Feasibility Study

South Road & Outer Harbor Rail Line Grade Separation

10th April 2013
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Executive Summary

For the proposed Feasibility Study – South Road and Outer Harbor Rail Line Grade; Edge Engineering has completed an inclusive review of the possible design options that would facilitate a successful project objective. This review analyses the feasibility of four different possible scenarios that where the rail line could be separated from the south road. The four scenarios were:

- **Scenario 1** – Rail line is elevated over South Road
- **Scenario 2** – Rail Line is taken underneath South Road
- **Scenario 3** – South Road is depressed while the rail line stays at grade
- **Scenario 4** – Both South Road and the rail line are depressed and elevated respectfully

Recommendations have been made by each division group on these scenarios. They have been weighted with respect to their advantageous and disadvantageous characteristics, as well as a comprehensive cost benefit analysis counting towards the final recommendation.
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1. Project Background

North-South Corridor

The release of the *30-Year Plan for Greater Adelaide* by the South Australian Government reflects a policy shift towards stronger population growth, demographic change, land development and employment increases over the next 30 years.

The main objective of the plan is to create an environment which promotes stronger economic performance through more efficient and effective land use arrangements to support the growth of new industries. The current transport network will constrain this future growth in the northern region and ultimately, in the state and national economies.

The North-South Corridor, from Gawler in the north to Old Noarlunga in the south, has a series of strategic non-stop road links to connect the rapidly expanding industrial and residential growth areas in the north and the south, providing new opportunities for economic development. The 78 kilometre corridor will comprise four road links:

- Northern Expressway from Gawler to Port Wakefield Road
- Northern Connector from Port Wakefield Road to the Port River Expressway
- South Road from Port River Expressway to the Southern Expressway
- Southern Expressway from Darlington to Old Noarlunga

With the opening of the Northern Expressway to traffic in 2010, the completion of the Northern Connector planning study in 2011 and the commencement of the duplication of the Southern Expressway between Darlington and Old Noarlunga in 2011, planning of the South Road link between the Port River Expressway and the Southern Expressway is essential to secure this important North-South Corridor.

Planning for and delivering this South Road component of the non-stop corridor commenced with the completion of the Gallipoli Underpass at South Road / Anzac Highway and the grade separation of the Glenelg tram overpass of South Road in 2009.

The South Road Superway (currently under construction), features an elevated transit corridor with multiple lanes in each direction, from the Port River Expressway and above the major intersections of South Terrace, Wingfield rail line, Cormack Road, Grand Junction Road and Days Road, returning
to ground level near Taminga Street at Regency Park. Construction is anticipated to be completed by late 2013.

The Department of Planning, Transport and Infrastructure (DPTI) has now commenced a major planning study to investigate options for the non-stop corridor for the 9 kilometre section between the southern end of the South Road Superway (at Regency Park) and the Gallipoli Underpass at Anzac Highway (Everard Park). The planning study will look at both long term planning and immediate infrastructure needs for this critical link in Adelaide’s road network.

**Outer Harbor Rail Line**

The planning study area also includes the Outer Harbor rail line; a dual broad-gauge track that intersects with South Road, Croydon, at a signalised level crossing. Heavy rail passenger services to and from Grange and Outer Harbor run at approximately four services per hour in each direction.

Through this area, the Outer Harbor rail line is in close proximity to the Queen Street precinct, a significant community focal area with its cafés and community meeting spaces. Hence, there is a strong preference to remove the existing rail level crossing as part of this project, but not a requirement.
Figure 1-1 Locality map of project area
2. Introduction

The following document outlines Edge Engineering’s finding and recommendations on the feasibility study for the grade separation of South Road and the Outer Harbor Rail Line.

At this stage of the project (the feasibility stage) Edge Engineering engaged its staff to complete the study. Specialty divisions were created based on the project needs and our employees’ knowledge and experience, which encompassed all the parameters of the study. Our approach to this study phase has been as holistic as possible with time constraints that the project had. We aim to provide a service and a solution that integrates the existing with the new seamlessly and productively improving the community and connecting areas.

Our division groups for this phase were divided up as so:

- Environmental Management Division
- Transport Management Division
- Urban Planning Management Division
- Structural Management Division
- Water & Services Management Division
- Geotechnical Management Division
- Quality Assurance Management Division

Each division groups (consisting of 3-6 employees) has elected a team leader. This team leader has been elected due to their specialist experience and knowledge in that specific field. Have this tiered management system coupled with the quality management plans enforced ensures an effective solution has been achieved for each aspect of the project, through superior communication within the management structure.
3. Project Funding

The Australian and South Australian Governments will be funding this project as it contributes to the continued development of the South Road North – South corridor, stated by the 30 year plan. Both levels of government have needs for this project to go ahead. Federal Government is funding this project in order to create a freight network which easily links all around Australia, and the State Government is funding this project in order to fill the 30 year plan for South Australia and the greater Adelaide.

Areas that future possible funding opportunities may come from:

- Local Government
- Private Sector
- PPP (Public-Private Partnerships)
4. Deliverables and Assumptions

4.1 Deliverables

Edge Engineering has delivered the following items both within and with adjoined documentation for the feasibility study:

- The Feasibility Study and Report
- A Quality Management System complete with documents, processes and logs of their implementation
- The Environmental Plan including an Environmental Impact Assessment
- An incorporated offer to the Client to undertake the Preliminary & Detailed Design works
4.2 Assumptions

- Due to the close proximity of the South Road & Outer Harbor Rail Line junction to Port Road the option to have South Road exist as an elevated freeway has been ruled by the client (DPTI) due to complications with on and off ramps from the elevated freeway.

- The electrical sub-station is to be assumed disposable/removable within this project due to a relocation program being initiated by the client (DPTI).

