting options. A plan for land acquisition is needed to minimise the impacts on the surrounding environment, economy and community. It should be designed specifically for the chosen design option.

6.2.13.1. *Recommended mitigation measures*

Land acquisition for the project would be undertaken in accordance with the Land Acquisition Information Guide (Roads and Maritime, 2012) and the Land Acquisition (Just Terms Compensation) Act 1991.

It is necessary to review urban planning and contact Adelaide Land Division Services to find out if there is any reserved land available that can be used for the project temporarily within the subject area. All businesses and residents affected by land acquisition for the project will be appropriately compensated.

6.2.13.2. *Impact on chosen design*

Option 2 - Swale design, requires the acquisition of a large area of land adjacent to the road, for this reason this would not be a suitable design option. Option 1 - Existing stormwater upgrade, will implement a detention basins and will require the acquisition of some nearby land. Option 3 – WSUD with infiltration, Option 4 –Water Harvesting and Option 5 – Combined WSUD will require the least amount of land acquisition and are the preferred design options.

6.2.14. Waste Management

Appropriate strategies should be applied to reduce resources as well as the waste produced by the project. Resource recovery includes re-using, recycling and reprocessing. A waste management plan will be developed to provide a basis for all. Generally, construction waste and waste from earthworks or demolition of existing drainage systems would consist of the following:

- Excavation materials of site i.e. soil
- Redundant materials or green waste i.e. existing pipes, pits and vegetation
- Miscellaneous building materials
- Wastewater from construction activities
- Packaging materials
- Office and domestic waste generated by project administration activities

Through effective waste management, negative impacts on the surrounding environment can be minimised.

6.2.14.1. *Potential impacts*

6.2.14.1.1. Operation

The flooded stormwater in the project area is a source of waste itself. It may become contaminated be prolonged contact with the roadway and can be a breeding area for mosquitoes as well as bacteria and other microbes.

6.2.14.1.2. Construction

The amount of waste generated during construction activities would be subject to the site environmental management system. Careful planning and management of the construction stage will be essential to minimise the potential waste impact on the local community and environment.

6.2.14.2. Recommended Mitigation Measures

The Contractor would be required to manage waste in accordance with the environmental performance criteria for the project. The waste must also be managed in accordance with the Environment Protection (Waste Management) Policy 1994, and South Australia's Waste Strategy 2005-2010. Relevantly, the Policy provides that a person who transports waste on or in a vehicle must take all reasonable and practicable steps to cover, contain or secure the waste to ensure that it remains on or in the vehicle throughout the course of transportation.

6.2.14.2.1. Resource consumption

- Avoid unnecessary resource consumption
- Reuse waste materials generated by the project as much as possible
- Segregate resources for recycling i.e. paper, plastic, glass, cans
- Use appropriate recycling facilities to treat the recyclable materials
- Mulch or chip cleared vegetation and use for landscaping

6.2.14.2.2. Construction waste

- Reuse the excavation material on site for same and similar use i.e. excavated spoil
- Control the wastewater according to Section 19
- Sort and store the demolition materials for recycling
- Control packaging materials and office waste
- Classify and appropriately handle and store removed materials from site

6.2.14.3. Impact on chosen design

In the construction phase, all options will require waste and recourse management. Option 1 – existing stormwater upgrade, involves the least construction and is recommended from a waste management point of view. This option is the most economical in terms of resources as it makes full use of the existing infrastructure.

Option 4 – water harvesting, would have an additional benefit of recycling the collected stormwater post construction.

Option 2 – swale design, option 3 – WSUD with infiltration and option 5 – combined WSUD, post construction these designs will have additional maintenance requirements to manage the accumulation of waste in the newly installed infrastructure.

6.2.15. Flora and Fauna

A number of environmental issues are considered with this Environmental Impact Statement and flora and fauna is considered to be fundamental to the environmental impact that the North Terrace Drainage Design project will have. Depending on the project design chosen, the flora and fauna could be affected both during and after construction which will require a management plan to ensure no extensive damage is done that would impact the flora and fauna.

Upon conducting site evaluations and fauna surveys it has been determined that the area of construction does not contain any rare fauna species or any significant or regulated trees. Consequently, no in-depth studies of fauna have been under taken during this feasibility study.

However investigations will be conducted into the current flora and the potential impacts on the existing flora surrounding the project area. The natural flora and fauna will be preserved wherever possible and re-vegetation works will be undertaken, if required, in order to sustain a healthy environment.

6.2.15.1. Potential Environmental Impacts

6.2.15.1.1. Construction impacts

After conducting a site evaluation it was noted that there are currently no trees in this location that meet criteria to be classed as a significant or regulated tree. A regulated tree in metropolitan Adelaide is a tree with a circumference of 2.0 metres or more (SA Gov 2015). Vegetation in the area was very minimal due to the pavements and buildings. This suggests that local flora and fauna will not be impacted during the construction process however there is still a potential risk that the construction may affect the surrounding environment in the following ways:

- Long term decrease in vegetation
- Disrupt breeding cycle of fauna in the area
- Potentially decrease the size and quality of the habitat of the local flora and fauna
- Construction vehicles and personnel may accidentally introduce flora species to the project area and contaminates to natural environment
- Construction materials and vehicles may contaminate the site
- Removal or disruption of native flora may reduce aesthetic value of the area and residential/commercial properties
- Dust from construction may pollute surrounding suburbs vegetation and bodies of water
- Ground compaction from heavy vehicles/materials disrupting vegetation growth
- Chemical/oil spillage may poison native flora and fauna

6.2.15.1.2. Construction Activities that Impact Flora and Fauna

Environmental impacts that may be potentially harmful to the flora and fauna of the project area and the surrounding areas caused by construction have been identified in Section 20.1.2. Multiple activities conducted during construction could be potentially harmful to the environment with a majority of these activities being unintentional. The potentially harmful construction activities are as listed below:

- Use of power tools over or near vegetation
- Parking or operating heavy machinery on or near vegetation causing ground compaction and crushing of plant roots
- Poorly maintained machinery
- Site workers walking on vegetated areas
- Storage of construction materials in vegetated areas

6.2.15.2. Recommended Mitigation Measures

Environmental preservation plans will be developed based on the requirements of the project to allow maximum functionality with minimum environmental damage to the surrounding vegetation. Any vegetation flora affected by the construction process will be replaced or relocated. The following mitigation measures are provided:

- Preventing fires which may damage local flora and fauna (refer to section 10)
- Avoid damage to flora and fauna on site when undertaking construction activities, particularly with operation of vehicles/machinery/equipment on site

- Avoid damage to flora and fauna on site through use/storage/handling of potentially hazardous materials (refer to section 11)
- Required clearing of vegetation only to be done only with prior approval and kept to a minimum
- No removal of native vegetation unless authorised in accordance with the Native Vegetation Act 1991
- Works area to be clearly defined, no disturbance beyond edge of designated works area and bunting or staking out of areas with significant vegetation
- Restrict construction traffic to roads and designated access tracks
- Stabilise disturbed areas to protect existing vegetation
- Minimise compaction in the vicinity of any trees by avoiding: parking of heavy equipment/vehicles and stockpiling within tree drip lines
- Locate stockpiles, construction materials and any potentially hazardous chemicals away from sensitive areas
- Remove excess spoil from the site in accordance with EPA and the Hydro-Future requirements
- Maintenance/watering of existing vegetation in the project area during the construction phase

6.2.15.3. Impact on Chosen Design

Design option 3: WSUD with infiltration is the most suitable design in terms of the preservation and improvement on the local flora and fauna. This option will have more construction requirements than option 1 – existing stormwater upgrade, however it is still the preferred option as it promotes biodiversity. Existing vegetation may be affected during the construction process but will be either replaced or relocated to minimise environmental impacts.

6.2.16. Environmental Impact Rating

Table 62 below shows the environmental impact rating for each of the designs post construction. Table 63 below gives the explanation of the rating system used from 1-4.

Table 62: Environmental Impact Rating Table (Post Construction)

Post Construction ***Option***	**Water Quality**	**Flora and Fauna**	**Social Impact**	**Heritage**	**Air Quality**	**Noise and Vibration**	**Soil Contamination**	**Sediment Control**	**Waste Management**	**Total/36**
Option 1: Existing Stormwater System Upgrade	3	3	4	4	4	4	4	4	3	33
Option2: Swale Design	4	4	3	4	4	4	3	3	3	32
Option 3: Water Sensitive Urban Design with infiltration	4	4	4	4	4	4	4	4	3	35
Option 4: Water harvesting	4	4	4	4	4	4	4	4	4	36
Option 5: Combined water sensitive urban design	4	4	4	4	4	4	4	4	3	35

Table 63: Environmental Impact Rating Scoring System

Scoring Table

Unsatisfactory	**Average**	**Good**	**Excellent**
1	2	3	4

Table 64 below shows the environmental impact rating for each of the designs during construction. Table 65 below gives the explanation of the rating system used from 1-4.

Table 64: Environmental Impact Rating Table (During Construction)

During Construction ***Option***	Water Quality	Flora and Fauna	Social Impact	Heritage	Air Quality	Noise and Vibration	Soil Contamination	Sediment Control	Waste Management	Total/36
Option 1: Existing Stormwater System Upgrade	1	2	1	4	1	1	2	2	1	15
Option2: Swale Design	2	1	1	4	1	1	1	1	1	13
Option 3: Water Sensitive Urban Design with infiltration	2	2	2	4	1	1	2	2	2	18
Option 4: Water harvesting	2	3	1	4	1	1	2	2	2	18
Option 5: Combined water sensitive urban design	1	2	2	4	1	1	2	1	2	16

Table 65 - Environmental Impact Rating Scoring System

Scoring Table

Unsatisfactory	Average	Good	Excellent
1	2	3	4

6.2.17. Design Evaluation Based on Environmental Impact Rating

The Environmental Impact Rating table is based on a 1-4 scoring system with 4 being excellent and 1 being unsatisfactory. Each heading was evaluated by the environmental engineering group to determine the score of each option out of a total of 36.

6.2.17.1. Option 1 – Existing Stormwater System Upgrade:

The option of upgrading the existing stormwater system scored the second lowest in both post construction and during construction phases for the environmental impact rating. This design could be improved environmentally by installing additional waste management control devices as well as devices to improve water quality throughout the system. Although the rating for Flora and Fauna was considered as good it is difficult to further improve the design as there is minimal area available where increased vegetation would be possible. The construction phase can be improved in the environmental rating by following the suggest mitigation processes outlined in each section.

6.2.17.2. Option 2 – Swale Design:

The Swale design scored the lowest for environmental impact rating in both the post construction phase and the during construction phase. The disadvantages of constructing a swale is the amount of space that would be required as well as the high amount of construction needed in this location which is why the design scored lower compared to other options. To further improve the rating of the swale design mitigation measures would need to be followed as well as increased treatments for both sediment control and soil contamination.

6.2.17.3. Option 3 – Water Sensitive Urban Design with Infiltration:

Option 3 had the second highest score for the post construction phase and was tied equally as high as option 4 during the construction phase. This option lost points for waste management which can be improved by installing devices for further waste management treatments. The construction phase can be improved in the environmental rating by following the suggest mitigation processes outlined in each section.

6.2.17.4. Option 4 – Water Harvesting:

The Water Harvesting design scored a perfect rating for the post construction phase which was mainly due to the amount of increased vegetation that would improve various environmental issues and social impacts. It also scored equal highest during the construction phase with a total of 18/36 although improvements could be made to this score by ensuring mitigation measures and followed throughout the construction of the project. While Option 3 scores extremely highly it will still need to be evaluated to determine if this is the option that will give the highest functionality as well as the best environmental impact.

6.2.17.5. Option 5 – Combined Water Sensitive Urban Design:

Option 5 is a combination of the Water Sensitive Urban Design with infiltration with any of the other design options listed which would enable the system to be able to completely carry all the stormwater flow rate in the occurrence of a major storm system and was tied for second highest in the post construction environmental impact rating. To improve the score for this design further waste management treatments will need to be considered as well as mitigation measures to improve air and water quality during the construction phase.

7. Transportation Engineering

7.1. Introduction

North Terrace is a class 6 major arterial road on the outskirts of the CBD meaning that it experiences heavy use of motorists, heavy vehicles, pedestrians, cyclists and public transport (buses in this area) in its existing condition. Our aim is to analysis current conditions within the design area to not only determine what impact construction from the proposed options would have but to understand and develop appropriate management strategies that can minimise the effect of the construction works to the road users.

The transport team will look into using traffic management devices and strategies such as signs, detours, temporary traffic lights, altering traffic single timings, lane closures, altering speed limits, using traffic directors, managing construction times as well as any other required traffic management impact mitigation strategies.

We aim to put forward recommendations on the proposed options in terms of transport will be the most manageable and feasible option.

7.2. Proposed options

7.2.1. Conventional Stormwater Upgrade

The Conventional Stormwater Upgrade (Option 1) will take place within the design area of North Terrace where a pipe will be laid under the North side of North Terrace with pits on both sides of the road connected by pipes under the roadway. This option requires a large amount of construction along the roadway, with the largest pipes required of any of the options it can be assumed construction times may be increased.

7.2.2. Swale

The construction of the Swale (Option 2) would take place within the design area similar to the Conventional Stormwater Upgrade. It does require a single lane of North Terrace be removed to allow space for its installation and has therefore been removed from the project design options as stated in Section 3.3.1.12.

7.2.3. Water Sensitive Urban Design and Infiltration

The Water Sensitive Urban Design and Infiltration Design (Option 2) will require a stormwater system to be constructed on North Terrace. However, this option will require less construction time then the Conventional Stormwater Upgrade as flows would be reduced, therefore requiring smaller pipe diameters, due to the adjacent properties having Water Sensitive Urban Design and Infiltration features to reduce the design flows entering the stormwater system.

7.2.4. Water Harvesting

The Water Harvesting, similarly to Water Sensitive Urban Design and Infiltration option, will still require a storm water system upgrade to carry any remaining flows not captured by the harvesting system, as well as to capture any overflows. For this option, construction would occur both on and away from North Terrace, with the option requiring a similar level of construction as the Water Sensitive Urban Design and Infiltration Design option.

7.2.5. Combined Drainage Design

The Combined Drainage Design features a number of components of both the Water Sensitive Urban Design and Infiltration Design, as well as Water Harvesting. As both of these options require a large amount of construction away from the road, as well as require a level of

Conventional Stormwater Upgrade, this option can be considered to have a similar impact on traffic management as those options.

7.3. Current Conditions/Potential Issues

7.3.1. Traffic Volumes

Using data obtained from the Department of Planning Transport and Infrastructure (DPTI), reasonable estimations of the Average Annual Daily Traffic (AADT) estimates along North Terrace were obtained.

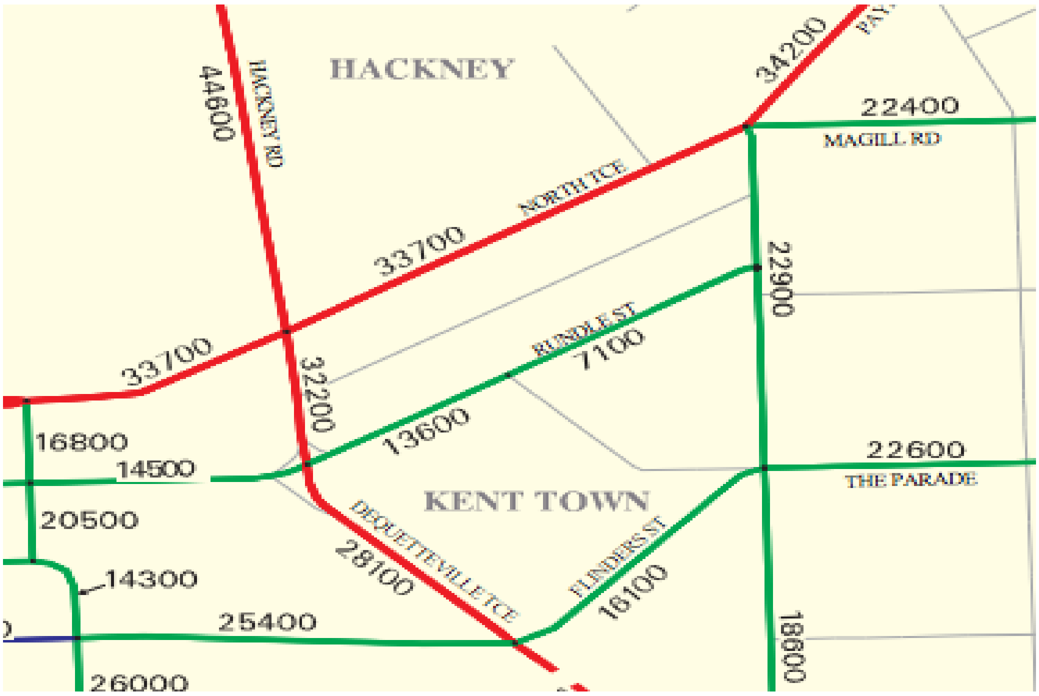


Figure 134: Traffic Volume, Design Area (DPTI, 2015c)

Figure 134 shows the AADT estimates for two-way traffic flows. These maps from DPTI enable us to clearly see and define the primary roads used for heavy traffic flows within the design area. North Terrace is a major arterial road defined as a class 6 road (DPTI, 2015c), meaning its main role is to act the primary avenue for massive traffic movements (DPTI, 2008).