- With respect to the cost benefit analysis benefits for the project outcomes have been laid out by the client (DPTI) and are as below:
  - Major Roads
  - Minor Roads

- The increasing demand from the diverse users of South Road is increasing congestion, travel time and reducing reliability of the road, hence causing high costs for business and reducing Adelaide’s liveability

- Poor accessibility between east and west of Adelaide (including public transport)

- The current high incident rate (including road crashes) along South Road causing direct and indirect costs to the community.
5. Project Goals & Objectives

5.1 Goals

- Ensure the National Network Transport Link (South Road) fulfils its role in accordance with both State and National plans, and as a freight link as outlined in the 30-Year Plan for Greater Adelaide

- Support Adelaide’s future economic prosperity and liveability by ensuring efficient and effective connectivity for people accessing employment, leisure and service opportunities (both regional and local) and optimise the opportunity for integrated land use outcomes

- Provide an integrated solution that directly and indirectly enhances transport system safety for all road users (including motorists, public transport, pedestrians and cyclists)

- Develop a corridor wide solution that makes the best use of both new and existing transport network infrastructure, and is integrated with the broader multi-modal transport network of Greater Adelaide

- Develop a sustainable solution that provides the optimal balance between economic, social and environmental outcomes.
5.2 Objectives

- To protect and provide freight priority consistent with a National Network Transport Link between Wingfield and Darlington to the Port of Adelaide, Adelaide Airport and other industrial and commercial centres consistent with Adelaide’s 30-Year Plan.

- To improve travel time, reliability and vehicle operating costs in Adelaide’s north-south transport corridor.

- To improve accessibility to employment, leisure and service opportunities of Adelaide’s east-west traffic (including by motorists, public transport, pedestrians and cyclists).

- To contribute to the achievement of the SA Government’s public transport mode share target as outlined in the SA Strategic Plan.

- To minimise greenhouse gas emissions and improve air quality within the South Road corridor.

- To reduce the incidence and severity of South Road crashes.

- To deliver a solution with positive net benefits (monetised plus non-monetised) for South Australia.
5.3 Further considerations

In developing feasible solutions for the grade separation of the Outer Harbor rail line from South Road (Croydon), the following were considered:

- Connectivity requirements
  - Transport modes (vehicles, cycle, pedestrian)
  - Local road network
  - Access (local road network, rail station, DDA compliance etc.)
- Public transport impacts and opportunities
- Environmental impacts and opportunities
- Social impacts and opportunities
- Identification of key stakeholders
- Existing site conditions
- Land acquisition requirements
- Capital cost for solutions
- Constructability and construction impacts
- Operation and maintenance requirements
- Economic viability of the solution.
Feasibility Breakdown

6. Transport Investigation

6.1 Overview

The Edge Engineering Transportation team understands that road design is a significant element of the South Road planning project. The team is to ensure that the project’s transportation objectives are achieved in an effective and efficient manner by maximising safety using the highest level of design processes.

Our Team will investigate all possible solutions whilst liaising with other division teams (particularly the structural and urban planning elements) to develop proposals for bridge and tunnel designs, super-elevation and lane widening of South Road. The aim of this Traffic Impact Statement is to identify and document the likely impacts on traffic flow created by the clients (DPTI) proposal whilst recommending solutions and treatments to mitigate issues at the outer harbor rail crossing location.

The study will look for the following areas of the project:

- Proposed grade separation of the outer harbor rail line or South Road to minimise traffic impact and maximise traffic flow along the corridor.

- Current road network condition within the vicinity of the site including traffic volumes and general traffic safety along South Road.

- Categorizing traffic volume likely to be generated along North - South corridor.

- Propose train flows at crossing and its impacts on South Road.

- Look at the proposed locations and find turning moments of traffic from different directions onto South Road between Port Road and Torrens Road.

- Safe passage for traffic movement along the corridor and provide elementary traffic movement during construction.

- Consider future volumes of North – South Corridor over the next 30 years.

- Provide specifications of the 4 design options.

- Assess each option with respect to the project’s objectives, and weigh up the advantages and disadvantages of each.
6.2 Objectives

EDGE Engineering has the following objectives according to Australian Traffic Management Plan:

- Firstly follow the OHS rules as safety of its employees, contractors, the general public are important.
- To have a zero fatality rate.
- Keep traffic delay to minimum.
- Maintain satisfactory property access for factories, offices, shopping centres and public housing in the area.
- Provide detour information, Road signs and Speed limit recommendations.
- Minimise environmental impact and disturbances.
- EDGE Engineering activities will minimize pollution of ground water caused by road traffic and operations to minimum whilst reducing noise pollution and improving the roadside environment.
- Complete these objectives within budget.
- Meet or exceed project expectations.
- Stakeholder satisfaction.
6.3 Scope

The Edge Engineering transport team will review the four options for developing this project; each one of these will have its own impact on road design and traffic management, as a result these impacts will be investigated to ensure that they comply with the clients' objectives on site. Another important aspect of this development is its ability to deliver the necessary improvements whilst maintaining the clients' objectives during the construction period. Plans will be developed and implemented to process and manage general traffic to ensure safe movement for vehicles, pedestrians as well as providing adequate temporary services (e.g., buses to maintain the train service) whilst providing safe working conditions on site. Furthermore, maintaining good relations with the community as their roads are used as temporary detours is of the utmost importance. To minimise inconvenience to road users and provide provisional traffic controllers at all times, the installation of temporary signs, road markings, lighting, trenches, and safety barriers also need to be considered.
6.4 Surrounding Land Uses

The North – South Corridor is located between Torrens Road and Port Road for the Outer Harbor Rail Line Grade Separation. The rail line is situated close to a power sub-station and many small businesses in the surrounding areas. The best thing about this section of South Road is that the houses on the west side of the crossing can be removed to pave the way for the construction of several of the options mentioned below. The only problem with the area is that not all heritage houses are listed which may create complications in the future.

The grade separation of the rail line and South Road project is a large scale improvement for South Road which will affect land surrounding the site. Therefore it is important to study the surrounding area to avoid destroying heritage listed sites and environment. A brief description of the surrounding land-use characteristics are as follows:

- South Road provides access to major freight companies from inter-state. These freight transports include goods and services to the people of South Australia, Adelaide included.

- It will affect the industrial Heart land of the North Western suburbs.

- Effects small business surrounding the construction site during construction.

Figure 6-1 Surrounding land uses for the project
6.5 Design Layout

There are various design layout options being processed below in order to evaluate the best design option and the most cost effective design for South Road and Outer Harbor Rail Line. Below is also a map produced by DPTI for the 30 year Greater Adelaide Plan of the North – South Corridor. This documents the plan to provide a smooth traffic flow between the Port River Expressway and Gallipoli Underpass with greater speed and less congestion. The purpose of this plan was that they have predicted that Adelaide’s population will grow exponentially and as society matures over the years, there will be more motorists on road. One of the elements which are significant to the study area is the need for constant improvement with respect to roads and traffic conditions.

![Figure 6-2 Design area (circled in blue)](image)

6.5.1 Recommended Design Layout

**Scenario 1**

![Figure 6-3 Rail line overpass (top view)](image)
6.6 Existing Geometry

In order to develop projections for the separate proposals, the existing traffic situation was examined using current peak traffic volumes, and predicted volumes for the final year of the proposed traffic network’s design life. The results obtained through SIDRA analysis shall be compared with the proposed road layouts (seen in the figures below) for the affected sections of South Road at Port Road and Torrens Road Intersections, during the detailed design. All the major intersections within South Road have been drawn in detail below to illustrate the impacts of traffic flow during the construction of the South Road and Outer Harbor Rail Line Grade Separation. Later on we will be using a software to analyse turning moments for each effected intersection that surrounds the site during constructions.
Figure 6-6 Outer Harbor rail line and South Road cross-section

Figure 6-7 South Road and Torrens Road intersection
Figure 6-8 South Road and Hawker Street intersection

Figure 6-9 South Road and Port Road intersection
6.7 Traffic Analysis

The North – South Corridor is planned to be designed as a free-flowing traffic corridor from Port River Expressway to Gallipoli Underpass. It is to maintain the growing demand for better roads as our population grows. The need for efficient traffic systems increases due to this and therefore the need for good investigation and analysis of different modes is needed. Computer software analysis can be used to estimate traffic volumes, traffic delay times, road capacity and environmental impacts. Capacities of South Road were determined using traffic volumes specified at level crossings rather than a computer analysis, as the free-flowing aspect results are more comparable to a freeway than an arterial road network.

6.7.1 Traffic Modelling Using SIDRA

In order to estimate the efficiency of the existing road network, a software program called SIDRA has been used to analyse all proposed corridors along the concerned section of South Road. SIDRA is software used for junctions and intersection capacities, level of complacency, presentation inquiry of traffic designs, operations and planning. This is a software package that is renowned and used all over the world for designing intersections and level crossings by analysing the capacity, delay, traffic volume, and queue lengths of each site. SIDRA is the software package which can produce current and future estimates of traffic flow. SIDRA has a function called the Level of Service that is an instantaneous indicator extending from “A” to “F” and is normally established by calculating delay factors. SIDRA also offers the degree of saturation for an intersection or junction, which represents the ratio of the demand of an approach and/or entire intersection to its capacity. SIDRA uses detailed analytical traffic models coupled with an iterative approximation method to estimate the level of service, degree of saturation, performance statistics etc. All the intersections along the road will be designed and/or modified using the SIDRA software to come to a solution. Below in the current turning moment section we have used SIDRA to analyse daily traffic movements along those corridors.

6.7.2 Traffic Surveying

Traffic surveys conducted our client and analysed by Edge Engineering for this section of the North – South Corridor were to investigate actual traffic volumes during the afternoon peak hour. Taking into consideration the following phases that can impact intermediate and future traffic flow along the North – South Corridor in this section of the South Road.

- Time passing each fixed point and total trip time.
- Accurate section distances.
- Gap acceptance and saturation flow surveys.
- Average speed between each fixed object and for entire trip.
- Speed statistics for whole survey period.
- Precise delay information comprising location and period of delay.

The traffic survey is modelled below to illustrate the full picture of our investigations.

### Table 6-1 Probability versus actual frequency

<table>
<thead>
<tr>
<th>Number of Vehicles</th>
<th>Frequency</th>
<th>Probability %</th>
<th>Actual Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>56</td>
<td>54.95</td>
<td>40</td>
</tr>
<tr>
<td>2</td>
<td>36</td>
<td>47.12</td>
<td>37.13</td>
</tr>
<tr>
<td>4</td>
<td>23</td>
<td>43.95</td>
<td>22.57</td>
</tr>
<tr>
<td>7</td>
<td>39</td>
<td>38.15</td>
<td>11.33</td>
</tr>
<tr>
<td>6</td>
<td>15</td>
<td>35.51</td>
<td>7.59</td>
</tr>
<tr>
<td>3</td>
<td>11</td>
<td>31.21</td>
<td>4.87</td>
</tr>
<tr>
<td>8</td>
<td>7</td>
<td>26.34</td>
<td>2.17</td>
</tr>
<tr>
<td>9</td>
<td>1</td>
<td>22.83</td>
<td>1.79</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>20.75</td>
<td>0.91</td>
</tr>
</tbody>
</table>

In order to compare the observed frequencies of arrival with the theoretical results, the results were tabulated for the amount of cars passing the observation point in each 10 second interval. The actual frequencies and theoretical/probable frequencies can be seen in Table 6-1 Probability versus actual frequency above.

By definition ‘A Poisson distribution gives the probability of a given number of occurrences in terms of the mean number of occurrence expected in that given time period’.
It can be seen that the maximum number of cars during a 10 second interval is 11; this implies that the road is simply busy or congested at this time of the day. It also shows that there is a good chance that the headway is not large enough for pedestrians to cross the road and for vehicles to make turns. Although the road is a dual lane carriage way with two lanes in each direction it was observed that the road was congested at any time interval during the period of data collection, and still the road users were able to use the road without any dilemma.