Using, the AADT for North Terrace is around 33700 vehicles; with an estimated 3000-4000 vehicles per hour during peak hour traffic flows. This is a huge number of vehicles and construction within this area could be quite difficult to manage, especially during peak hour traffic while still trying to maintain good traffic control and minimising delays.

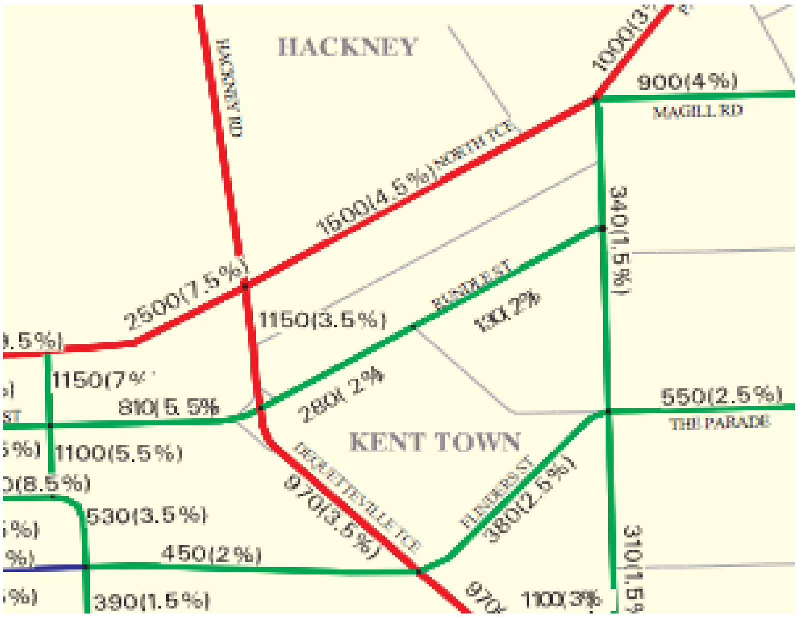


Figure 135: Heavy Vehicle Traffic Volume (DPTI, 2015e)

Using Figure 135 the AADT for heavy vehicles within the design area is around 1530 vehicles, at 4.5% of the total estimated traffic volumes shown in Figure 134 (DPTI, 2015e).

Knowing that there is reasonable amount of heavy vehicle traffic, requires additional traffic management considerations. These additional problems include the correct choice and planning of detour routes, as when the road is fully closed down for night works appropriate detours would need to be provided for heavy vehicles.

Appropriate detours must be allocated and planned as some roads are not designed for heavy vehicles and will be significantly deteriorated by the forces associated with heavy vehicles. There is also concern in regards to the amount of manoeuvrable or space for heavy vehicles on smaller roads in the area such as Little King William St.

7.3.2. Public and Pedestrian Transport

As North Terrace is a major arterial road, the system is used frequently by public transport such as buses and their associated pedestrian traffic, as well as general pedestrian traffic, cyclists and students from nearby schools (St Peter's College). Knowing this, considerations must be taken in regards to these users to try to maintain road function by minimising delays, inconveniences and providing a safe environment during construction for these road users.

7.3.3. Buses

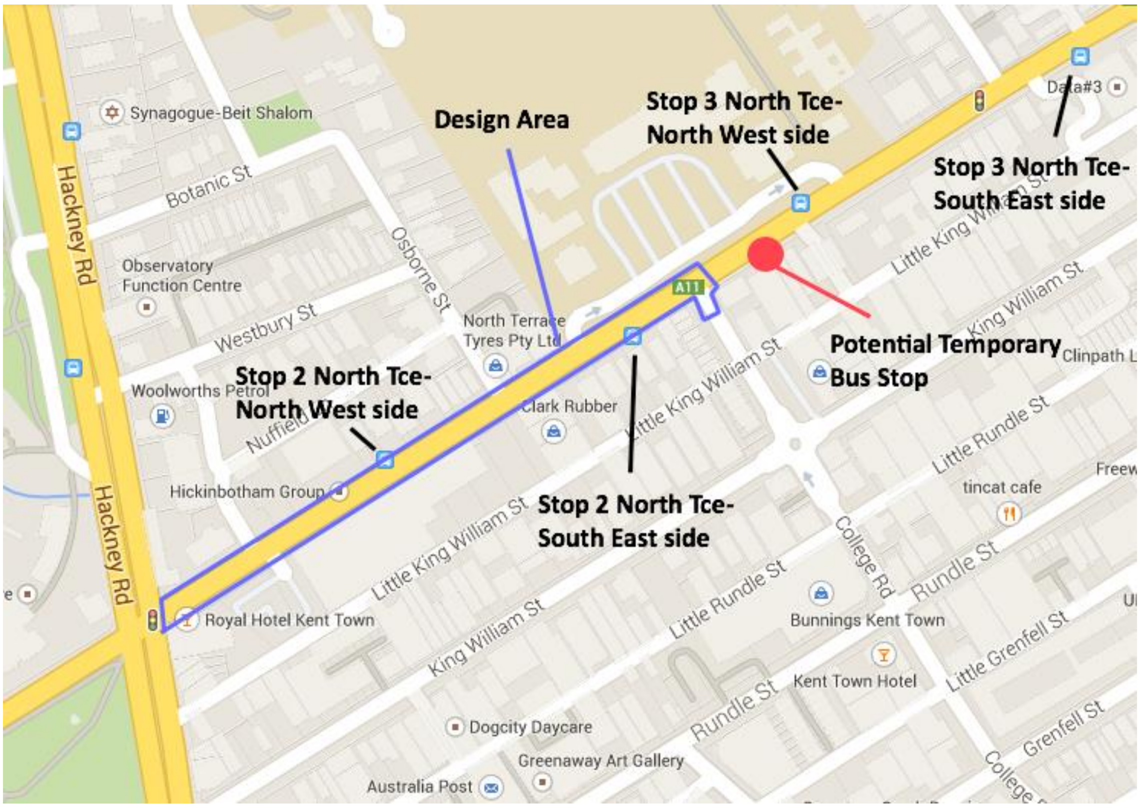


Figure 136: Bus Stops (Google Maps, 2015)

The two bus stops located within the design area, shown in Figure 136, are Stop 2 North Tce-North West side and Stop 2 North Tce-South East side (Adelaide Metro, 2015b). Additionally Figure 136 shows two other bus stops, Stop 3 North Tce-North Side and Stop 3 North Tce-South East side (Adelaide Metro, 2015b), that could be affected during detours or construction of the proposed options.

The bus stop most affected will be Stop 2 North Tce-North West side, as this is within the design area on the side of the road where stormwater pipes will be laid though there is only a 4 minute walk between Stop 2 & 3 on this side of the road. Additionally the use of a temporary bus stop could be used a little up the road North East as shown in Figure 136.

It has been observed that these bus stops are used from approximately 5:30am until 12 midnight Monday to Friday and 7am until 12 midnight on weekends (Adelaide Metro, 2015a), with the exception of the late night weekend buses, all bus routes and times can be found in Section 0 of the Appendices. This would allow for night work to be completed from 12am-5am on weekday nights and 12am-6am on weekend nights without disturbing the normal bus routes and times with the exception to the late night weekend buses which could be rerouted along Rundle St, as shown in Figure 140. This detour is considered acceptable as during these times the primary function of buses is to get people home safe, with less concern to travel time as there is little traffic (Adelaide Metro, 2015a).

7.3.4. Pedestrians and Cyclists

A site inspection has shown that the design area has no dedicated bike lanes along the road. Additionally knowing that North Terrace is a busy road with narrow lane widths it has been assumed that many cyclists do not use this section of road as part of their commute.

Furthermore there is a viable option to bypass the area, linear park trial which runs along the nearby River Torrens that is nearby, it is assumed that many cyclist already use this trail or will use the trail as an alternate route.

Additionally there are two primary crossings that could be used, which is demonstrated in Figure 141 in Pedestrian. This also leads to the conclusion that there would be adequate crossings to allow pedestrians to cross the road safety and avoid the risks of accidents occurring during construction.

7.3.5. Potential Detour Roads

During Construction the need for detours is a significant problem that will need to be considered for any of the proposed options, as at some stage all options will require large scale, heavy or potentially dangerous constructions. These considerations for detours are necessary in order to maintain desired traffic flows, minimise delays, maintain a safe environment for workers and motorists alike, allow heavy constructions to occur safely while also allowing the project to be conducted quickly to maintain the intended construction schedule.

Potential detours routes that could be used for consideration include Little King William St, King William St, Little Rundle St and Rundle St.

Little King William Street

Little King William St is only a lane and could possibly be used for small motor vehicles, however due to the road being narrow it would not be feasible to use the road as an detour option for heavy vehicles nor buses or two way traffic flows. Additionally there is no right turn onto Dequetteville Terrace from Little King William St, which further impacts this option.

Little Rundle Street

Similarly to Little King William St Little Rundle St is just a small lane and is not an appropriate detour for heavy vehicles, buses or two way traffic flows.

King William Street

King William St is a more viable detour options as it has two lanes, allowing for two way traffic. However the roundabout at the College Rd-King William Intersection will cause manoeuvrability issues for large vehicles (trucks and buses) and significantly increase the traffic on this local road.

Rundle Street

The most viable option for detours has been deemed to be Rundle Street as this is class 7 road (DPTI, 2015c), meaning its job is to supplement the flow of class 6 roads such as North Terrace (DPTI, 2008) which is what it will be used for during construction shows there is heavy vehicle use along Rundle St, therefore it has been the determined the road is sufficient for slight increase in heavy vehicles due night works detours.

For all vehicles the detour may start at the traffic light intersections (Payneham Rd-Magill Rd-North Terrace-Fullarton Rd-Baliol St intersection and North Terrace-Hackney Rd-Dequetteville Tce), this would allow easy manoeuvrability for large heavy vehicles and buses at open large intersections.

There is also a large slip lane on Fullarton Rd to allow vehicles to turn right onto Rundle St and, with the addition of temporary traffic lights at Fullarton Road-Rundle St intersection, it would allow adequate traffic conditions for larger vehicles to make turns right hand from Fullarton Rd onto Rundle St.

This Detour would require changed traffic conditions at the Hackney Rd-North Terrace intersection as currently there is no right turn from North Terrace onto Hackney Rd when travelling East, which will require adjustments to the current traffic lights or the use of temporary traffic lights. Furthermore for the alternation of light signal timings could be considered at the all intersections involved within the detour.

7.4. Traffic Management Tools and Strategies

During construction it is important that effective and appropriate equipment strategies are used in order to maintain suitable and safe traffic conditions for North Terrace. The correct use of signs, sign placement, speed limits, detours, traffic directors, barriers and selective construction times are all key features in traffic management. Accompanying these key features are associated costs, the aim in terms of traffic management is the manage these features and associated cost to provide cost effective solutions that are designed in order to maintain traffic function ability.

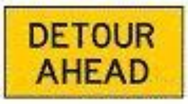
7.4.1. Potential Signs and Cost

Road construction signs are important in any road construction project as they assist the communication with, and management of, traffic. Therefore, it is important to determine the types and amount of signs/safety devices needed for the project in order to produce a cost estimate of proposed options. The signs to be used for this road construction project will include caution signs, detour signs, notification signs, traffic cones and speed limit changes.

Table 66 shows a list of potential signs that are assumed to be required in the project during construction, with their description, quantity and cost. All signs within the table are readily available in the market, with numerous suppliers online that can easily produce the signs required in a small time frame (1-2 days) (Advanced Road Signs, 2015).

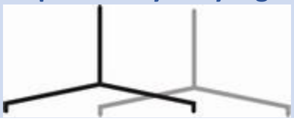
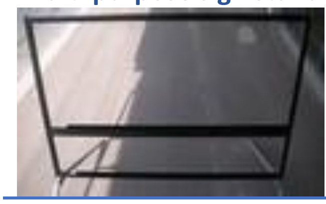
The cost of multi sign units is also addressed in Table 66, which are basically smaller signs that can fit multi sign stand frames to display more then one message within the same sign stand. This can save potential costs on the price of sign and amount of stands needed. (Advanced Road Signs, 2015). The full range of multi-purpose sign arrangements is shown in Section 0 of the Appendices.

Table 66: Signage Cost Analysis (Advanced Road Signs, 2015)

Sign/Safety Device	Description	Cost per single sign unit (Cost per multi sign unit)	Estimated Quantity	Total Cost single sign unit (multi sign unit)
Be prepared to stop 	This sign advises drivers to prepare to stop	$50	2	$100
Roadwork ahead 	This sign notifies road users there are road works ahead	$175(40)	2	$350(80)
End Roadwork 	Informs road users the road work has ended	125(40)	2	$250(80)
Detour ahead 	Notifies road users of upcoming detours during construction	$ 120(40)	2	$240(80)
Detour left/right 	Notifies road users the direction of the detour (left or right)	$ 75(40)ea	4	$300(160)
End detour 	Signifies to road users that the detour has ended	$120(40)	2	$240(80)
Lane closed ahead 	Notifies road users when a lane is closed	$80(40)	2	$160(80)

Men at work ahead 	This sign warns users to expect construction workers on the road ahead	$ 70(40)	2	$140(80)
Traffic controller ahead 	Informs traffic users that there will be traffic directors used ahead	$80(40)	2	$160(80)
Stop and slow double sided lollypop signs 	Signs used by traffic controllers to manipulate traffic flows	$80ea	2	$160
Electronic LED sign 	This sign will be used to provide messages to road users on different conditions. For example, users can be notified about sections that may be closed	TBA	2	TBA
Reflective hazard strip tape 50m roll 	Will warn road users of caution areas that they should avoid on the road as well as restrict access to pedestrians	$ 150	5	$750
Weighted reflective cone 	Reflective cones will be used for directing traffic along work areas far safety	$ 20ea	25	$500
Local traffic only 	Informs road users road is closed to all non local traffic users	$120(40)	2	$240(80)

Lane Status 	Informs road users of lane closures	$120	2	$240
Pedestrians watch your step 	Used to provide caution for pedestrians due to footpath changes/constructions	$100	2	$200
Use other footpath 	Informs pedestrians to use other footpath as this one is closed or unsafe	$100	2	$200
Speed Limit 60km/h 	Informs users they can return to 60km/h once safety past road works	$100(40)	4	$400(160)
Speed Limit 40km/h 	Informs users to slow to 40km/h for road works/changed traffic conditions	$100(40)	4	$400(160)
Speed limit 25km/h 	Informs users to travel 25km/h as road works construction is heavy or dangerous for higher speeds	$100(40)	4	$400(160)
Barrier board 	**Barrier used for to close roads for detours and heavy block off construction to public**	**$70**	**4**	**$280**

Water fillable barrier H800mm x L1500mm x W465mm 	**Used for safety of construction to block out car from potential crash as well as keep workers safe in case of road incidents**	**$300**	**50**	**$15000**
Bipod heavy duty legs 	Used to hold large sign >600mm	$60	6	$360
Swing stand 600x600mm 	Used as a stand for single purpose signs	$45	6	$270
Swing stand 600x900mm 	Used as a stand for single purpose signs	$65	6	$390
Multi purpose sign stand 	Used as a stand for multipurpose signs	$60	6	$360
Total				**$22490(20490)**

The use of all signs in Table 1 will uphold the requirements for retro reflective material used on road work signs in the Australian & DTEI standards that are found in.

- AS1906 Retroreflective materials and devices for road traffic control purposes
    - Part 1: Retroreflective sheeting.
- AS1906 Retrorelecftive materials and devices for road traffic control purposes
    - Part 2 Retroreflective devices (nonpavement application).
- DTEI Part 248 Supply of Signs and Supports (DPTI, 2015)

7.4.2. Temporary Traffic Lights

Temporary traffic lights are incorporated in the Australian Standard (AS 4191-1994), portable traffic signal systems and are an integral part of traffic management, generally used on roadwork sites, or for event traffic control and management (Portable Traffic Lights, 2015). In this project, there will be two areas that require the use of temporary traffic lights so that drivers can safely turn right as well as to improve traffic flows and allow adequate turning time for larger vehicles.

The locations these temporary traffic lights will be used include the intersection of Fullarton Road and Rundle Street as well as Dequetteville Terrace, Hackney Road and North Terrace, as discussed in Section 7.5.1 and shown in Figure 139.

The basic configuration at each of these intersections will follow a 3-way shuttle control operational mode, as shown below in Figure 137.

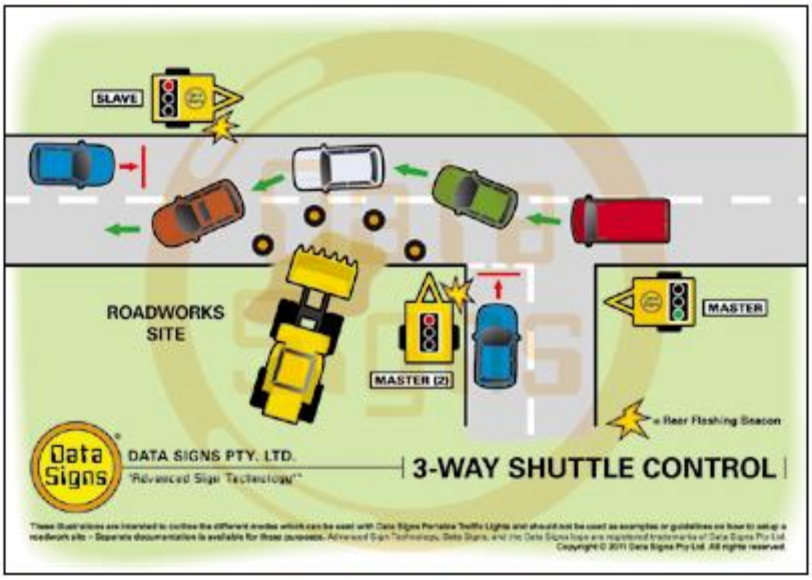


Figure 137: Operational Mode of 3-WAY SHUTTLE CONTROL (Portable Traffic Lights, 2015)

For this project the 100 mm LED traffic signal will be used, as shown in Figure 138. The cost of each traffic light is around $700, so the total cost of temporary traffic lights will be approximately $2100 (ADG Intelligent Detection Systems, 2015).