### 6.7.3 Traffic Volumes

The traffic volume on the roads involved in the intersection is expected to grow continuously over the next twenty to thirty years as planned by DPTI. As such, the Outer Harbor Rail line grade separation has been investigated and design option shown that will satisfy the ‘Level of Services’ for the projected traffic volumes. Traffic volume figures estimate the number of vehicles on State Government maintained roads such as South Road one of major freight for Adelaide. They are used to help manage, maintain and improve the traffic network therefore the two main measures are:

- AAD traffic estimates.
- Heavy vehicle estimates (Commercial Vehicles).

The projected traffic volumes were provided by DPTI (see Error! Reference source not found.) and are outlined below using SIDRA.

### 6.7.4 Current Turning Moments

These turning moments have been analysed using SIDRA for the each of the surrounding intersections. It is to show the volume of traffic flow through each intersection from South Road and what will be the consequences during the construction. As proven through geometrical analysis...
below that during construction there will be traffic congestion not only on South Road but also on
the main roads surrounding this part of South Road because of detours and traffic diversions into
these roads during the course of site construction. For graphical representation of turning
movements please refer to Error! Reference source not found., through to Error! Reference source
not found..

6.7.5 Turning Movements by 2043
Future turning moments will be effected by a traffic increase of 2% per year where this percentage is
an average summary of expected increases all over Australia. Therefore 2% increase will have
enormous effects on the future development of all these roads, to accommodate traffic demands.
Over 30 years the increase will impact communities, people’s lifestyles and business. Therefore the
following ideas will be implemented for future impacts of traffic flow surrounding the construction
site.

- Estimate increased traffic volume and capacity with future development.
- Identify possible improvements for future development of the related area of interest.
- Providing better decision for communities in terms of land use.
- Enhance potentials hazards with suggested future developments that may affect
  communities decision making.
- Communicate with communities the potential impacts that may arise.
- Ensure safer and more reliable traffic conditions on the suburban streets surrounding
  construction site.
- Decrease the negative impacts produced by developments in accommodating future
  transportation networks.
- Offer possible outcomes to broader community decision makers and developers of the
  possible impacts.

6.7.6 Capacity
North – South Corridor has to keep with the demand of 2% increase in traffic volume each year for
the next thirty years. Which means that that it can be classified as major arterial road for Adelaide
and especially the north-western and southern suburbs. Expansion of the northern and southern
suburbs by has already commenced through new suburbs and townships. The data has been used by
following the specified design requirements of this project. Design speed limit for the South Road
and the Outer Harbor rail line and lane widths determine the capacity of the corridor over the next
thirty year. The design must follow the AustRoads Guide to Road Design while taking into
consideration the future population for South Australia.
Road capacity (Equation 6-1) is the maximum volume of vehicles per hour that can easily travel through each segment of intersection. The capacity for each direction is determined through each intersection by using the following equation:

\[
C = \frac{k_j V_f}{4}
\]

- \(C\) = Capacity (vehicles per hour)
- \(k_j\) = Jam density (vehicles per km)
- \(V_f\) = Free speed (km per hour)

The graphs below are a representation of SIDRA. By using the above equation, we can show the capacity for each intersection.

**CAPACITY**

**Site: Port Road/South Road Morning Peak**

Total capacity per movement determined as Total Flow / Degree of Saturation (veh/h)

New Site Signals - Fixed Time  
Cycle Time = 150 seconds (Practical Cycle Time)

![Diagram of Port Road/South Road Morning Peak traffic counts](image)

**Figure 6-12 Morning traffic counts peak for Port Road/South Road**
CAPACITY
Site: Port Road/South Road Afternoon Peak
Total capacity per movement determined as Total Flow / Degree of Saturation (veh/h)
New Site Signals - Fixed Time  Cycle Time = 150 seconds (Practical Cycle Time)

Figure 6-13 Afternoon traffic counts peak for Port Road/South Road

CAPACITY
Site: South Road/Torrens Road Morning Peak
Total capacity per movement determined as Total Flow / Degree of Saturation (veh/h)
New Site Signals - Fixed Time  Cycle Time = 150 seconds (Practical Cycle Time)

Figure 6-14 Morning traffic counts peak for South Road/Torrens Road
CAPACITY
Site: South Road/Torrens Road Afternoon Peak
Total capacity per movement determined as Total Flow / Degree of Saturation (veh/h)
New Site Signals - Fixed Time  Cycle Time = 150 seconds (Practical Cycle Time)

Figure 6-15 Afternoon traffic counts peak for South Road/Torrens Road

CAPACITY
Site: Grange Road/South Road Morning Peak
Total capacity per movement determined as Total Flow / Degree of Saturation (veh/h)
New Site Signals - Fixed Time  Cycle Time = 110 seconds (Practical Cycle Time)

Figure 6-16 Morning traffic count peak for South Road/Grange Road
CAPACITY
Site: Grange Road/South Road Afternoon Peak
Total capacity per movement determined as Total Flow / Degree of Saturation (veh/h)
New Site Signals - Fixed Time    Cycle Time = 150 seconds (Practical Cycle Time)

Figure 6-17 Afternoon traffic count peak for South Road/Grange Road

CAPACITY
Site: South Road/Hawker Street Morning Peak
Total capacity per movement determined as Total Flow / Degree of Saturation (veh/h)
New Site Signals - Fixed Time    Cycle Time = 60 seconds (Practical Cycle Time)

Figure 6-18 Morning traffic count peak for South Road/Hawker Street
CAPACITY
Site: South Road/Hawker Street Afternoon Peak
Total capacity per movement determined as Total Flow / Degree of Saturation (veh/h)
New Site Signals - Fixed Time  Cycle Time = 60 seconds (Practical Cycle Time)

Figure 6-19 Afternoon traffic count peak for South Road/Hawker Street
6.8 Technical Specifications

The majority of the technical specifications have been sourced from the Austroads Guide to manage and design roads and traffic volumes for roads within DPTI's guide for rail design for the railway. These standards will be considered for both the interim road layout as well as future north south corridor and will have a significant Bering on the dimensions and scale of the project.

In addition to the specifications level of service will be considered.

One of the challenges associated with this project is the fact that the north south corridor doesn't exist yet and may be subject to change before construction is undertaken, as a result designs will be done with respect to current proposed specifications of the corridor.

6.8.1 Design Requirements

The design requirements have been provided by the client DPTI and are as follows

- 80Km/h posted Speed on the North South Corridor.
- 80Km/h posted Speed for Rail Services.
- Rail services are to cater for existing passenger demand.
- Maximum grade of 2% for rail services.
- Minimum clearance of 5.8m above the roadway.
- Provide a high level of service for all modes of transport.
- Provide a good access for local traffic.
- During construction maintain a minimum of 1 lane either direction on South Rd.
- Maintain the rail timetables during construction.
- Platform sizes for the stations are 7.8m width by 120m long.
- Design must be able to accommodate the future North-South Corridor Road Widening.
- Design must accommodate the future electrification of the Outer harbor passenger line.
- Minimise redundant infrastructure whilst minimising the disruption to traffic flow.

In order to implement these requirements, specifications will be obtained from the aforementioned standards.
6.8.2 Design Specifications

In order to meet the design requirements several technical conditions must be considered and satisfied, these involve sight distances calculations along the length of proposed roadways, minimum horizontal and vertical alignment specifications, road element specifications as well as safety and speed management it was imperative to know these values early on in the project as they have a large bearing on the dimensions of the final roadway and the associated structure built to accommodate the grade separation.

6.8.3 Road Element Dimensions

The ideal road dimensions are provided in the North-South Corridor cross section Figure 6-20 they can be clearly seen in Table 6-2.

<table>
<thead>
<tr>
<th>Specification</th>
<th>Width (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lane</td>
<td>3.5</td>
</tr>
<tr>
<td>Central Breakdown lane</td>
<td>2.1</td>
</tr>
<tr>
<td>Outer Breakdown lane</td>
<td>3</td>
</tr>
<tr>
<td>Bike lane</td>
<td>1.5</td>
</tr>
<tr>
<td>Busbay/protected left turn lanes</td>
<td>3.0</td>
</tr>
<tr>
<td>Border (to accommodate footpaths ect)</td>
<td>5.0</td>
</tr>
<tr>
<td>Barrier</td>
<td>0.6</td>
</tr>
</tbody>
</table>
6.8.4 Sight Distances

Sight distances are critical to the design of safe and smooth operating traffic corridors; as a result, minimum stopping sight distances will be provided for the length of all road sections in this project. This distance is dependent on several factors including the height of the object being viewed by the driver and driver eye height, example recommendations for these values can be found in Table 6-3.

Table 6-3 Taken from AustRoads geometry design

<table>
<thead>
<tr>
<th>Vertical Height Parameter</th>
<th>Height (M)</th>
<th>Typical Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height of eye of Driver ( h_f )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Passenger car</td>
<td>1.1</td>
<td>All car sight distance models.</td>
</tr>
<tr>
<td>2. Truck</td>
<td>2.4</td>
<td>All truck sight distance models where a truck is travelling in daylight hours and at night time where the road is lit.</td>
</tr>
<tr>
<td>3. Bus</td>
<td>1.8</td>
<td>Specific case for bus only facilities, e.g. busways.</td>
</tr>
<tr>
<td>Headlight height ( h_f )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Passenger car</td>
<td>0.65</td>
<td>1. Headlight stopping sight distance in sags. 2. Check case for night time stopping for cars (no road lighting).</td>
</tr>
<tr>
<td>2. Commercial vehicle</td>
<td>1.05</td>
<td>Check case for night time stopping for trucks (no road lighting).</td>
</tr>
<tr>
<td>Object cut-off height ( h_z )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Road surface</td>
<td>0.0</td>
<td>1. Approach sight distance at intersections. 2. Approach sight distance to taper at end of auxiliary lane. 3. Headlight sight distance in sags. 4. Horizontal curve perception distance. 5. Water surface at flood-ways.</td>
</tr>
<tr>
<td>2. Stationary object on road</td>
<td>0.2</td>
<td>Normal stopping distance for cars and trucks to hazard on roadway.</td>
</tr>
<tr>
<td>3. Front turn indicator</td>
<td>0.65</td>
<td>Minimum gap sight distance at intersections.</td>
</tr>
<tr>
<td>4. Car tail light/stop light/turn indicator</td>
<td>0.8</td>
<td>1. Car stopping sight distance to hazards over roadside safety barriers on a horizontally curved bridge with road lighting.</td>
</tr>
<tr>
<td>5. Top of car</td>
<td>1.25</td>
<td>1. Car stopping sight distance to hazards over roadside safety barriers in constrained locations. 2. Truck stopping sight distance to hazards over roadside safety barriers in constrained locations. 3. Stopping sight distance where there are overhead obstructions.</td>
</tr>
</tbody>
</table>
Edge Engineering recognises the impact that this variety is eye height can have on road design particularly when overhead structures are involved as they can restrict the view of commercial vehicles and buses on sag curves see Figure 6-21.

Figure 6-21 From AustRoads geometry

In addition to the sight distance considerations of commercial vehicles; consideration also will also be given to driver reaction times which will be taken to be 2.5 seconds across this development as well as stopping distance corrections based on grades listed in the standard.
6.9 Design Options

6.9.1 Scenario 1 Rail Overpass

6.9.1.1 Design Features

The rail overpass at the intersection of South Road and Outer Harbor Railway line would be a suitable design for the intersection as we need to keep one line of traffic open in both directions on South Road at all times. Railway overpasses are used to replace level crossings as it is a safer alternative.

Rail lines are governmentally owned therefore are reserve corridors and does not require acquisition of any private land. This option greatly reduces the physical barrier presented by the existing ground level railway corridor and greatly improves accessibility across the South Road and rail crossing for pedestrians, cyclists or road vehicles passing below the elevated structure. Constructing overpasses allows for unobstructed rail traffic to flow without obstructing vehicle and pedestrian traffic.