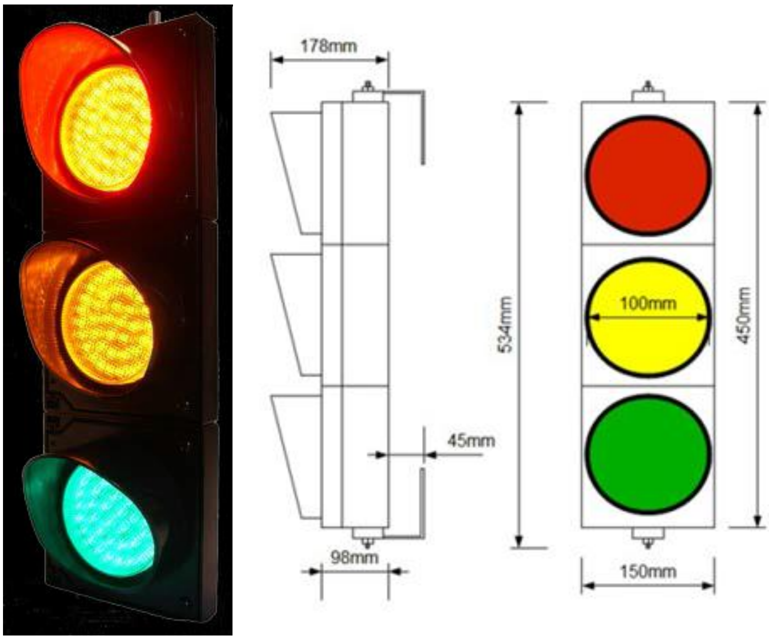


Figure 138: 100 mm LED TRAFFIC SIGNAL with 3 ASPECT & Dimensions (ADG Intelligent Detection Systems, 2015)

7.4.3. Variable Message Sign

The use of portable variable message signs (LED notification signs) will be used in the project in order to notify traffic users of upcoming roadworks. The planned positions for these signs is at either end of the North Terrace study area.

Portable variable message signs must comply with AS 4852.2 – Variable Message Signs (VMS) Part 2: Portable Signs. The only pixel colours permitted to be displayed are: (a) white and red when a regulatory sign in accordance with AS 1742 is displayed; (b) white and yellow otherwise (Clark, 2010).

Planned construction time and date information is required for VMS messages providing advance notice of road works affecting future traffic operations. One week is considered to be an appropriate advance notice period (Clark, 2010).

The required distance is dictated by the size of characters, approach speed, vertical offset of VMS and is referred to as the legibility distance, and example of these variables can be found in Figure 139, with the required calculation process shown below.

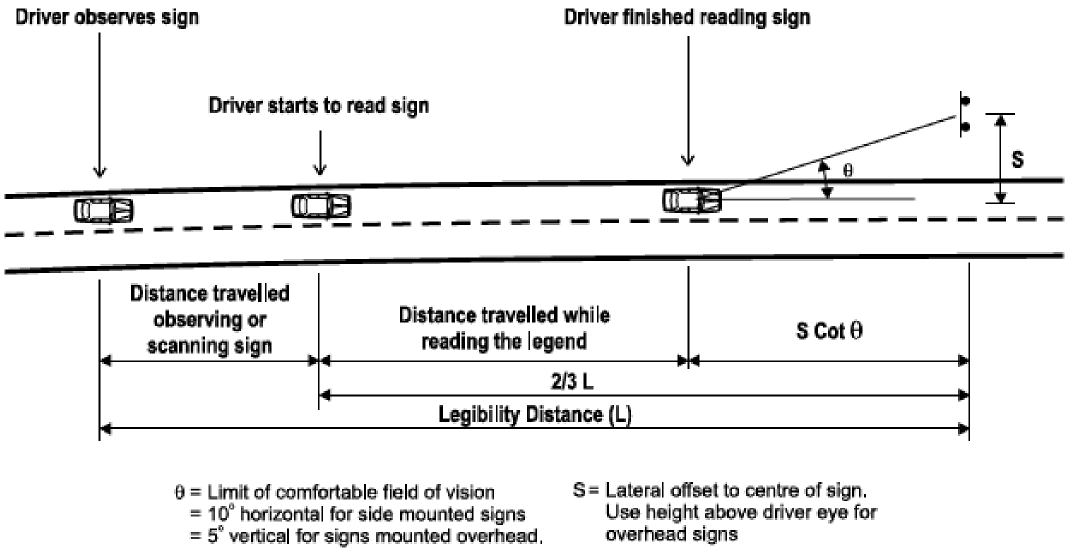


Figure 139: Sign legibility distance (Traffic and Road Use Management, 2015)

To determine the total sign legibility distance of roadside VMS the following formula can be used:

$$L = 0.105NV - 8.55S$$

Where

L = total legibility distance needed (m)

N = number of words on screen

V = approach speed in km/h

S = offset distance from driver eye position to centre of sign

7.4.4. Speed Limit and Regulation

In order for the project to be safe and successful, regulations must be upheld with the appropriate use of set speed limits.

Within the project our key aim is to maintain healthy traffic flows, this requires setting appropriate speed limits. In order to maintain North Terrace's primary function of a class 6 main arterial road it has been decided that 40km/h speed limits will be preferable during peak hour traffic flows by minimising roadside construction whenever possible.

The use of 25km/h speed must be used when construction occur in close proximity to traffic flows. Therefore, as construction is planned to be completed as night works and in-between traffic flows, it will generally be required to reduce the speed to 25km/h during these times, specific requirements for a 25km/h speed limit on North Terrace are shown below

- Single lane two way traffic (two lanes on one side of the road closed)
- Work being carried out on foot in close proximity to traffic (1.5m)
- Plant working in close proximity to traffic (1.5m)
- Significantly changed traffic conditions
- Reduction in lane widths beyond minimum requirements

(DPTI, 2010)

In general, when works are being conducted, the speed limit will be reduced to 25km/h, where this speed limit will not have a significant effect on traffic flows and travel times to reduce the risk of accident or injuries during the project.

7.5. Traffic Management Plan

7.5.1. Detour

The three detours required for traffic management are discussed below.

If heading out of the city (North East) the detour will start at Hackney Rd-Dequetteville Tce-North Terrace Intersection as shown in Figure 7. The detoured traffic will turn right from North Terrace onto Dequetteville Tce. Currently there is no availability for this right hand turn, however a potential option here is to kill the lights and use traffic directors during the detours as shown in Figure 7.

The detour will then continue from North Terrace and turn left onto Rundle St, where temporary traffic lights will be located to assist right-hand turns for traffic using the detour in the opposite direction. The detour will then continue all the way along Rundle St until the Fullarton Rd intersection. This section of Rundle St presents a preferable route as it has right-of-way along its length, with all intersecting roadways have stop or give-way signs

The detour will then continue along Fullarton Rd to the Fullarton Rd-North Tce-Magill Rd-Payneham Rd-Baliol ST intersection where the detour ends.

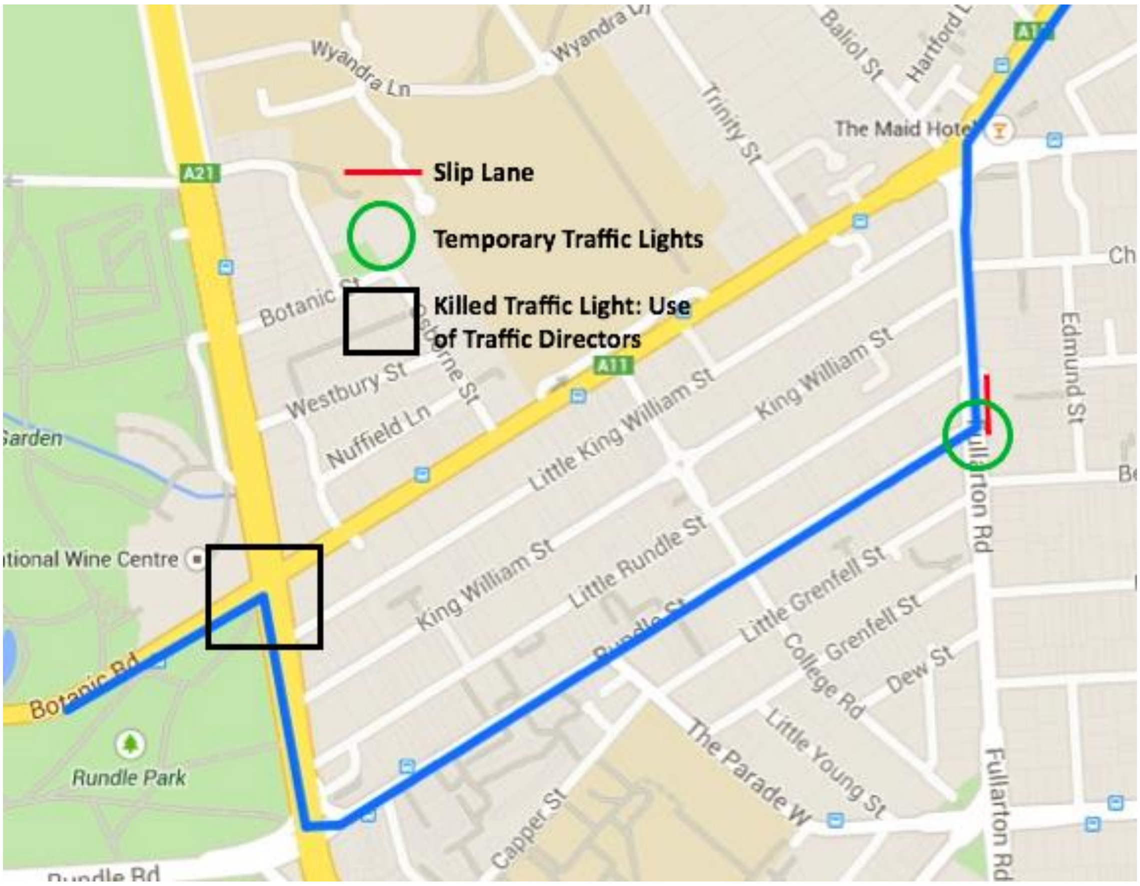


Figure 140: Detour (Google Maps, 2015)

In the opposite direction the traffic is redirected on the same detour, shown in Figure 140. It should be noted there is a large slip lane on Fullarton Rd enabling traffic to flow while also queuing to turn onto Rundle St.

The intersection of Rundle St and Dequetteville Terrace already has a set of traffic lights, though the signal timing of these lights may be adjusted to allow for the increased traffic flow along the detour.

The detour will include but is not limited to the use of, barriers, detour signs, end detour signs, temporary traffic signals, weight cones, local traffic only signs and traffic directors.

Though the detour shown above presents a valid option for the re-directing of traffic during off-peak periods, it is not a valid option to be used during peak traffic flows. As such traffic flows during peak hours must be kept on North Terrace using lane closure options to allow construction to progress, as discussed in Section 7.5.3.

7.5.2. Pedestrians

Pedestrians traffic will largely need to follow a detour to the South side of the road due to construction and closed footpaths on the North Side of the road. Crossings are already provided at each end of the design area, shown in Figure 141. During design, care will be taken during the definition of project work schedules to ensure safe and suitable access to businesses and St Peter's College, located on the North side of the road.

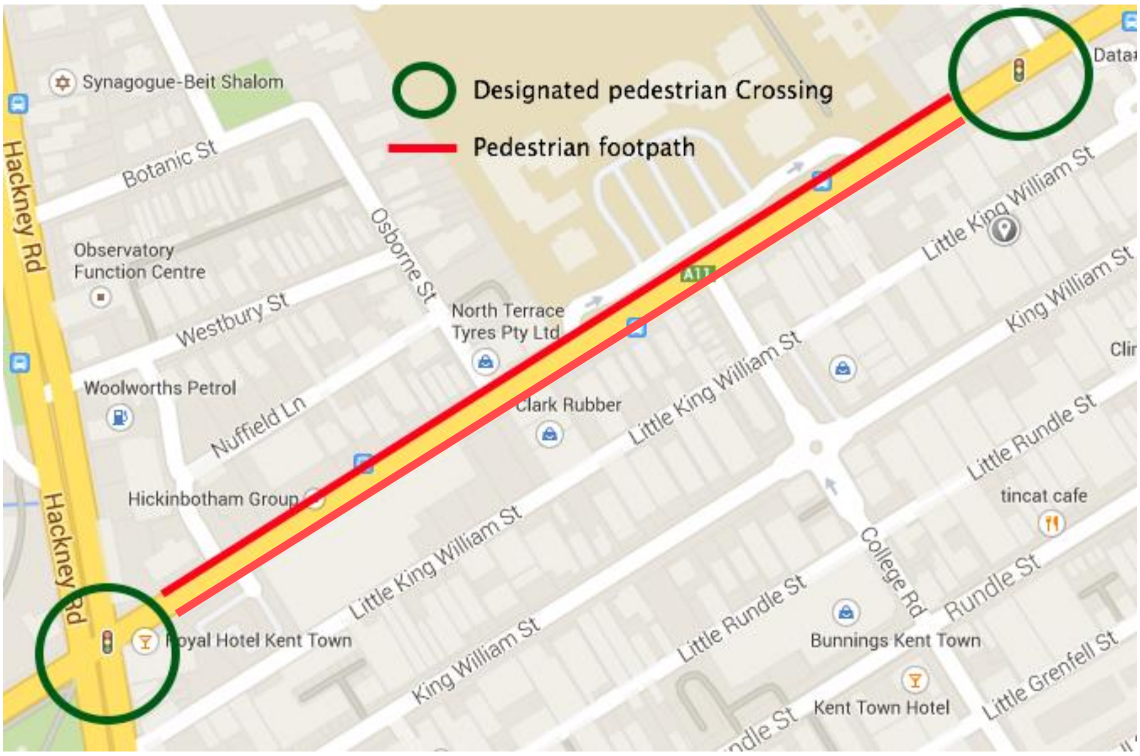


Figure 141: Pedestrian Detour (Google Maps, 2015)

The signs required pedestrian control, and safety, include but are not limited to, pedestrian 'watch your step' signs, pedestrian 'use other footpath' signs, weight cones and barriers.

7.5.3. Traffic Lane Options

During Construction operating lanes in each direction will be set accordingly. This will involve both traffic management for on and off peak traffic flows, both towards and away from the city.

7.5.3.1. Peak Hour Morning

During peak hour traffic, it is important that traffic flows are maintained. Therefore a minimum of two lanes in the primary direction of traffic flow and one lane in the non-primary direction will be used, as shown in Figure 142. The aim is to minimise construction during these time to obtain a speed limit of 40km/h to maintain reasonable traffic flows. However, at times this may not be possible and 25km/h will be used to ensure the safety of construction staff and road users.

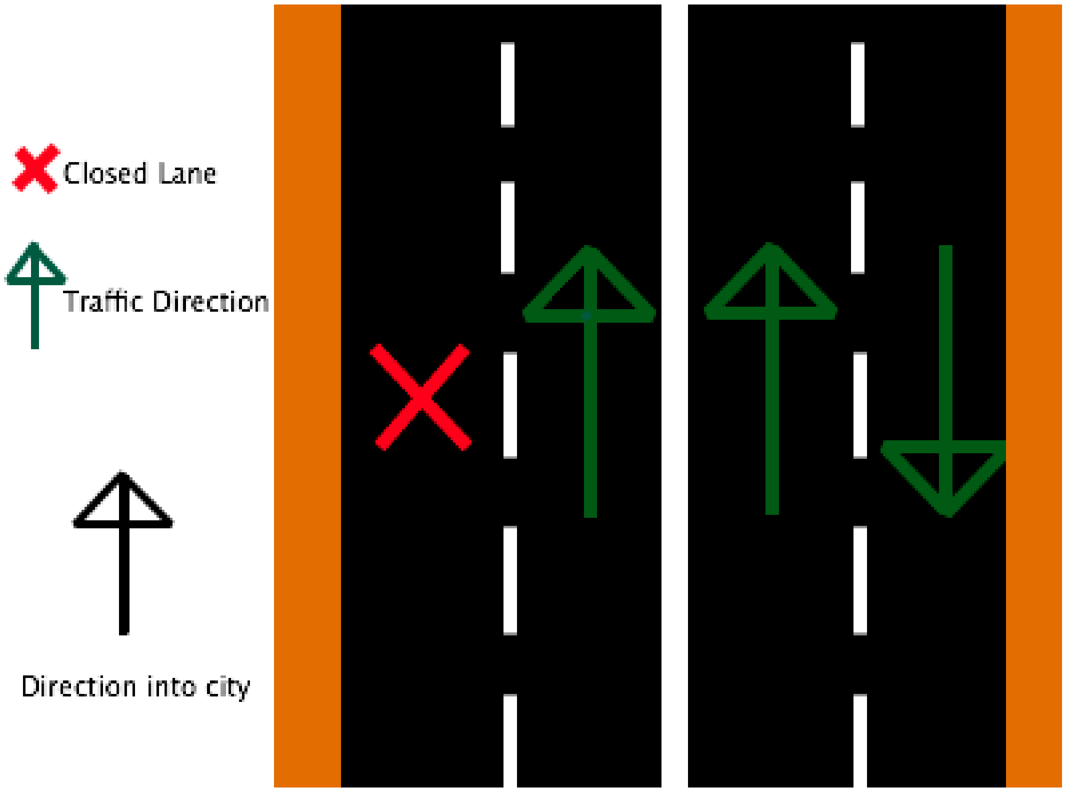


Figure 142:Peak hour morning (Hydro-Future, 2015)

The closed lane shown in Figure 142 will be closed using barriers, reflective weight cones reflective tape and lane closure signs. Additionally the speed limit will be reduced as required, using speed limit signs on both sides of the road as well as road work notification signs, end of road signs and more speed limit signs returning traffic to the normal road speed limit at the end of the road work areas. All appropriate, permanent speed limit sings in the area will be covered as required. Examples of these signs can be found within Table 1.