Also the overpass is financially cheaper than other designs considered in this review (ie. the train underpass, South Road going under rail line and half/half approach.

The maximum grade for train overpass being 2%, it requires over 800m for the train to safely travel form start and end of the overpass. The overpass having large distance will affect both the North Western Queen and Elizabeth Street precincts as well as the existing rail station, it may also affect Coglin Street on the North Eastern side. The proposed solution for streets being affected by the train overpass can be managed by building an underpass where the overpass intersects with the residential streets.

6.9.1.2 Advantages of Rail Overpass

- Better and safer access between the surrounding suburbs.
- Minimal Land Acquisitions.
- Improves the North-South road links Such as South Road Queen/Elizabeth St and Coglin St.
- Improves connections to public transport services.
- South Road can remain open in its current configuration during the construction phase.
- The width of the rail corridor is significantly narrower than the North South corridor thus associated structures are much smaller than for the corridor.

6.9.1.3 Disadvantages of Rail Overpass

- It requires long distance to safely pass the required 5.8m height.
• Queen Street and Coglin Street will both require an underpass; this will reduce access in those areas during construction.
• The Croydon railway station would need to be relocated or raised, increasing costs and may negatively impact the Queen Street precinct.
• Having the rail corridor raised for a long stretch will cause privacy concerns.
• Having columns in the middle of road segments.
• Large distance required for the 2% train grade.
• Noise pollution.

6.9.1.4 Traffic Diversion
During construction of the overpass, diversion is not a major issue. The existing configuration of South Road isn’t affected by the construction as it will be built in sections and therefore will be able to remain open throughout the entire construction period.

Commercial vehicles will be required to use South Road at all times as the current condition of the residential streets cannot cater for heavy vehicles and cannot accommodate the wider widths needed for them to safely pass. If diversion is required during construction period there are possible diversions that can be taken to reduce traffic volumes on South Road. The diversions are illustrated in Figure 6-22 for small vehicles in the overview map of the construction area.

• Traffic from the North East side of South Road would be diverted to Princes Street, right on Queen Street and followed onto Elizabeth Street then diverted back to South Road via Robert Street.
• Traffic from North West of South Road would be diverted onto Monmouth Street, then Left on to Coglin Street, right on to Ridley Street and back on to South Road.

Due to construction on Queen/Elizabeth Street, traffic can be diverted using the North West diversion paths, whole similar steps can be taken if Coglin Street needed to be closed during any stages of the construction.
6.9.1.5 **Train Overpass Layout**

- The overall length of the train overpass would be approximately 800m.
- The two ends will be 300m long with a 2% grade.
- The middle section would be 200m long with a 2% grade.
- Columns would be placed on the centreline of the South Road and roughly in three other locations which will depend on the structural analysis report within the detailed design.
- The height of bridge will be different due to different layers being used to support the train.
- The overpass will also not affect the power lines that run along the existing South Road corridor.
6.9.2 Scenario 2 Rail Underpass

Figure 6-24 Arial view of proposed rail underpass

6.9.2.1 Design Features

The rail underpass is one of the options proposed to achieve the free flowing motorway system desired for the South Road corridor. It is designed in such a way that South Road will remain at grade whilst the trains will be able to pass under South Road via an underpass. This shall be achieved by reducing the existing rail line by a grade of 2% to achieve a pass through a tunnel below South Road.

Usually, the traffic flow at this intersection is very slow during both the peak and off-peak hours. The ongoing trains in both directions from city to outer harbor make the traffic congestion even worst. Building an underpass will create a free flow of South Road without delaying traffic and decreasing congestion. The minimum one traffic lane in both directions will be very obtainable during the construction process.

The grade separation at this intersection will provide safety to all drivers, pedestrians, motorist, cyclists and public transports. The improved road conditions will ensure drivers have a easier and safer experience, reducing the number of car accidents. The danger of pedestrians crossing South Road wouldn’t be a problem anymore and with the improved road service, cyclist can ride safely and comfortably. It also delivers a safe environment for heavy vehicles with less stoppages and an improved road system. Likewise, the drivers who avoid driving South Road during congestion will be attracted back towards South Road.
The construction of the underpass will provide both advantages and disadvantages to the general public and local community; however it is be a feasible option which can improve the current situation.

6.9.2.2 Advantages of Rail Underpass

- Improves delay and traffic congestions.
- Provides safety to all road users.
- Reduces accidents.
- Increases traffic volume.
- Less chance of vehicle detouring during construction.
- The width of the rail corridor is significantly narrower than the North South corridor thus associated earthworks and structures are much smaller than for the corridor.

6.9.2.3 Disadvantages of Rail Underpass

- Cost of the underpass construction is expensive.
- The Croydon train station may have to relocate due to the change in the grade of the rail line.
- Some local areas near tracks might be used to construct retaining walls.
- It will be difficult to maintain traffic flow along south road during construction and detours into the surrounding suburbs will be required.

6.9.2.4 Traffic Diversion

Detours are very important in the case of traffic flow during construction.

- During construction, the traffic coming towards Port Road will be diverted to the Monmouth Street then Coglin Street followed by Ridley Street to South Road.
- Likewise, the traffic coming from the Port Road will be diverted to the Prince Street then Queen Street (connects to Elizabeth Street) followed by Robert Street. This detour will operate in a similar fashion to the option show in Figure 6-22.
6.9.3 Scenario 3 South Road Underpass

![Figure 6-25 Overview of the proposed South Road underpass](image)

6.9.3.1 Design Features
Option 3 explores the option of having a road underpass. The proposal is to have a road underpass with 3 lanes each direction (2 lanes for normal traffic and one lane each as emergency lane) under the outer harbor rail line so that the rail traffic can pass by un-interrupting the road traffic. The design will have the flexibility to accommodate the future widening of South Road, as part of the non-stop North-South corridor as seen in Error! Reference source not found.. As stated by the client DPTI) in the case of a road underpass South Road would have to continue under Port Road. The underpass entrance and end points will be constructed at about 150 meters north of the rail and South Road intersection. The design of the underpass will allow for a maximum road grade of 5% hence helping to maintain commercial vehicle speed and keeping the traffic flow at a maximum. The underpass will need to descend approximately 6.0m. Land will need to be acquired for the South Road underpass to occur in order to construct service roads.