7.5.3.2. Peak Hour Afternoon

Similarly to Section 7.5.3.1, the Afternoon traffic will have a minimum of two lanes in the primary direction of traffic flow and one lane in the non-primary direction, as shown in Figure 143. The aim is to minimise construction during these time to obtain a speed limit of 40km/h to maintain reasonable traffic flows. However, at times this may not be possible and 25km/h will be used to ensure the safety of construction staff and road users.

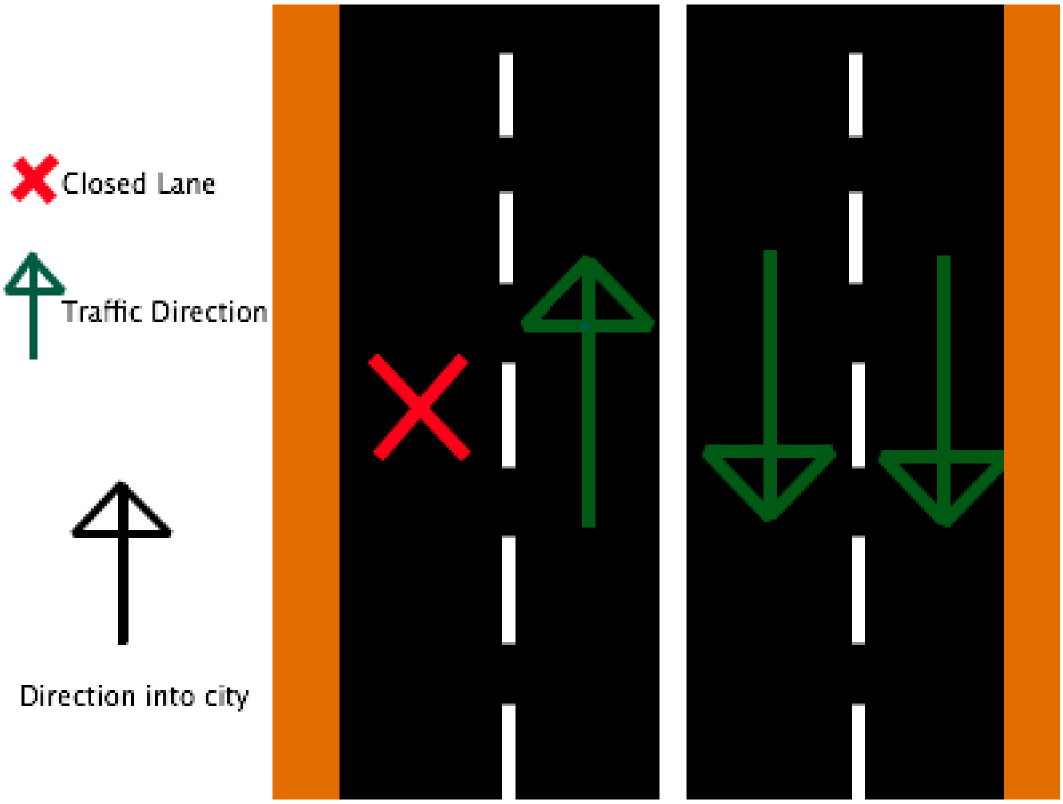


Figure 143: Peak Hour Afternoon (Hydro-Future, 2015)

The closed lane shown in Figure 143 will be closed using barriers, reflective weight cones reflective tape and lane closure signs. Additionally the speed limit will be reduced as required, using speed limit signs on both sides of the road as well as road work notification signs, end of road signs and more speed limit signs returning traffic to the normal road speed limit at the end of the road work areas. All appropriate, permanent speed limit sings in the area will be covered as required. Examples of these signs can be found within Table 1

7.5.3.3. Other Times

During the day, outside peak hour traffic conditions, more lanes may be closed down to allow an increased rate of construction. As the reduction in lanes, as well as speed limit to 25km/h (as required by a closure of more than one lane), will not have a significant effect on traffic flows and travel times. The arrangement, as shown in Figure 144, using a single lane in each direction can be used throughout the day.

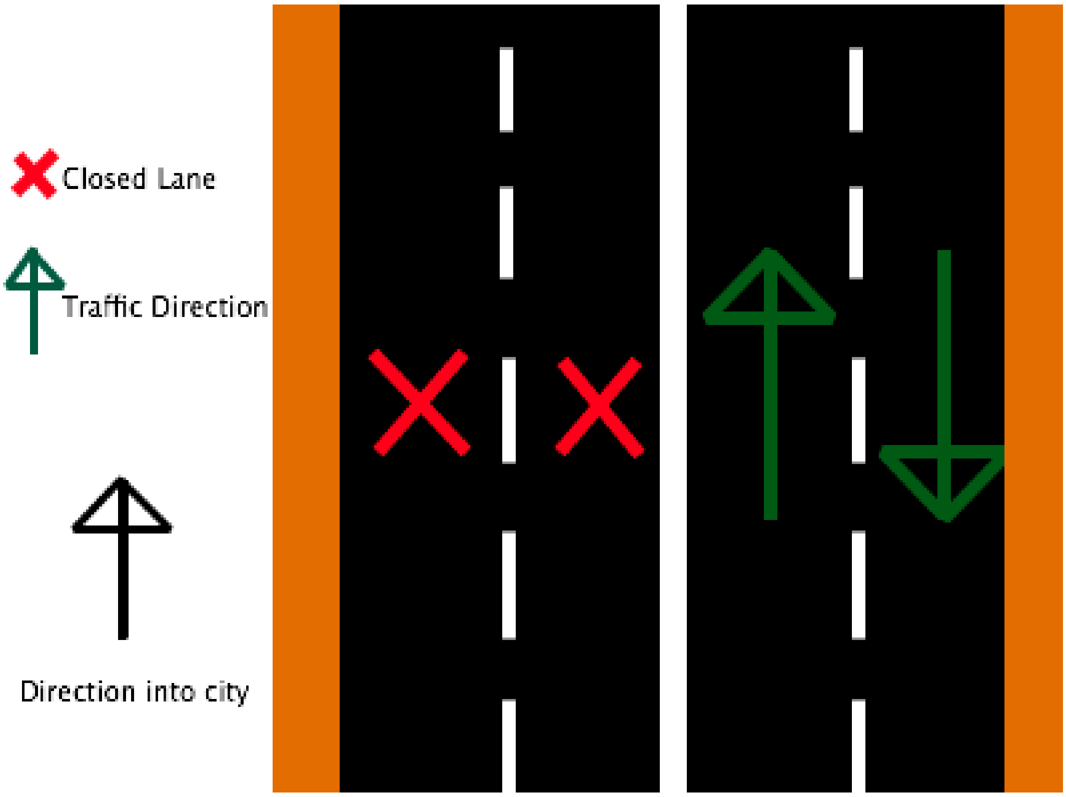


Figure 144: Single Lane Each For Both Directions (Hydro-Future, 2015)

Here the road would be controlled much the same as Figure 142 and Figure 143, using barriers, reflective weight cones reflective tape, lane closure signs speed limit change signs and road notification sign all found within Table 1.

The single shared lane shown in Figure 145 can be used with a speed limit of 25km/h. However, traffic directors will be required at all times during this arrangement to manage traffic. Traffic directors will stop and go signs (shown in Table 1) and be in communication using radios, following standard practices (DPTI, 2010), only allowing one direction of traffic flow at any given time. This situation would only occur at night as an alternative to the detour specified in Section 7.5.1.

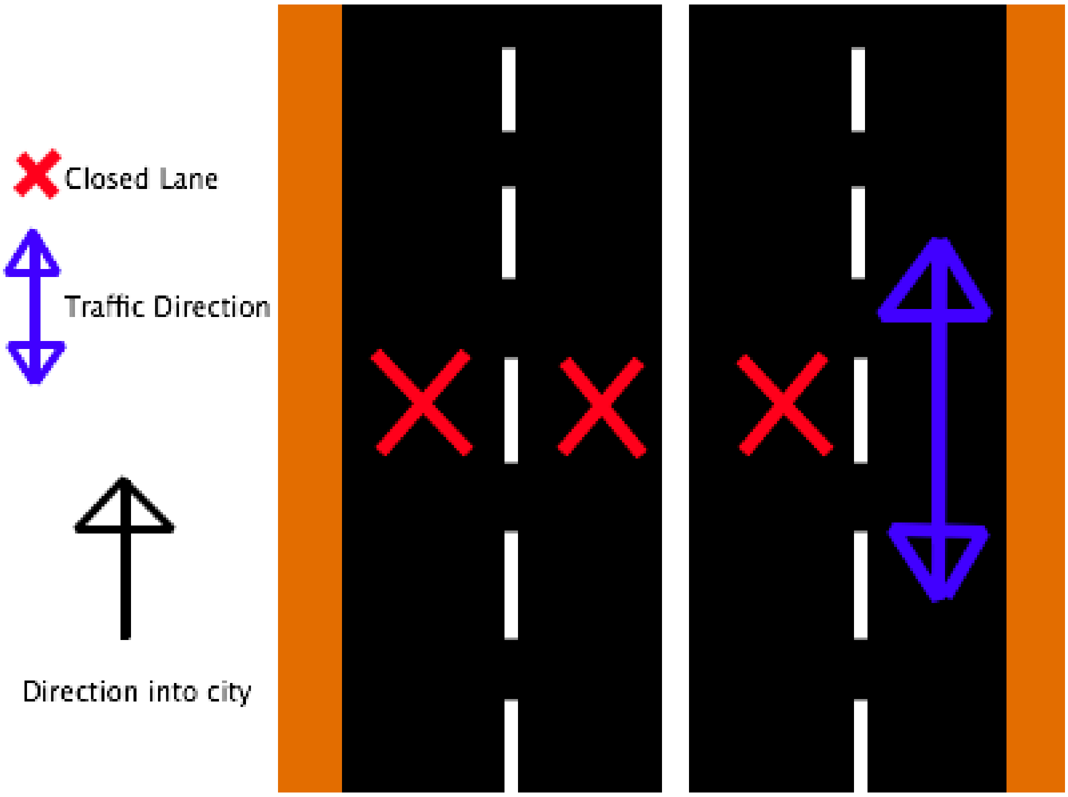


Figure 145: One Lane Shared For Both Directions (Hydro-Future, 2015)

7.5.3.4. Modelling

For each of the recommended lane closure options it has been assumed that the delays would be minimal in order to maintain desired traffic flows for North Terrace. However during the Detailed Design the transport team will conduct in depth traffic modelling for the associated AADT, and lane closure options in order to find the precise impacts that the lane closures will cause (delays, waiting time etc.) the transport team will use traffic modelling software, CUBE (Citilabs, 2013), during the Detailed Design.

7.6. Recommendations

After accessing all possible impacts of the proposed Water Design Options (Section 3) some recommendations in terms of the effect on traffic can be made.

In terms of traffic flows of cars or heavy vehicles the Conventional Stormwater Upgrade and Swale present the greatest impacts to traffic. This is due to both options requiring large amounts of construction on North Terrace.

Additionally the less road works required on the North Terrace the better, as this would not only reduce the impacted traffic flows of all road users but reduce the chances of accidents happening that may occur during road works.

7.6.1. Conventional Stormwater Upgrade

The conventional stormwater upgrade would require the largest stormwater pipes and therefore would have a, compared to the infiltration/retention method or water harvesting, long construction time along north Terrace. This increased construction time will cause prolonged delays for North Terrace, which is not desirable.

7.6.2. Swale

The swale requires a large space to be adequate for design flows which are not available in the design area as discussed in Section 3.3.1.11. There is a further problem that not will space be required for the swale, but also for construction. This raises concerns for the need of lane closures and possibly the need to shut down two lanes during peak hour which will significantly affect the traffic flows during this period.

For public transport and pedestrians, constructing a swale would have a significant effect as it would require that one or both of the footpaths be ripped up and used for space in order to keep lane widths at the appropriate 3.5m required for buses (DPTI, 2015). If the footpath were to be ripped up this would not only cause disturbance for the bus stops during construction but would require them to be removed entirely even after construction due to the lack of footpath.

7.6.3. Remaining Water Design Options

The Water Sensitive Urban Design and Infiltration, Water Harvesting and Combined Drainage Options will all smaller pipes then the Conventional Stormwater Upgrade. It is therefore assumed that this will require less lanes to be closed and/or shorter construction times, therefore making these option preferable in terms of traffic management.

7.6.4. Cyclists

In terms of cyclist, options are considered relatively equal as there is not currently a designated bike lane and therefore cyclists can be considered the same as small cars in terms of traffic modelling. It is, however, presumed that relatively few cyclist use North Terrace due to the nearby ‘linear trail’, which showed a large amount of cyclist traffic during peak hour times during a site inspection.

7.7. Cost

Table 2 shows an estimated cost for the entire project in terms of traffic modelling. The cost included in this feasibility study shows the cost of required materials only, with costing for items such as staff to be included in the Detailed Design.

Table 67: Transportation Model Costing Cost

Object	Cost $
Signage	22,490
Temporary Traffic Lights	2,100
Advance Notice Signboards	1,000
Total	$25,590

8. Urban Design

8.1. Maintenance of Proposed Options

Maintenance of the stormwater drainage network includes inspection, cleaning and repair of open and piped drains, pits, treatment devices, detention basins and outfall structures (VSC, 1999). This network needs to be regularly cleaned to maintain its performance (US EPA, 2001).

Many stormwater drainage system collect large amounts of pollutants such as, litter, branches, leaves, which has the potential to block the drainage system. This can temporarily reduce the capacity of drainage systems during rainfall events, especially during the heavy rainfall events, leading to potential flooding..

The US EPA (2001) reported that regular cleaning of the stormwater drainage network can increase dissolved oxygen levels in stormwater, reduce levels of bacteria, reduce the load of common stormwater pollutants entering receiving waters (e.g. sediment, nutrients, litter, organic matter).

8.1.1. Maintenance techniques

Maintenance techniques for all feasibility study options are different (AMG 2002). The urban design team will outline the most efficient and economic options for the project area. Below shows highlighted maintenance requirements, along with frequency for all the outlined water engineering design options.

8.1.1.1. Conventional Stormwater Upgrade

This option focusses on analysing and upgrading the existing stormwater system, including the stone arch culvert and First Creek, to ensure capacity meets required design flows. Outlined in this section of the report is the maintenance requirements for the pits, pipes and stone arch culvert at First creek. For this option, the main component that required maintenance is the stone arch culvert structure. Due to the age of this structure, the special maintenance is required. The maintenance tasks included for the culvert (USDA, 2014):

- Clearing of debris and growth from inlets and outlets
- Regular inspection is required after heavy rainfall, bushfire or in the seasons when trees shed their leaves
- Structure inspection, required twice a year to check for any damage to the culvert, with repairs conducted promptly
- Safety issues also should be taken into consideration when operations are undertaken in this stone arch culvert due to the age of the this structure

Figure 146 the outlet of the First Creek (Hydro-Future, 2015)

8.1.1.2. Reduce catchment area (infiltration/retention method)

This option focuses on community involvement and cooperation to modify a series of properties along the study area to reduce the levels of stormwater entering the catchment area. The maintenance requirements for this option are very different from other option due to its community involvement and cooperation. Some of components from this option require installation within private properties, so the maintenance of these components may become the responsibility of the owner of these properties. Including rainwater storage tanks, infiltration basin specific to a single or series of properties.

8.1.1.3. Bio-retention basin with overflow pit

The Bio-retention basin with overflow pit has two functions during the rainfall events, during small rainfall events, the systems priority is water quality, during the large rainfall events, the system has overflow protection to increase the capacity to discharge large amounts of stormwater. Regular inspection and maintenance is required to ensure functionality of the system. This design option had serval components that include pipe network, overflow pit, detention basin, vegetation systems and infiltration systems.

Detention basin had two different types, one is called “Wet Pond”, and another one is called “Dry Pond”. The “Wet Pond” is designed to contain large amount of water which is much like a lake, during the heavy rainfall events, the “Wet Pond” can store stormwater runoff temporarily, during the normal days, and the “Wet Pond” can released stormwater at a controlled rate. The advantages of a “Wet Pond” is that pond had higher pollutant removal and less chance that pollutants will be resuspended during a storm, but the detention basin also had some disadvantages include safety issues and mosquito issues during the summer.