6.9.3.2 Safety
- The underpass will comply with Australian standards (AS 5100, AS4825) emergency communication services; fire safety.
- The underpass will be dedicated to the freight route for commercial use as well as ordinary vehicles.
- A single lane service road at current grade will cater to the need of the local traffic.
- Cyclists and pedestrians will be prohibited from entering the underpass for safety reasons. A bike lane in each direction on each service road will cater the need of the cyclists.
Pedestrians will use footpaths created along service roads.

6.9.3.3 Traffic Diversion

While the construction of the underpass is underway the traffic on South Road will need to be diverted as one lane each direction will not be able to cope with traffic. To mitigate any huge traffic jams the following traffic detours are recommended.

Heavy Vehicle Detour

The heavy vehicle detour is recommended as big trucks will be hard to be detoured from the side streets near the construction site due to the width of the side streets and the noise pollution from the trucks/heavy vehicles. Any heavy vehicle intending to go over the South road and Outer harbor rail line intersection will be made to detour through Sir Donald Bradman Drive, James Congdon Drive, Port Road, Park Terrace, Torrens Road and back on to South Road.

Figure 6-26 Possible heavy vehicle detour
Passenger Vehicle Detour

A two lane service road will be built on the side of the construction site as shown in Figure 6-27. This service road will be built keeping in mind the client requirement. Any over flow of traffic during peak hours will have the option of using the detour listed below and displayed in Figure 6-27.

- For traffic heading north following detour is recommended. South Road, Port Road, Queen Street, Elizabeth Street, Harvey Street, South Road.
- For traffic heading south following the detour is recommended. The detour includes the following roads; South Road, Monmouth Street, Coglin Street, Port Road, South Road.

Figure 6-27 Passenger vehicle detours

6.9.3.4 Advantage of South Road Underpass

- Uninterrupted flow of traffic along South Road after construction.
- An underpass will eliminate any chance of accidents at the level crossings.
- No privacy issues arising as in case of an overpass.
The new underpass will accommodate any future widening of South Road, as part of the non-stop North-South Corridor.

6.9.3.5 Disadvantages of South Road Underpass

- Building an underpass is a costly option.
- There are a lot of services like high voltage power lines, water mains and other services running under the current rail line which will need to be moved, hence adding to the cost of the project.
- There will be significant disruption to the flow of traffic on South Road and rail line. The rail line will need to be closed during the construction phase for excavation and construction of the underpass.
- There will be an increase in the noise levels during the construction phase which will be needed to be mitigated.
- There could be issues with soil contamination and the water table.
- If greater Adelaide plan is taken into account the underpass will have to go under port road, making the project a lot bigger and a lot more land acquisition has to be done. This will make the project cost a lot more than other options available now.
- Large amounts lot of excavation.
- Rail crossing will still exist at side service roads.
- Would be an issue of dust from the construction site which will need to be addressed.
6.9.4 Scenario 4 Combined Road Underpass & Rail Overpass

![Diagram of Scenario 4](image)

Figure 6-28 Left turn at intersection

![Diagram of Scenario 4](image)

Figure 6-29 Side view of the combined overpass and underpass

6.9.4.1 Design Features

The fourth option is similar to the second option in which underpasses are located under South Road and between Queen Street & Elizabeth Street. The difference is this option consists of a combination of both an elevated train line while South Road becomes an underpass. This can be clearly seen in Figure 6-29. The arrow and dashed lines show there are two lanes in each direction for vehicles. Figure 6-30 shows a side view of the tunnel (with the 5% grade) under the rail line and Port Road. This option presents problematic issue whereby both parts of this scenario can be constructed at the same time without completely disrupting the surrounding areas. During construction of the tunnel either Euston Terrace or Day Terrace will need to remain open.

After achieving the tunnel for South Road, both Queen Street & Elizabeth Street roads will be shut down at grade. Moreover, in addition road widening shall take place on the western and eastern roads as well as the western side of Euston Terrace and Day Terrace for vehicle accessibility. In accordance to design requirements, rail speed limitation shall be taken into account for passenger rail services as well as considerations for traffic devices (traffic lights, speed limit signs) shall be
made as well. Widening or rebuilding both South Road and Queen Street & Elizabeth Street for bicycle and pedestrian paths shall be included in the consideration as well, which can decrease the amount of cyclist share vehicle roadway in order to improve safety for both cyclists and drivers.

6.9.4.2  Advantages of Combined Method
- The lead up to each structure is significantly less hence reducing the impact on surrounding infrastructure (level crossing will remain at Coglin St)

6.9.4.3  Disadvantages of Combined Method
- Widening road and realignment work shall be addressed as the requirements
- Land acquisition will impact liveability.
- Cost problems due to constructions of both an underpass and overpass
- The structures required are much greater than the straight overpass or underpass

6.9.4.4  Traffic Diversion
For South Road, Queen Street & Elizabeth Street, there is a combination of construction regarding the underpass and overpass on each road. Therefore, the diversion can be separated into two phases, the first phase includes constructions of underpass/overpass on South Road, and the second phase involves constructions of overpass/underpass between Queen Street & Elizabeth Street. Four constructions will be built in total. While constructing one of them, the other three shall not be constructed at the same period.

6.9.4.4.1  Phase One
This phase is a major issue for diversion. As shown in Figure 6-31 & Figure 6-32, after closing South Road, vehicles at the intersection of Port Road and South Road will not be able to travel along South Road, drivers will need an alternative route.
Figure 6-30 Left turn at intersection

Figure 6-31 Right turn at intersection
However, the travel lanes for diversion have been listed above, the traffic delay and congestions shall rapidly increase. The reason is that Port Road is the only arterial road, whilst the remaining roads are minor roads. Those roads cannot carry a large traffic volume, especially, the lane from Second St to Monmouth St where a roundabout located.