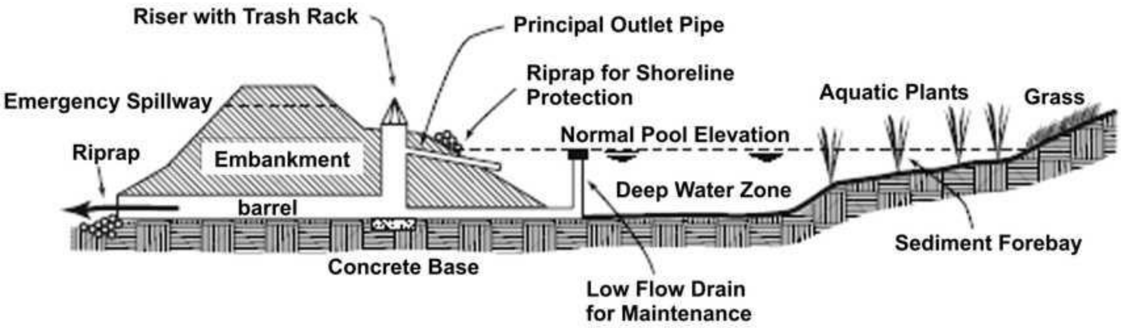


Figure 147 the cross section of wet pond and components included in this system (NVRC 2007)

The "Dry Pond" is designed to contain water for a specified period time after a heavy rainfall events, usually 48 hours after rainfall events, due to short time limit, and the pollutants need many of time to settle to the bottom, once the pollutants was settled, the "Dry Pond" can discharge stormwater at a controlled rate through an outlet.

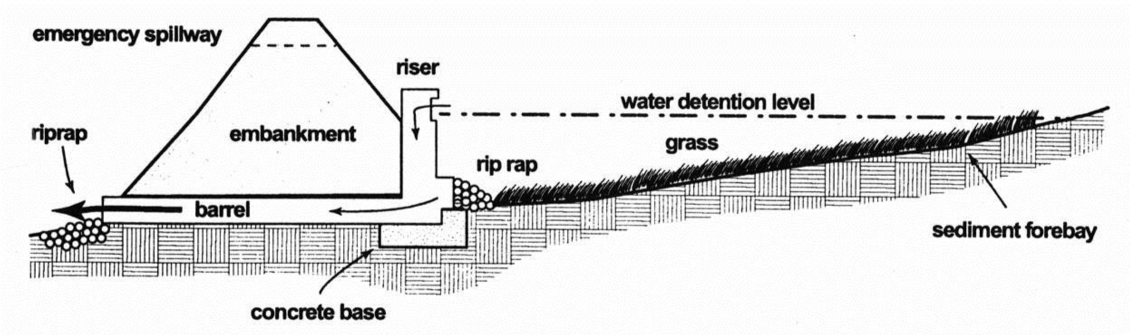


Figure 148 the cross section of dry pond and components included in this system (NVRC 2007)

The maintenance requirements were different for two types of detention basin. For "Dry Pond" the maintenance is required when (NVRC 2007):

- Stormwater water is visible in dry pond area 72 hours after a heavy rainfall event
- Mosquito and/or odour becoming a problem
- There is visible damage to the embankment (such as sinkholes) or to the mechanical components
- Animal lair or trees were found on the embankment or near riser
- Low flow orifice, or concrete trickle ditches blocked by trash, debris, or sediment

For "Wet Pond" the maintenance is required when (NVRC 2007):

- There are visible signs of sediment accumulation
- Mosquito and/or odour becoming a problem
- Algae blooms in the summer months or the ponded areas become dominated by a single aquatic plant
- There is visible damage to the embankment or to the mechanical components
- There are visible seeps on the downstream dam face
- Woody vegetation is growing on the dam

Inspect all stormwater drains and detention basins at least once a year, preferably immediately prior to the wet season. Typical maintenance frequencies are defined in the Water Corporation's Drainage Maintenance Standards (2004). During the inspection, identify the pollutant or sediment accumulation 'hot spots', during or before wet season, the frequency of inspection on these 'hot spots' should be increased to minimise the risk of flooding during the heavy rainfall events (WA Water 2004).

8.1.1.4. Water Sensitive Urban Design stormwater drainage system

Water sensitive urban design methods have more complicated maintenance techniques. However, the frequency of inspection and maintenance is reduced.

The unique components included in the WSUD stormwater drainage system include, soakaways, leaky wells, infiltration trenches, permeable pavements, vegetated swales, buffer strips and infiltration basins specific to a single or series of properties. Each option has different maintenance requirements and techniques.

For vegetated swales, maintenance is required when (NVRC, 2007):

- Stormwater is visible in vegetated swale area 48 hours after a heavy rainfall event
- Sediment has accumulated in the vegetated swale
- Trash, grass, leaves and woody debris have accumulated

For permeable pavements, maintenance is required when (NVRC, 2007):

- Stormwater water is visible on the surface area 48 hours after a heavy rainfall event
- Significant amounts of sediment have accumulated between the pavers

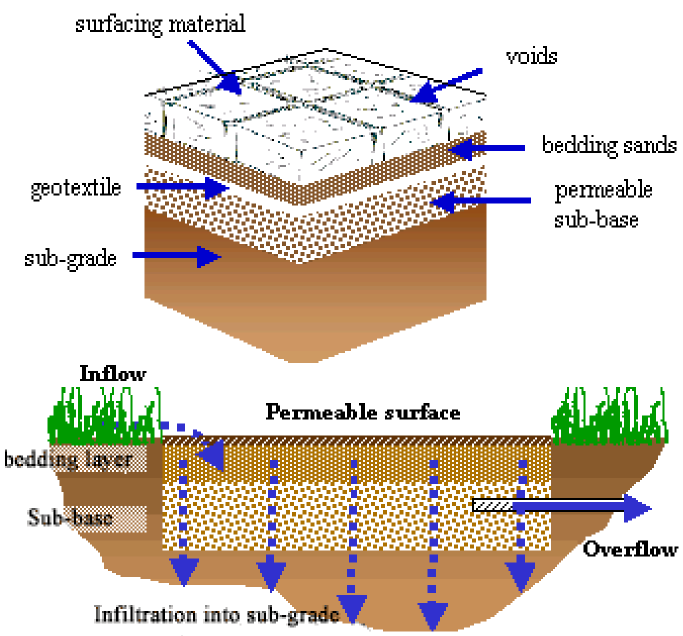


Figure 149 the cross section of permeable pavement and components included in this system (UNEP 2015)

For infiltration trenches maintenance is required when (NVRC 2007):

- Stormwater water is visible in the trenches area 48 hours after a heavy rainfall event
- Mosquito and/or odours are problematic
- There is visible damage to the embankment or to the mechanical components
- Trash, debris, or sediment are visible in the trenches area
- Stormwater runoff flows across trenches area, rather than infiltrate into the underlying soil

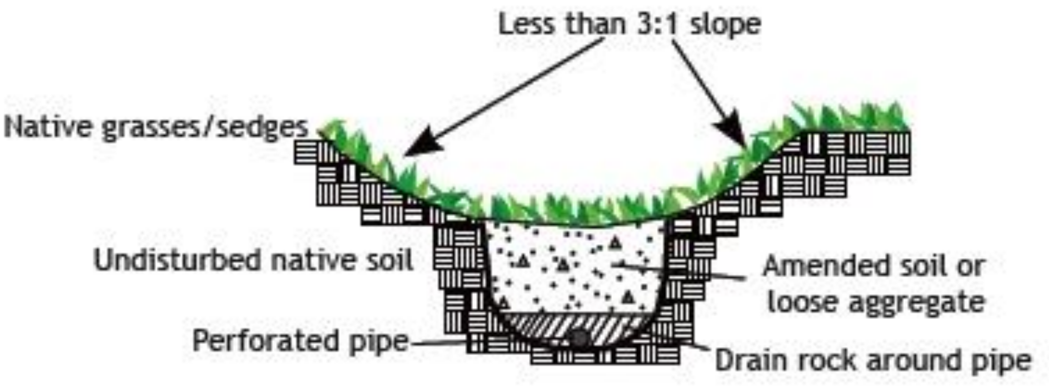


Figure 150 the cross section of infiltration trenches and components included in this system (WSMD 2013)

8.2. Community Consultation and Notification

8.2.1. Local community and local council consultation

Feedback from the local community and local council is very important to make the feasibility study of four proposed options much more effective and serviceable, also feedback can help the Urban Planning team to make better decision that had the best benefits for the local community and local council. To assist in gaining information from the local community and local council, questionnaire survey method can be used. At the early stage of feasibility, the team can summarize potential problems from the four proposed options that will have an impact on the local community, such as vegetated swale along the foot path, detention basin located at local opened spaces and so on, each proposed option has different problems and different scope affected, so to help the Urban Planning team to make appropriate decisions, random selections of people will be involved in the questionnaire survey.

During detailed design the opinions and suggestions from local community and local council is important, for example the issues that caused by the construction activities which includes construction noise, traffic control, and environment pollution.. To get opinions and suggestions, Meetings between the Project Management team and local community will be held regularly during the construction period.

8.2.2. Liaise with the local community

To assist in communicating the construction processes associated with the project, a brochure that contains the latest information about the project will be created and distributed to the community via letterbox drop, and/or the local community centre. Public Information sessions will be held with the local community to enable the project team to answer questions about the project. In addition, dedicated phone numbers, e-mail accounts and a website will be established to assist in community consultation. These methods allow for any issues of public concern to be identified and addressed appropriately It also allows us to help resolve any potential issues that may cause delays for the project. Suggestion boxes could also be established in the community hall, to collect ideas and suggestions from people that are directly affected by the project to assist in building a better environment for them.

8.2.3. Access to community areas

Access to community areas is extremely important during construction. A road closure, even a small road closure can has the potential to cause serious problems. As North Terrace is a vital road for all traffic from East (Magill road), North east (Payneham road) and South (Fullarton road) to get access to Adelaide city, there will be no closure of North Terrace during the day on weekdays. However, there may be some interruption to footpaths. At the same time, there must be other routes to help the North terrace to reduce the traffic pressure caused by footpaths interruption or site work. Once North Terrace is closed on weekend, Little King William St, King William St, Little Rundle St and Rundle St are the ideal routes to share and help to reduce the traffic pressure. Any of these routes must be open for public use at any time during the construction period. Wyandra Ln and Rugby St must be open at all times because after North Terrace is closed, these two routes are the only accesses to St Peter's College. Meantime, road closure will decrease patron's visiting to Hackney Gourmet Cafe & Snack bar, Antiques Avignon, North Terrace Tyres Pty Ltd, Balloons Galore and College Park Deli which are all located on North Terrace. In order to ensure no future conflicts will happen between the shop or company owners and the project contractor, either avoid road closure or detour other routes should be organised in advance. A coincide agreement must be reached before the construction work starts.

8.2.4. Fencing

When there is development in peri-urban areas, there is a need for adequate security measures to ensure the safety of the public and the project contractor and staff. In order to have a safe construction environment, strict guidelines must be followed; everything must be done in accordance with WHS standards.

Security must be guaranteed during the period of road construction along North Terrace. Barriers should be set to alert drivers and protect contractors at the same time. To redevelop the drainage system there is a need to excavate on and along the roadway. Wire fencing or solid fencing is needed to be used at North Terrace to block off the site and will accompany the work in the construction period. Solid fencing creates a good and safe barrier and gives less diversion. Especially when road cannot be fully closed, to reducing the danger as much as possible is very important. Solid fencing is an ideal choice to avoid people being distracted by the site while driving or walking. 200 roadblocks should be enough for the project. A budget of $ 8,000 is approximately needed for fencing to be hired.

8.2.5. Tree removal

Many issues may be caused by vegetation removal, mainly in regards to time and cost. For the community amenity and environment, it is necessary to replant these trees after the construction work is done. There are 3 significant trees on North Terrace. Approximately 79 other small trees might need to be removed for the construction work. These trees are from 2 meters to 4 meters in height.

8.3. Amenities

8.3.1. Proposal Options Overview

In the North Terrace Drainage Design, there are five options for the stormwater drainage system design. All options will require some level of stormwater system to be installed to direct flow and contain any overflow.

The conventional stormwater solution involves analysing the existing stormwater infrastructure along North Terrance. As the existing drainage system is inadequate in major stormwater events, a range of potential changes to the existing infrastructure has been examined in order to increase the drainage capacity of the system. These changes include pipes, side entry pits and grated pits. In this option, some gardening vegetation needs to be removed and re-allocated due to construction.

Swale design is another potential option to promote drainage, also reducing the rate of surface water flow, improving water quality and increasing the aesthetic qualities of North Terrace. Designed swale would be situated in a position on North Terrace, adjacent to the road. Hence, some vegetation may be removed during the construction and replaced if needed.

Water Sensitive Urban Design and Infiltration option involves assessing the feasibility of WSUD options to be executed along North Terrace and in surrounding areas. Design systems including vegetation systems along the roadway, buried infiltration pipes and an updated stormwater system with detention basin. In this option, there are approximately 35 trees along the both roadsides need to be removed to make way for the infiltration pipes installation. A majority of these trees are along the southern side of North Terrace. These trees range from sapling generally less than 2 metres tall, to approximately 4 metres tall trees.

Water harvesting option involves analysing the possibilities to implement on one or numeral water harvesting measures to collect and store stormwater for re-use purpose. Furthermore, the fifth option is combined WSUD. It incorporates the use of multiple water sensitive urban design and infiltration methods. These options may be require the removal of vegetation and it will be specified in the Detailed Design.

8.3.2. Amenities required for the construction site

8.3.2.1. Facilities for meal, storage and shelter

During construction, facilities for shelter, storage and meals are required for worker, they should be readily accessible, but not interfere with operations. A joint facility can be provided for one or more of the needs as long as the clear space is sufficient to seat the number of workers on site.

Floor area for the joint facility should be at least 4.65 square meters for 4 workers and no less than 9 square meters for five or more workers.

The standard of facility should include:

- Lined ceiling and walls and a washable impervious floor
- Adequate ventilation including windows with fitted fly screens
- Adequate lighting for the working hours
- Exit doors

Meal storage and shelter facilities should not be used for the storage of construction materials and equipment. Meal facilities should be cleaned and kept tidy.

Meal facilities should include:

- Sufficient tables and chairs for the number of workers
- Facilities for boiling water
- Separate vermin-proof containers for the hygienic storage of any provided food, tea, coffee or sugar
- Separate vermin-proof containers for the disposal of rubbish and scraps

8.3.2.2. Drinking water facilities

Readily accessible and plentiful supply of clean and drinkable water must be provided for all workers. At the site area, a mains water connection is available. As the drinking water supply source is an external hose bib-tap, the surrounding area needs to be drained and kept clear of rubbish and site debris. Drinking water facilities must be separated from toilet and washing facilities.

8.3.2.3. Toilets facilities

Each site must provide toilet facilities. The Code of Practice for Building and Construction Workplaces (Construction & Utilities, 2002) requires a minimum of one closet where less than six employees are on site; and a minimum of one closet and one urinal where six to ten employees are on site.

Toilets must be self-contained, fresh water flushing and water seal portable if toilets are not connected to a sewerage system. Regularly service with the supplier's information and instructions at least once a month. Toilets and hand-washing facilities should be cleaned daily and kept tidy (Construction & Utilities, 2002).

To meet an acceptable standard of hygiene and privacy toilets, it requires:

- Conveniently located and readily accessible to all on-site workers
- Set up to remain level and stable under all working conditions
- Constructed with lined ceiling and walls, durable and waterproof
- Weatherproof
- Well lit and ventilated
- Provided with a hinged seat and lid
- Provided with a door which can be locked from the inside
- Provided with a well-drained floor above ground level which is covered with a durable waterproof material
- Provided with plentiful toilet paper
- Provided with regularly-serviced sanitary disposal units

8.3.2.4. Washing facilities

Hand-washing facilities should be located within or near toilets and should be provided for meal areas. Soap or cleaning agents and towels or paper should be available at each washing facility (Construction & Utilities, 2002).

At the location where a worker is required to change into protective clothing, the protective clothing and personal clothing should not be stored in the same location. Washing facilities should be suitable for employees to wash thoroughly before changing clothes (Construction & Utilities, 2002).

9. Project Cost

The total cost of the project, including all recommended options presented by each team is shown below in Table 68: Total Cost of Project.

Table 68: Total Cost of Project

Item	Description	Unit	Quantity	Rate	Cost
		Combined Drainage			
1	Bio-retention basin	m^2	150	140	21,000
2	Rain water tank (3800L)	No.	20	2,750	55,000
			Sub-total (1)		**76,000**
		Conventional Stormwater System			
3	Side Entry Pits	mm	600^3	930	5,580
4	Grate (Lid of Concrete Box)	mm	600^2	231	924
5	Precast Concrete Box	mm	600^2	338	1,352
6	Reinforced Concrete Pipe	m	0.90	325	136,500
7	Reinforced Concrete Pipe	m	0.375	138	11,040
			Sub-total (2)		**155,396**
		Sandstone Arch Culvert Structural Support System			
8	Precast Slab Bridge Deck	m^3	2.5	243	608
9	Reinforcement	t	0.3	1850	555
10	Mortar Bridge Deck	m^3	0.6	243	146
11	Reinforcement (Anchor-Tendon)	t	0.2	1850	370
12	Pre-Stressing Continuity	t	0.2	6300	1260
			Sub-total (3)		**2939**
		Trench Stability			
13	Shoring of Trenches	per m	700	42	29,400
			Sub-total (3)		**29,400**

		Gabion Retaining Wall			
14	Crushed Rock Fill	per m	390	3	1170
15	Mesh Sheeting	per m	118	3	354
			Sub-total (4)		**1,524**
		Gross Pollutant Trap			
16	Gross Pollutant Traps	item	1	20,000	20,000
			Sub-total (5)		**20,000**
		Traffic Management			
17	Signage	unit	152	148 (ave.)	22,496
18	Temporary Traffic Lights	item	3	700	2,100
19	Advance Notice Signboards	item	2	500	1,000
			Sub-total (6)		**25,590**
		Urban Design			
20	Fencing	unit	1	8,000	8,000
			Sub-total (7)		**8,000**
			Total (1+2+3+4+5+6+7)		**318,849**
21	Project Management Costs			15%	47,828
22	Contingency			10%	31,885
23	Fees & Charges (inc. CITB & Ins.			12%	38,262
				Total	**436,824**

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11. Appendices

Appendix A – Water Preliminary Design Calculations

A1. Design Flow Determination

A1.1. Design Flow Runoff for Pavements and Roads

The WSUD design flow runoff was calculated using 5 years ARI (Melbourne Water, 2005) this is considering that the WSUD will be design for a minor storm event. In other words, this means that a major stormwater drainage system will have to be implemented together with the WSUD technologies to accommodate major storm events of 20 years ARI. WSUD options will be implemented to not only improve drainage but also for environmental reasons to ensure that the storm water quality is improved. The following calculations show the determination of the flow runoff for both pavements and roads in the contributing catchment area.

$$Q = \frac{CIA}{360}$$

$$t_c = 5\,\text{min}\ (\,Paved\ area\,).$$

$$I_{s,s} = 83.6$$

$$A = Area\ of\ Catchment\ contributing\ (Road\ and\ Pavement).$$

$$Length\ o\ fthe\ road\ in\ Catchment = 388 + 423 = 811\ m$$

$$Width\ of\ pavment\ and\ road = (2 \times 2.5 + 15)$$

$$\therefore (5 + 15) = 20\ m$$

$$Area\ (A) = 20 \times 811$$

$$Area\ (A)\ = 16.220\ m^2$$

$$C = 0.9\ (\,Paved\ area)$$

$$F_5 = 0.95$$

$$Q = \frac{0.9 \times 0.95 \times 1.622 \times 83.6}{360}$$

$$\boldsymbol{Q = 0.322\ {}^{m^3}/_{sec}}$$

A1.2. Design Flow Runoff for Catchment Area

The runoff coefficient for the sub-catchment 1:

$$C_1 = \frac{C_i A_i + C_p A_p}{\sum A}$$

$$C_1 = \frac{(92.6*0.945)+(7.4*0.105)}{100}$$

$$C_1 = 0.88$$

The Runoff coefficient for the sub-catchment 2:

$$C_2 = \frac{C_i A_i + C_p A_p}{\sum A}$$

$$C_2 = \frac{(92.9*0.945)+(7.1*0.105)}{100}$$

$$C_2 = 0.89$$

The Runoff coefficient for the sub-catchment 3:

$$C_3 = \frac{C_i A_i + C_p A_p}{\sum A}$$

$$C_3 = \frac{(92.5*0.945)+(7.5*0.105)}{100}$$

$$C_3 = 0.88$$

1.2 Design flow Calculations

Sub-Catchment Area 1- flow rate calculation:

$$\rightarrow Q_1 = \frac{(0.88)(62.2)(4.34)}{360} = 0.662\ m^3/s$$

Sub-Catchment Area 2- flow rate calculation:

$$\rightarrow Q_2 = \frac{(0.89)(62.2)(3.11)}{360} = 0.475\ m^3/s$$

Sub-Catchment Area 3- flow rate calculation:

$$\rightarrow Q_3 = \frac{(0.88)(62.2)(1.47)}{360} = 0.223 m^3/s$$

A2. Dry Swale Design

A2.1. Assume Dimensions

Before final design dimensions can be decided upon, a number of preliminary and assumed dimensions need to be used. From here calculations are made to determine if the designed swale can sustain the required runoff. If not, the dimensions are altered and then the calculations are performed again.

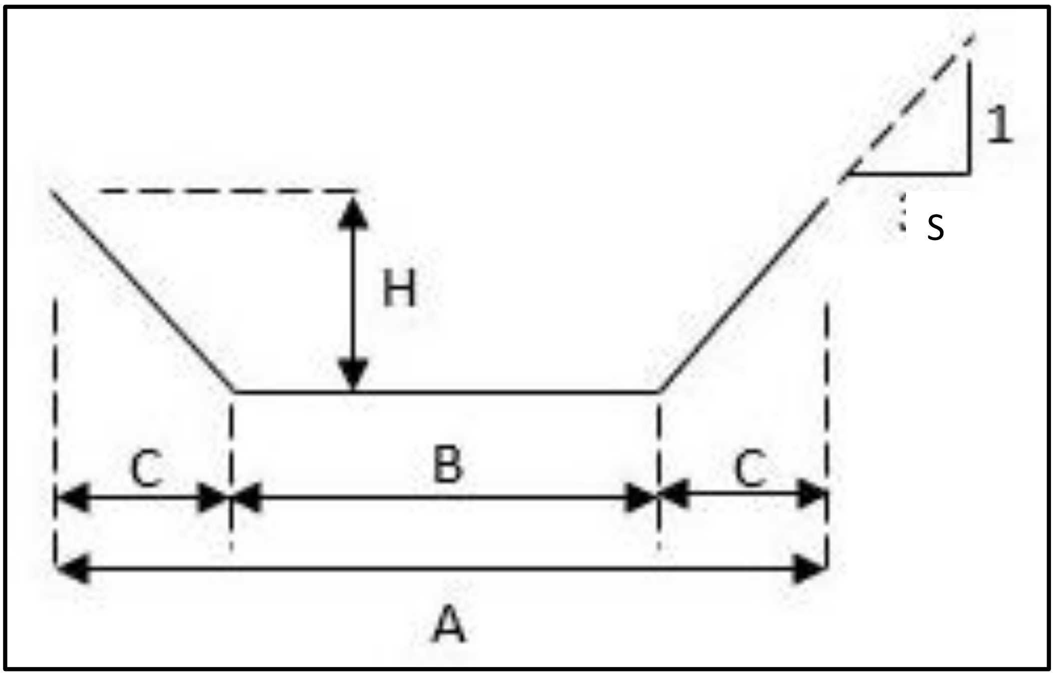

Figure 151 - Diagram of Trapezoidal Swale for Calculations (Hydro-Future Consulting, 2015)

Assume Manning's Rougness (n) = 0.15 (Stormwater Management Manual for Western Australia, 2006). Where Manning's roughness is the coefficient for roughness in Hydraulic applications and is usually between 0.15 and 0.4 for swales with flow depths below the height of vegetation within the swale (Stormwater Management Manual for Western Australia, 2006).

Assume Slope (s) = 2% / S_0=0.02

Assume Base Width (B) = 2m

Assume Height (H) = 0.35m

Assume Side Slope (S) = 3m

Assume Side Width (C) = 1.5m

Assume Overall Width (A) = 5m

A2.2. Determine Swale Area

$$Area\ (A) = (B + SH)H$$

$$Area\ (A) = \big(2m + (3m \times 0.35m)\big) \times 0.35m$$

$$Area\ (A) = 1.07m^2$$

A2.3. Determine Swale Perimeter

$$Perimeter\ (P) = B + 2H\sqrt{S^2 + 1}$$

$$Perimeter\ (P) = 2m + (2 \times 0.35m)\sqrt{(3m)^2 + 1}$$

$$Perimeter\ (P) = 4.21m$$

A2.4. Determine Hydraulic Radius

$$Hydraulic\ Radius\ (R) = \frac{A}{P}$$

$$Hydraulic\ Radius\ (R) = \frac{1.07m^2}{4.21m} = 0.25m$$

A2.5. Estimate Flow Rate

$$Flow\ Rate\ (Q) = \frac{1}{n}AR^{\frac{2}{3}}S_0^{\frac{1}{2}}$$

$$Flow\ Rate\ (Q) = \left(\frac{1}{0.15}\right) \times 1.07m^2 \times 0.25m^{\frac{2}{3}} \times 0.02^{\frac{1}{2}}$$

$$Flow\ Rate\ (Q) = 0.40m^3/s$$

$$\therefore \boldsymbol{Designed\ Flow\ Rate}\ \left(\mathbf{0.400m^3/s}\right) > \boldsymbol{Required\ Flow\ Rate}\ (\mathbf{0.332m^3/s})$$

Therefore design is OK and will now require checking for suitability along North Terrace.

A2.6. Check Velocity

$$Velocity\ (V) = \frac{Q}{A}$$

$$Velocity\ (V) = \frac{0.40m^3/s}{1.07m^2}$$

$$Velocity\ (V) = 0.37m/s\ < 0.5m/s$$

Design is OK as velocity is to be below 0.5 metres per second for a storm event with a 5 year ARI (Stormwater Management Manual for Western Australia, 2006).

A3. Water Sensitive Urban Design

A3.1. Porous Pavements

A_{inf} can be calculated using the following equation:

(Argue, J.R, 2005 and Infiltration Systems Design by Department of water, Government of Western Australia, 2007).

$$A_{inf} = \frac{CiA}{1000 * 60^2 * [(1 - \Psi)K_h * U - \frac{i}{60^2 * 1000}]}$$

Where:

Ψ= infiltration surface blockage factor

K_h= Hydraulic conductivity of the underling soil

U= Moderation factor of the hydraulic conductivity; U= 2.0 for Clay soils; 1.0 for sandy clay.

A_{inf} = required infiltration Area

A= Total catchment area considered (roads and pavements)

i = Rainfall intensity for 5 years ARI

C=0.9

Therefore,

$$A_{inf} = \frac{CiA}{1000 * 60^2 * [(1 - \Psi)K_h * U - \frac{i}{60^2 * 1000}]}$$

$$C_5 = 0.9 \times 0.95$$

$$I_{5,5} = 83.6 \ {}^{mm}/_{hr}$$

$$A = 16220 \ m^2$$

$$\Psi = 0.2 \ (\ estimated \ using \ Argue \ 2005)$$

$K_h = 1 \times 10^{-5} m/s$ Using K_h for Sandy Clay (Melbourne Water, 2002)

N.B: This could be over estimate as clay has a smaller hydraulic Conductivity than Sandy Clay.

$$A_{inf} = \frac{0.9 \times 0.95 \times 83.6 \times 16.220}{1000 \times 60^2 \times \left[(1 - 0.2) \times 2 \times 10^{-5} \times 2 - \frac{83.6}{60^2 \times 1000}\right]}$$

$= 36689\ m^2$

A3.2. Sedimentation Basins

3.2.3.1.1.1. Flow Rate

A sedimentation basin is designed to utilize runoff from the road and pavement areas within the catchment area. Therefore, as shown in previous calculations, the corresponding flow rate for this area size and type is 0.332m^3/second.

3.2.3.1.1.2. Hydraulic Efficiency

The hydraulic efficiency of the system (λ) can be assumed to be 0.26, as the shape of the basin is likely to be rectangular, where the water enters and leaves the system along the same path. This value ranges from 0 to 1 and should be confirmed as part of the detailed design. For the feasibility study, assuming a rectangular arrangement is a conservative assumption made for high level design purposes.

3.2.3.1.1.3. Turbulence Factor

The turbulence factor, n, was then calculated using the following formula:

$$n = \frac{1}{1-\lambda}$$

In this case

$$n = \frac{1}{1-0.26}$$

$$n = 1.35$$

3.2.3.1.1.4. Sediment Removal Efficiency

For a sedimentation basin to be considered feasible for implementation, the removal efficiency of sediments must be equal to, or greater than, 80%. By trial and error, if it is assumed that the area is equal to 50m^2, the following removal efficiency is produced:

$$R = 1 - (1 + \frac{1}{n}\ x\ \frac{V_s\,(\frac{mm}{sec})}{\frac{Q(\frac{m^3}{sec})}{A\,(m^2)}}\ x\ \frac{d_e(m) + d_p(m)}{d_e(m) + d^*(m)})^{-n}$$

In the above equation, n is the turbulence factor, V_s is the settling velocity, Q is the flow rate, A is the area of the sedimentation basin, d_e is the extended detention depth, d_p is the depth of the permanent pool and d* is the depth below the permanent pool level that will still achieve the target sedimentation depth.

$$R = 1 - (1 + \frac{1}{1.35}\ x\ \frac{0.011}{\frac{0.332}{50}}\ x\ \frac{0.25+2}{0.25+1})^{-1.35}$$

This gives a removal efficiency of:

$$R = 0.797 \approx 80\%$$

Therefore, designing a basin, which has a total area of 50m^2, will meet sediment removal efficiency requirements.

3.2.3.1.1.5. Required Storage

The required storage area was then calculated using the following:

$$S_t = C_a\ x\ R\ x\ L_o\ x\ F_R$$

The required storage, is the area which is required to store the expected runoff in the basin. This is dependent on the size of the catchment which will contribute runoff, the expected removal efficiency of the basin, sediment loading rate and how often it is expected that the basin will be cleaned. For this option to be considered feasible the available storage, the area used in the above equation as A (50 square meters) must be greater than or equal to the required storage.

In this equation S_t represents the storage area, C_a is the catchment area which contributes to runoff, R is the removal efficiency as calculated above, L_o is the sediment loading rate and F_R is the clean out frequency.

$$S_t(m^3) = 1.66(ha)x\ 0.8\ (\%)x\ 1.6(m^3\ per\ ha\ per\ year)x\ 5(years)$$

Therefore, the required storage area is:

$$S_t = 10.62\text{m}^2$$

As this value is less than the area of the basin (50m^2), then the system will work as the available storage is less than the required storage. Though the available storage greatly exceeds the required storage, the basin must be a minimum of 50m^2, otherwise the pollutants and sediments will not settle and be removed from the water.

3.2.3.1.1.6. Design of Outlet Pit

The outlet pit for the sedimentation basin was then designed. First the required perimeter was found using the following:

$$P = \frac{Q(\frac{m^3}{\sec})}{B\ x\ C_w\ x\ H^{1.5}(m)}$$

Where, P represents the perimeter, B is the blockage factor, C_w is the weir coefficient and H is the extended detention depth.

$$P = \frac{0.332}{0.5\ x\ 1.7\ x\ 0.25^{1.5}}$$

$$P = 3.12m$$

The area of the outlet pit was also found:

$$A = \frac{Q(\frac{m^3}{\sec})}{B\ x\ C_d\ x\ \sqrt{2g(\frac{m}{\sec})H(m)}}$$

The C_d value in this formula represents the discharge coefficient.

$$A = \frac{0.332}{0.5\ x\ 0.6\ x\ \sqrt{2(9.81)(0.25)}}$$

This gives a required area of:

$$A = 0.5\text{m}^2$$

A3.3. Infiltration Trench

A3.3.1. Critical Stormwater Runoff Volume

First, the volume of water which would contribute to runoff and be captured in the infiltration trench was calculated using the following:

$$V\ (m^3) = CI(\frac{m}{hr})A(m^2)t_c(hrs)$$

In this equation, V is the stormwater runoff volume, C is the runoff coefficient, A is the contributing catchment area and t_c is the time of concentration.

$$V = 0.9\ x \frac{83.6}{1000}\ x\ 16{,}220\ x \frac{5}{60}$$

$$V = 101.7\text{m}^3$$

A3.3.2. Length of Infiltration Trench

The required length of the infiltration trench was then calculated using the following:

$$L\ (m) = \frac{V\ (m^3)}{eb(m)H(m) + 60K_h(\frac{m}{\text{sec}})\tau(mins)\left(b + \frac{H}{2}\right)U}$$

V represents the runoff volume calculated above, e is the void ratio, b is the width of the infiltration trench, H is the height of the infiltration tench, K_h is the hydraulic conductivity of the soil, τ is the critical storm duration and U is a moderation factor which is dependent on the soil type.

An estimate of the required depth of the infiltration trench is required. Assuming that the infiltration trench lies within the top two layers of the soil profile and taking the average hydraulic conductivity values of both these layers results in a hydraulic conductivity of 5×10^{-6}, m/sec, therefore.

$$L = \frac{101.7}{0.9\ x\ 0.5\ x\ 1 + 60\ x\ 5x10^{-6}\ x\ 15\ x\left(1 + \frac{0.5}{2}\right)x\ 2}$$

$$L = 220.5m$$

It should be noted that the length of this trench was determined using the standard dimensions of an infiltration trench, 1m wide and 0.5m high, as it is the smallest size that will provide an acceptable emptying time.

A3.3.3. Emptying Time

The emptying time for the infiltration trench designed above was then checked.

$$T_e = \frac{-4.6Lbe}{2K_h(L+b)} \, log_{10}(\frac{Lb}{Lb + 2H\ (L+b)}$$

Therefore, using this formula:

$$T_e = \frac{-4.6\ x\ 220.5\ x\ 1\ x\ 0.9}{2\ x\ 5x10^{-6}(220.5+1)} \, log_{10}(\frac{220.5\ x\ 1}{220.5\ x\ 1 + 2\ x\ 0.5\ (220.5+1)}$$

This gives an emptying time of:

$$T_e = 124469.2\ seconds$$

$$T_e = 34.5\ hours$$

A3.4. Soak-Away Crates

A3.4.1. Critical Stormwater Runoff Volume

First, the critical stormwater runoff volume was estimated using:

$$V = CI(\frac{m}{hr})A(m^2)t_c(hrs)$$

In this equation, V is the stormwater runoff volume, C is the runoff coefficient (0.9 as it is assumed the water will only travel along paved surfaces before reaching an inlet), A is the contributing catchment area (5.81ha for business and residential roof area), t_c is the time of concentration (assumed to be 10 minutes as will travel along roof and paved surface) and I is the intensity of the rainfall.

The rainfall intensity was found using an Intensity-Frequency-Duration Table provided by the Bureau of Meteorology for an ARI of 5 years and a time of concentration of 10 minutes (see Section 1.3.1.2, Figure 3).

As can be seen, this gives an intensity of 62.2mm/hr. Therefore:

$$V = 0.9\,x\,\frac{62.2}{1000}\,x\,58{,}100\,x\,\frac{10}{60}$$

$$V = 542.1\text{m}^3$$

A3.4.2. Area of Soak-Away

The required area of the soak-away was then calculated using the following:

$$A = \frac{V}{eH + 60K_h\tau U}$$

The variables in this equation have been identified in Section 4.4.4.3.

$$A = \frac{542.1}{0.9\,x\,0.5 + 60\,x\,5x10^{-6}\,x\,20\,x\,2}$$

Therefore, the required area is:

$$A = 1173.4\text{m}^2$$

A3.4.3. Emptying Time

The emptying time of the soak-away designed above was then checked using the following:

$$T_e = \frac{2He}{K_h}$$

Therefore:

$$T_e = \frac{2 \ x \ 0.5 \ x \ 0.9}{5x10^{-6}}$$

This gives an emptying time of:

$$T_e = \ 180{,}000 \ seconds$$

$$T_e = \ 50 \ hours$$

The recommended emptying time for a 5-year ARI is 1.5 days, which may make this option unsuitable.

A3.5. Leaky Well

A3.5.1. Design Calculations/Considerations (Leaky Well)

All preliminary calculations and results for the leaky well are included in Appendix A3.4.

A3.5.1.1. Critical Stormwater Runoff Volume

First, the critical stormwater runoff volume was estimated using:

$$V = CIAt_c$$

For the same runoff type, this will produce the same runoff volume.

$$V = 542.1\text{m}^3$$

A3.5.1.2. Diameter of Leaky Well

The required diameter of the leaky well was then calculated using the following:

$$D = \sqrt{\frac{V}{\frac{\pi\,(H + 120K_h\tau U)}{4}}}$$

The variables in this equation have been identified in Section 4.4.4.3.

$$D = \sqrt{\frac{542.1}{\frac{\pi\,(2 + 120\,x\,5x10^{-6}\,x\,20\,x\,2)}{4}}}$$

Therefore, the required diameter is:

$$D = 18.5m$$

This would not be considered acceptable because the diameter greatly exceeds the nominated height of 2m, and they should be approximately equal. To overcome this, the height could be altered until the height is approximately equal to the diameter or multiple wells could be used.

A3.5.1.2.1. Diameter of Single Leaky Well

For the diameter of the well to be approximately equal to the height, a height of 9m was trialled:

$$D = \sqrt{\frac{542.1}{\frac{\pi\,(9 + 120\,x\,5x10^{-6}\,x\,20\,x\,2}{4}}}$$

A height of 9m gives a corresponding diameter of:

$$D = 8.7m$$

Though this requires an incredibly high well, the ratio of the height to diameter would be considered acceptable.

A3.5.1.2.2. Multiple Leaky Wells

If it assumed that standard sized leaky wells were installed, with a diameter of approximately 2m and height of 2m, then each tank could hold almost 7m^3 of water. Therefore, if multiple wells were used, a total of 78 tanks would be required. This would mean each tank would hold approximately 6.95m^3 of water and that the diameter and height are equal. See equations below:

$$\frac{542.1}{7} = 77.5 = 78\, tanks$$

Therefore, the new volume that each tank would be required to utilise is:

$$\frac{542.1}{78} = 6.95m^3$$

Recalculating the diameter, this would be equal to

$$D = \sqrt{\frac{6.95}{\frac{\pi\,(2 + 120\; x\; 5x10^{-6}\; x\; 20\; x\; 2}{4}}}$$

$$D = 2.1m \approx H$$

A3.5.1.3. Emptying Time

The emptying time of both of the leaky wells designed above was then checked using the following:

$$T_e = \frac{-4.6D}{4K_h}\log\left(\frac{\frac{D}{4}}{H + \frac{D}{4}}\right)$$

A3.5.1.3.1. Emptying Time – Single Leaky Well

The emptying time for a large, single, leaky well is shown below:

$$T_e = \frac{-4.6\; x\; 8.7}{4\; x\; 5x10^{-6}}\log\left(\frac{\frac{8.7}{4}}{9 + \frac{8.7}{4}}\right)$$

Therefore:

$$T_e = 1422291 \text{ seconds}$$

$$T_e = 395 \text{ hours}$$

This greatly exceeds the recommended emptying time for a 5 year ARI (1.5 days), which may make this option unsuitable.

A3.5.1.3.2. Emptying Time – Multiple Leaky Wells

The emptying time for a large, single, leaky well is shown below:

$$T_e = \frac{-4.6\ x\ 2.1}{4\ x\ 5x10^{-6}} \log\left(\frac{\frac{2.1}{4}}{2 + \frac{2.1}{4}}\right)$$

Therefore:

$$T_e = 329476 \text{ seconds}$$

$$T_e = 91 \text{ hours}$$

Appendix B – Water Decision Making Matrix

	DECISION MAKING MATRIX FOR NORTH TERRACE DRAINAGE SOLUTION OPTIONS									
	Cost		**Flood Mitigation**		**Quality**		**Amenity**			
	Weight	35%	Weight	35%	Weight	20%	Weight	10%		
Drainage Options	Rank	Weighted Rank	Rank	Weighted Rank	Rank	Weighted Rank	Rank	Weighted Rank	**Total**	**Weighted Total**
Conventional S/W										
Swale Design										
WSUD / Infiltration										
Water Harvesting										
Combined										

Ranking Scale Of 1-5

1. Poor
2. Below Average
3. Average
4. Good
5. Very Good

Appendix C – Water Associated Information

C1. Pollutant Concentration Table (France)

Table 69 - Pollutant concentration of roof runoff water in France (International Conference on Urban Drainage, 2008)

Parameter	Statistics	Flat roof	Tile	Zinc sheets	Slate
pH	Median	5.4	5.1	5.8	5.5
	Min	4.5	3.2	5.3	4.8
	Max	5.5	5.4	6.1	6.0
SS (mg L^{-1})	Median	16	4.3	6.2	6.6
	Min	5.6	1.6	3.1	1.0
	Max	38	10	23	20
TOC (mg C L^{-1})	Median	7.7	5.3	3.5	3.0
	Min	3.3	2.9	2.9	2.1
	Max	23	8.6	5.3	5.5
Cd (µg L^{-1})	Median	0.97	0.44	0.66	0.94
	Min	0.81	0.16	0.50	0.22
	Max	1.18	0.62	0.75	1.62
Ni (µg L^{-1})	Median	2.8	1.9	1.8	4.3
	Min	1.0	1.0	1.0	1.0
	Max	3.9	2.9	2.7	16.
Cr (µg L^{-1})	Median	1.5	1.5	1.9	2.3
	Min	1.4	1.3	1.2	1.8
	Max	2.0	3.4	4.6	2.9
Cu (µg L^{-1})	Median	5.7	4.4	4.1	2.8
	Min	3.5	2.1	2.0	2.3
	Max	11	11	11	6.6
Pb (µg L^{-1})	Median	57	109	20	5.4
	Min	40	44	5.8	1.0
	Max	169	129	58	50
Zn (µg L^{-1})	Median	394	567	4574	1598
	Min	163	409	1263	1114
	Max	517	588	7903	7300

C2. Pollutant Concentration Table (Texas)

Table 70 - Pollutant concentration of roof runoff water in US, Texas (A&T State Univesity, 2009)

	Location	Roof Type	pH	FC (CFU/100mL)	Al (mg/L)	Mg (mg/L)	Mn (mg/L)	Cr (mg/L)	Cd (mg/L)	Cu (mg/L)	Pb (mg/L)	Fe (mg/L)	Zn (mg/L)
N.C. DENR Freshwater Standards (Class C Waters)	—	—	6.0 – 9.0	200	none	none	0.2	0.05	0.002	0.007	0.025	1	0.05
U.S. EPA Drinking Water Standards (Primary standard unless otherwise noted)	—	—	6.5 – 8.5*	0	0.2*	none	0.05*	0.1	0.005	1.3 (1.0*)	0.015	0.3*	5*
Chang et al., 2004	Texas	Rainwater (prior to contact with roof)	5.55	—	0.354	0.823	0.030	—	—	0.043	0.034	—	0.139
Chang & Crowley, 1993	Texas	Rainwater (prior to contact with roof)	—	—	—	—	—	—	—	—	0.023	—	0.98
Chang et al., 2004	Texas	Aluminum	6.2	—	0.381	0.372	0.015	—	—	0.026	0.037	—	3.230
Chang & Crowley, 1993	Texas	Asphalt Shingle	—	—	—	—	—	—	—	—	0.056	—	2.33
Chang et al., 2004	Texas	Composition Shingle	6.69	—	0.495	0.713	0.028	—	—	0.025	0.038	—	1.372
Chang, et al., 2004	Texas	Galvanized Iron	6.6	—	0.435	0.362	0.017	—	—	0.028	0.049	—	11.788
Tobiason, 2004	Washington	Galvanized Metal	—	—	—	—	—	—	—	1.4‡	0	—	14.7‡
Good, 1993	Washington	New anodized Alum.	—	—	—	—	—	—	—	0.025	0.01	—	0.297
Good, 1993	Washington	Old Metal w/ Alum. Paint	4.1	—	—	—	—	—	—	0.02	0.302	—	12.2
Good, 1993	Washington	Plywood w/ Tar Paper	4.3	—	—	—	—	—	—	0.166	0.011	—	0.877
Chang & Crowley, 1993	Texas	Rock and Tar	—	—	—	—	—	—	—	—	0.05	—	4.88
Good, 1993	Washington	Rusty Galvanized Metal	5.9	—	—	—	—	—	—	—	—	—	—
Good, 1993	Washington	Tar w/ Alum. Paint	5.9	—	—	—	—	—	—	0.011	0.01	—	1.98
Chang & Crowley, 1993	Texas	Terra Cotta	—	—	—	—	—	—	—	—	0.028	—	1.08
Chang et al., 2004	Texas	Wood Shingle	5.07	—	0.382	0.982	0.044	—	—	0.029	0.045	—	16.317
Chang & Crowley, 1993	Texas	Wood Shingle	—	—	—	—	—	—	—	—	0.045	—	5.64
Pitt et al., 1995	Alabama	Assortment	6.9	—	6.85	—	—	0.085	0.0034	0.11	0.041	—	0.25
Bannerman, et al., 1993	Wisconsin	Assort. (Industrial Area)	—	144	—	—	—	—	—	0.006	0.008	—	1.155
Bannerman, et al., 1993	Wisconsin	Assort. (Commercial Area)	—	1117	—	—	—	—	—	0.009	0.009	—	0.33
Bannerman, et al., 1993	Wisconsin	Assort. (Residential Area)	—	294	—	—	—	—	—	0.015	0.021	—	0.149

C3. DRAINS Output for Existing Infrastructure

PIT & NODE DETAILS — Version 3

Node	Area (ha)	Impervious %	Pervious %	Impervious C	Pervious C	Sum CA (ha)	Tc (min)	I (mm/h)	Arriving Fl (cu.m/s)	Inflow (cu.m/s)	Base Inflow (cu.m/s)
Pit1	4.260*	92.6	7.4	0.945	0.105	3.823	15	73.1	0.776	0.093	0
Pit2	4.260*					3.823	15.6	71.7	0.761	0.078	0
Pit3	7.327*	92.9	7.1	0.945	0.105	6.572	16.1	70.4	1.284	0.132	0
Pit4	7.327*					6.572	16.7	69.1	1.261	0.109	0
Pit5	8.781*	92.5	7.5	0.945	0.105	7.867	17.2	67.9	1.483	0.117	0
Pit6	8.781*					7.867	17.8	66.7	1.457	0.091	0
N1	8.781*					7.867	18.3	65.6	1.432	0	0

PIPE DETAILS

Node	Length (m)	U/S IL (m)	D/S IL (m)	Slope (%)	Dia (mm)	Rough (mm)	Nom.Capa (cu.m/s)	Under pressure	V (m/sec)	Headloss Coeff (Ku)	HGL (m)	Free-board	Overflow (cu.m/s)	Constraint
Pit1	100	40.6	39.6	1	900	0.013	1.81	No	1.7	1.5	40.858	1.24		None
Pit2	100	39.6	38.6	1	900	0.013	1.81	No	1.6	1.5	39.836	1.27		None
Pit3	100	38.6	37.6	1	900	0.013	1.81	No	1.9	1.5	38.912	1.19		None
Pit4	100	37.528	36.528	1	900	0.013	1.81	No	1.8	1.5	37.81	1.29		None
Pit5	100	36.6	35.6	1	900	0.013	1.81	No	1.8	1.5	36.892	1.21		None
Pit6	100	35.6	34.6	1	900	0.013	1.81	No	1.7	1.5	35.857	1.24		None
N1											34.727			

* Partial Area

Note: The pipe Nominal Capacity may be exceeded if the pipe is pressurised.

SUB-CATCHMENT DETAILS

Catchmen	Imperv. (ha)	Pervious (ha)	Imperv. C	Pervious C	Sum CA (ha)	Tc (min)	I (mm/h)	Q (cu.m/s)	
Cat1	4.019	0.321	0.94	0.1	3.832	20	62.4	0.665	
					3.82	15	73.1	0.776	Partial Area Effect
Cat2	2.889	0.221	0.94	0.1	2.753	20	62.4	0.478	
					2.75	15	73.1	0.558	Partial Area Effect
Cat3	1.36	0.11	0.94	0.1	1.297	20	62.4	0.225	
					1.29	15	73.1	0.263	Partial Area Effect

LINK FLOWS

Node	Item	Max.Flow (cu.m/s)	Max. Vel. (m/s)	Max U/S HGL (m)	Max D/S HGL (m)	
Pit1	Cat1	0.776				
	Pipe1	0.093	1.7	40.728	39.836	Partial Area Effect
Pit2	Pipe2	0.078	1.6	39.719	38.912	Partial Area Effect
Pit3	Cat2	0.558				
	Pipe3	0.132	1.9	38.751	37.81	Partial Area Effect
Pit4	Pipe4	0.109	1.8	37.666	36.892	Partial Area Effect
Pit5	Cat3	0.263				
	Pipe5	0.117	1.8	36.742	35.857	Partial Area Effect
Pit6	Pipe6	0.091	1.7	35.727	34.727	Partial Area Effect

C4. PCR Positive Results for Potential Pathogens

Table 1. PCR positive results for potential pathogens.

Gene of target pathogen	PCR positive results/ No. samples tested (% of sample positive)	Range of gene copies/100ml
A. *hydrophila lip* gene	7/84 (8.3)	Not tested
Campylobacter coli ceuE gene	10/27 (37)	Not tested
C. jejuni mapA gene	1/84 (1.1)	Below qPCR detection limit
E. coli O157 LPS gene	0/84 (0)	Not tested
E. coli VT1 gene	0/84 (0)	Not tested
E. coli VT2 gene	0/84 (0)	Not tested
L. pneumophila mip gene	8/84 (9.5)	6-17
Salmonella invA gene	17/84 (20)	6.6-38
Salmonella spvC gene	0/27 (0)	Not tested
G. lamblia β-giradin gene	15/84 (18)	9-51
Cryptosporidium parvum COWP gene	0/84 (0)	Not tested

Figure 152: PCR positive results for potential pathogens (Ahmed, W. Goonetilleke, A. Gardner, T. 2009)

C5. Faecal Indicators and the Presence of Pathogens in Rainwater Tanks

Table 2. The relationship between faecal indicators and the presence/absence of selected pathogens in samples from rainwater tanks.

Indicators vs. pathogenic microorganisms	Nagelkerke's R square*	P-value [Δ]	Odds ratio
E. coli vs. *A. hydrophila*	0.055	0.460	1.00
E. coli vs. *C. jejun*	0.008	0.775	1.00
E. coli vs. *L. pneumophila*	0.006	0.640	1.00
E. coli vs. Salmonella	0.048	0.198	1.00
E. coli vs. *G. lamblia*	0.019	0.484	1.00
Ent vs. *A. hydrophila*	0.006	0.700	1.00
Ent vs. *C. jejuni*	0.001	0.943	1.00
Ent vs. *L. pneumophila*	0.007	0.555	1.00
Ent vs. Salmonella	0.016	0.388	1.00
Ent vs. *G. lamblia*	0.001	0.928	1.00

* Nagelkerke's *R* square, which can range from 0.0-1.0, denotes the effect size (the strength of the relationship); stronger associations have values closer to 1.0.

Δ *P*-value for the model chi square was <0.05 and the confidence interval for the odds ratio did not include 1.0.
Greater odds ratios indicate a higher probability of change in the dependent variable with a change in the independent variable.

Figure 153: The relationship between faecal indicators and the presence/absence of selected pathogens in samples from rainwater tanks (Ahmed et al 2009)

Appendix D – Transport Engineering

D1. Bus Timetables

Table 71: Monday-Friday Stop 2 North Tce, North West side (Adelaide Metro, 2015c)

Route	Time
174	06:29 AM – 11:30 PM
176, 178,176G, 178M, 178S& 178X	06:29 AM – 12:30 AM
B10, B10X	06:19 AM – 12:13 AM
H30, X30, H30S &X30S	05:58 AM – 11:58 PM
H33, H33C	07:15 AM – 11:28 PM
W90, W91 &W90M	06:08 AM – 12:02 AM
AO11	10:07 PM – 10:37 PM
AO12	10:06 PM – 10:36 PM

Table 72: Saturday Stop 2 North Tce, North West side (Adelaide Metro, 2015c)

Route	Time
174	07:50 AM – 11:43 PM
178, 178S	08:05 AM – 11:31 PM
B10	07:43 AM – 12:14 AM
H30, H30S	07:12 AM – 11:59 PM
H33	09:28 AM – 11:29 PM
W90, W91 &W90M	07:22 AM – 11:45 PM

Table 73: Sunday & Public Holidays Stop 2 North Tce, North West side (Adelaide Metro, 2015c)

Route	Time
174	08:50 AM – 11:43 PM
178, 178S	09:05 AM – 11:31 PM
B10	08:43 AM – 11:14 PM
H30, H30S	08:42 AM – 11:59 PM
H33	09:28 AM – 11:29 PM
W90, W91 &W90M	08:52 AM – 11:45 PM

Table 74: Saturday PM—Sunday AM (Late Night) Stop 2 North Tce, North West side (Adelaide Metro, 2015c)

Route	Time
N178	12:13 AM – 04:08 AM

Table 75: Monday-Friday Stop 2 North Tce, South East side (Adelaide Metro, 2015c)

Route	Time
174	05:46 AM – 11:25 PM
176, 178, 178A &178X	06:16 AM – 11:09 PM
B10, B10C	05:46 AM – 11:51 PM
H30, X30 &H30C	06:01 AM – 12:13 AM
H33, H33C	06:16 AM – 08:55 PM
W90, W91	05:49 AM – 11:20 PM
626	04:12 PM
630	04:03 PM – 04:47 PM
638	03:46 PM
AO11	12:36 PM – 01:21 PM
AO12	12:36 PM – 01:21 PM

Table 76: Saturday Stop 2 North Tce, South East side (Adelaide Metro, 2015c)

Route	Time
174	07:09 AM – 11:10 PM
178	06:45 AM – 11:24 PM
B10	06:58 AM – 11:53 PM
H30	07:00 AM – 12:12 AM
H33C	07:13 AM – 12:12 AM
W90, W91	07:47 AM – 11:07 PM

Table 77: Sunday & Public Holidays Stop 2 North Tce, South East side (Adelaide Metro, 2015c)

Route	Time
174	08:39 AM – 11:10 PM
178	08:44 AM – 11:24 PM
B10	08:28 AM – 11:53 PM
H30	08:30 AM – 12:12 AM
H33C	09:13 AM – 12:12 AM
W90, W91	08:47 AM – 11:07 PM

Table 78: Saturday PM—Sunday AM (Late Night) Stop 2 North Tce, South East side (Adelaide Metro, 2015c)

Route	Time
178, N178	01:01 AM – 3:54 AM

Table 79: Monday-Friday Stop 3 North Tce, North West side (Adelaide Metro, 2015c)

Route	Time
174	06:30 AM – 11:31 PM
176, 178,176G, 178M, 178S	06:30 AM – 12:31 AM
B10	06:21 AM – 12:15 AM
H30, X30, H30S &X30S	05:59 AM – 11:59 PM
H33	07:15 AM – 11:28 PM
W90, W91 &W90M	06:09 AM – 12:03 AM

Table 80: Saturday Stop 3 North Tce, North West side (Adelaide Metro, 2015c)

Route	Time
174	07:50 AM – 11:43 PM
178, 178S	08:06 AM – 11:32 PM
B10	07:45 AM – 12:16 AM
H30, H30S	07:13 AM – 12:00 AM
H33	09:29 AM – 11:30 PM
W90, W91 &W90M	07:23 AM – 11:45 PM
AO11	10:09 PM – 10:49 PM
AO12	10:07 PM – 10:47 PM

Table 81: Sunday & Public Holidays Stop 3 North Tce, North West side (Adelaide Metro, 2015c)

Route	Time
174	08:50 AM – 11:43 PM
178, 178S	09:06 AM – 11:32 PM
B10	08:45 AM – 11:16 PM
H30, H30S	08:43 AM – 12:00 AM
H33	09:29 AM – 11:30 PM
W90, W91 &W90M	08:53 AM – 11:45 PM

Table 82: Saturday PM—Sunday AM (Late Night) Stop 3 North Tce, North West side (Adelaide Metro, 2015c)

Route	Time
N178	12:17 AM – 04:12 AM

Table 83: Monday-Friday Stop 3 North Tce, South East side (Adelaide Metro, 2015c)

Route	Time
174	05:45 AM – 11:25 PM
176, 178	06:16 AM – 11:09 PM
B10, B10C	05:46 AM – 11:51 PM
H30, X30 &H30C	06:01 AM – 12:13 AM
H33, H33C	06:15 AM – 08:55 PM
W90, W91	05:47 AM – 11:18 PM
626	04:12 PM
630	04:02 PM – 04:46 PM
638	03:44 PM

Table 84: Saturday Stop 3 North Tce, South East side (Adelaide Metro, 2015c)

Route	Time
174	07:09 AM – 11:10 PM
178	06:44 AM – 12:54 AM
B10	06:57 AM – 11:53 PM
H30	06:59 AM – 10:42 PM
H33C	07:13 AM – 12:12 AM
W90, W91	07:46 AM – 11:05 PM
AO11	05:09 PM – 06:29 PM
AO12	05:19 PM – 06:29 PM

Table 85: Sunday & Public Holidays Stop 3 North Tce, South East side (Adelaide Metro, 2015c)

Route	Time
174	08:39 AM – 11:10 PM
178	08:44 AM – 11:24 PM
B10	08:27 AM – 11:53 PM
H30	08:29 AM – 10:42 PM
H33C	09:12 AM – 12:12 AM
W90, W91	08:46 AM – 11:05 PM

Table 86: Saturday PM—Sunday AM (Late Night) Stop 3 North Tce, South East side (Adelaide Metro, 2015c)

Route	Time
178, N178	01:00 AM – 3:53 AM

D2. Multi-Purpose Signs

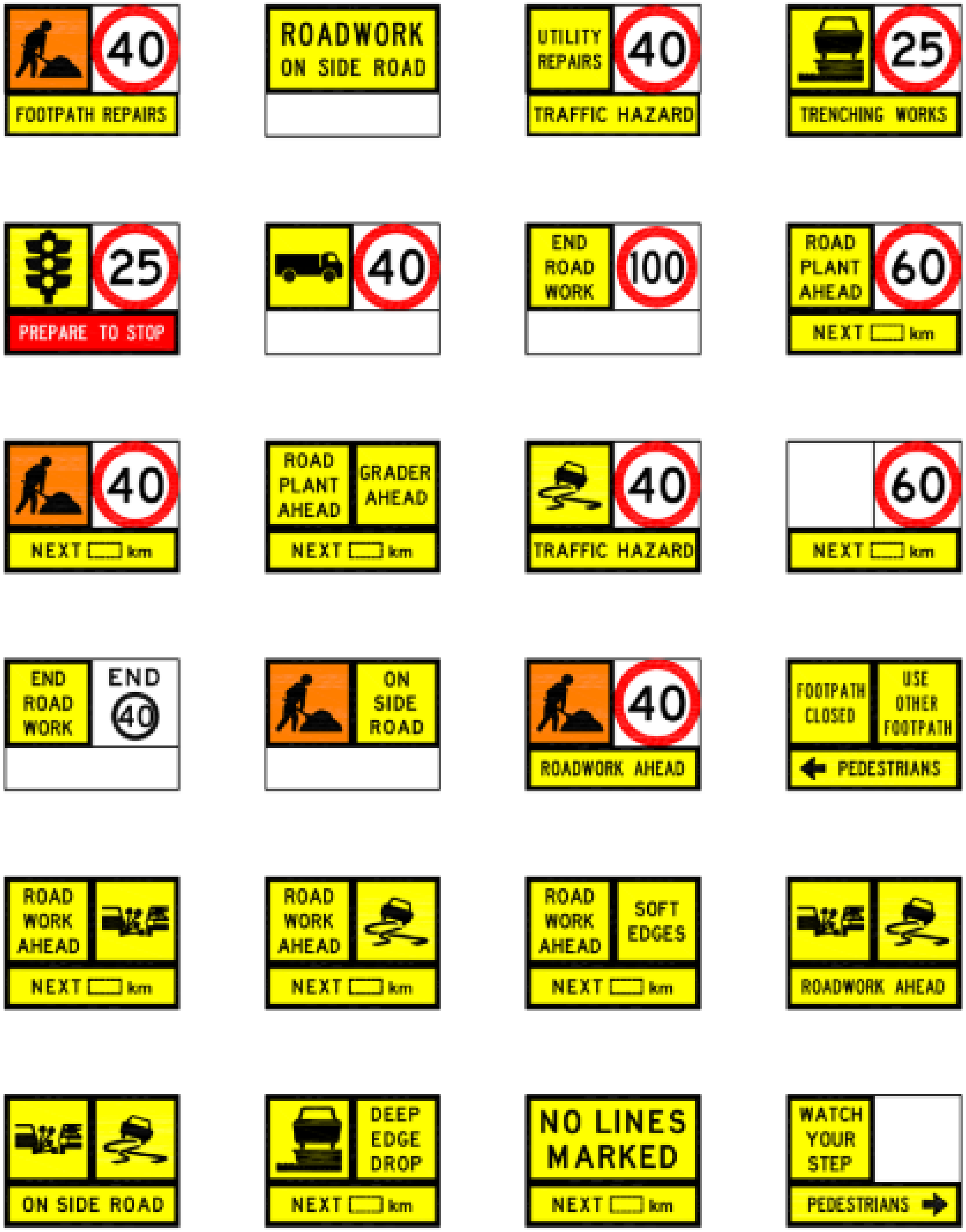

Figure 154: Multi Purpose Signs (DPTI, 2014)

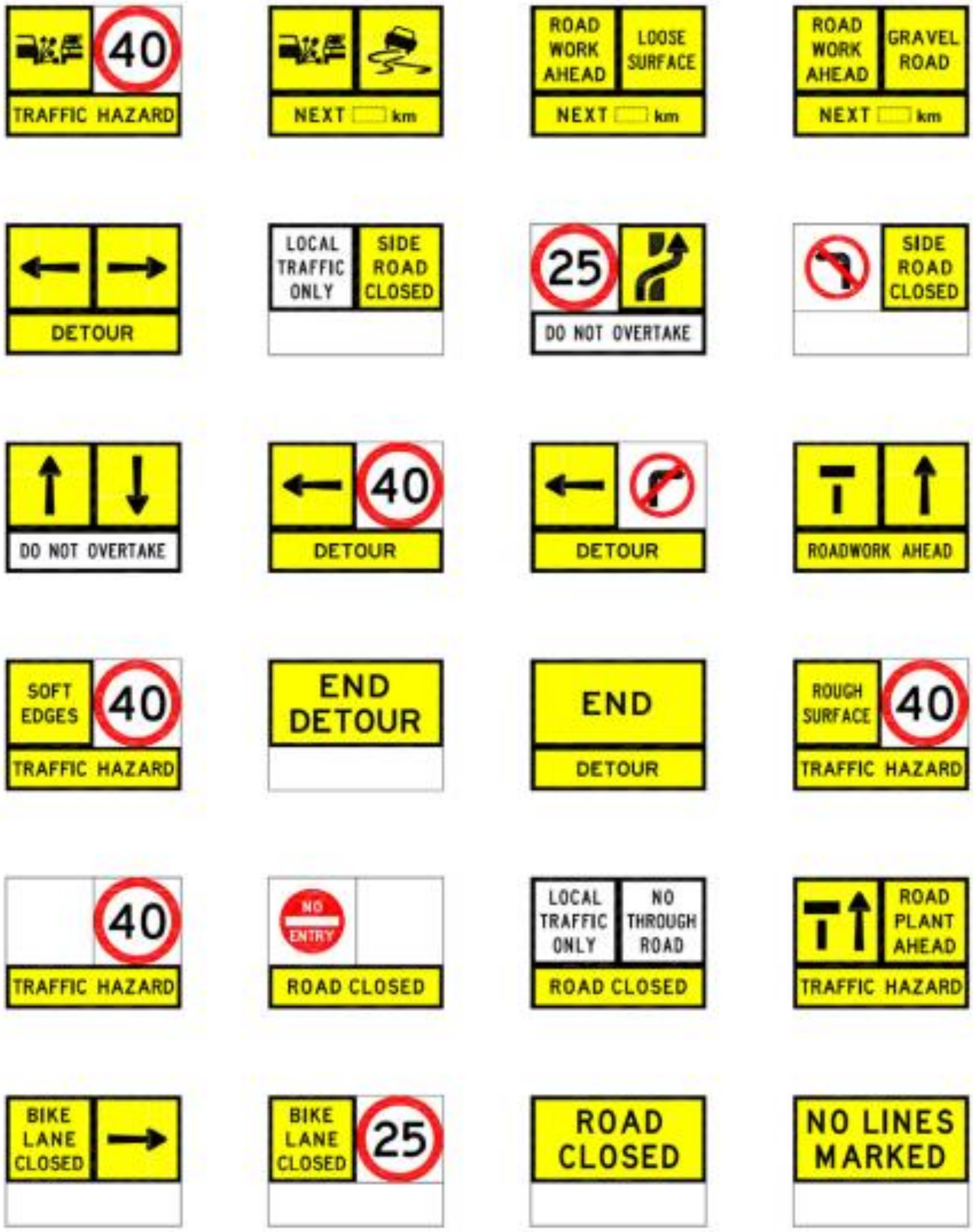

Figure 155: Multi Purpose Signs Continued (DPTI, 2014)

Appendix E – Structural Road Cross Section

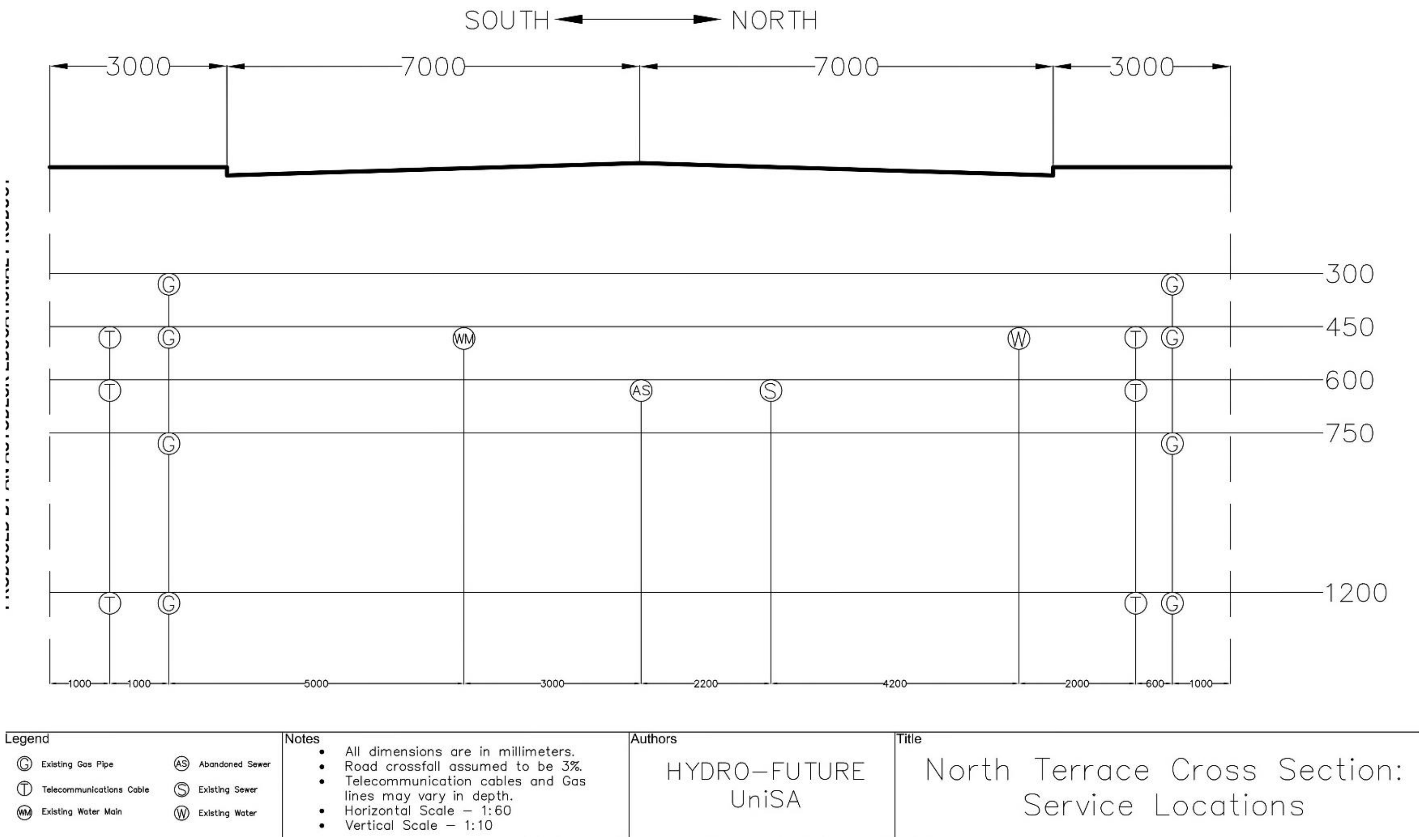

Figure 156: Road Cross Section showing Ultility locations