6.9.4.4.2 Phase Two

This phase occurs during the construction of the underpass at Queen/Elizabeth Street. It would be preferable to have this part of construction occur whilst South Road is still open/re opened to enable vehicles to take a path similar to the one shown in Figure 6-32.

Figure 6-32 The route for diversion
6.10 Costing

For the overpass option there aren’t many detours required as the construction does not affect South Road. The table in Error! Reference source not found. shows the costing applied for the designs one till the completion of the construction. The equipment such as barrier, VMS board, traffic controllers, temporary traffic lights, fencing and bus as train substitution will be used during the construction. The overall cost of the equipment will be $900,360 AUD + GST; the cost may vary slightly depending on the duration of the construction period. The detailed costing is obtained from Filcon Traffic Solution based on current practices.

The table in Error! Reference source not found. shows the costing applied for the design option 2 (Train Underpass) till the end of the construction period. The equipment such as barriers, VMS boards, traffic controllers, temporary traffic lights, fencing and bus as train substitution will be used during the construction. The overall cost of the equipment will be $1,602,360 AUD + GST. Due to the requirement of extra traffic controllers for the detour structure, the overall cost varies with other options. The detailed costing is obtained from Filcon Traffic Solution based on current practices. This is to utilise current market values for the prices to enhance future changes to our costing for each options because based on the design used by the structural team.

The table in Error! Reference source not found. shows the costing for design option three (road underpass) till the completion of the construction. These costing are just an estimate as the individual costs of different elements may vary over the period. During the construction phase; to eliminate any safety hazards equipment such as barrier, VMS board, traffic controllers, temporary traffic lights and fencing will be used. To carter for any rail line closures, train substitute busses will be used during the construction. The overall cost for the option 3 will be $943,560 AUD + GST. The detailed costing is obtained from Filcon Traffic Solution based on current practices. All prices are an overall estimate of costs for option 3 according the design constraints provided above in each design options.

The table in Error! Reference source not found. shows the costing applied for the four designs till the completion of the construction. The equipment such as barrier, VMS board, traffic controllers, temporary traffic lights, fencing and bus as train substitution will be used during the construction. due to the cost of implementing the traffic management for the detours there is a large increase in the cost of traffic controllers for this option. When the detour rejoins south road provisions have been made for two temporary traffic lights to ensure smooth traffic flow. The overall cost of the equipment will be 2 423 160 AUD + GST till the completion of the construction.
6.11 Recommendations

The transport department recommends the construction of Scenario 1 the rail overpass on this site. This option involves the creation of a rail overpass over south road to be at least 5.8m high and will have a span sufficient to clear the future north south corridor. Associated with the overpass over south road will be two additional rail overpasses at both Queen/Elizabeth Street and Coglin st.

It is recommended that the overpass be constructed using sections over south road so that its existing configuration can remain open throughout the construction period, this will reduce the impact that the project will have on the surrounding community as detours for south road will not be required.

During construction a traffic management plan will be implemented, that will follow Austroads Guidelines and its aim is to make recommendations for speed management, the use traffic control devices on site and ensuring motorists are notified of impeding works and are able to negotiate the site in a safe and efficient manner. Also included in this plan are guidelines for the use of plant and heavy equipment on site and possible storage locations.
7. Traffic Management Plan

7.1 Safety

Road safety design is a key component in traffic engineering as it promotes the development safety and effective traffic movement. The factors that affect road safety that shall be taken into account are as follows:

As stated in the design requirements road safety along this corridor is considered a high priority; in order to maintain a high safety standard along the corridor, measures have been taken to ensure that the road geometry is adequately designed, by taking into account appropriate sight distances, road dimensions etc. Then policy and strategy development for this corridor shall be addressed to facilitate traffic safety management. A road safety plan of short term and long term is required in order to complete sustainable developments in road safety. It includes measurable short term and long term targets to test road safety and guide road safety further.

Measures will be taken to incorporate audit processes during both the detailed design and construction phases; the purpose of these audits is to ensure that measures taken during design translate to construction and then to the finished project as intended. In addition there will be an ongoing education to advance road user behaviour and monitoring of the roadway to ensure that it functions in a safe manner as well as keeping the roadway maintained.

<table>
<thead>
<tr>
<th><strong>Data</strong></th>
<th>Corridor speed, vehicle turning movement survey, incidents, types of vehicles and road features.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Guidance</strong></td>
<td>Guideline to Road Safety, Austroads Information &amp; Australian Standard for road design</td>
</tr>
<tr>
<td><strong>Procedures and processes</strong></td>
<td>Policy and strategy development, investigation of crashes, deaths and injuries and enforcement of the road rules</td>
</tr>
</tbody>
</table>
### Table 7-2 Crash phase

<table>
<thead>
<tr>
<th>System component</th>
<th>Before crash</th>
<th>During crash</th>
<th>After crash</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Road environment</strong></td>
<td>Affecting exposure</td>
<td>Road network factors (traffic volume, road type, travel time)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Affecting probability</td>
<td>Road engineering factors (alignment, grade, shoulders, pavement, drainage)</td>
<td>Traffic engineering factors (delineation, signs, signals, markings, speed limits, sight distances, gaps)</td>
</tr>
<tr>
<td></td>
<td>Affecting severity</td>
<td></td>
<td>Roadside factors (trees, poles, culverts, bridges, fences, posts, barriers, embankments)</td>
</tr>
</tbody>
</table>
7.2 Speed Management

The major design speeds that have been given as objectives for this project are 80Km/h for both the North - South corridor while the rail services need to be developed with a design speed of 90km/h. Design speeds on the side and access roads will be 60km/h and a posted speed of 50km/h to ensure a safer operating environment for the large variety of road users found in these areas. It is important to note that Edge Engineering is not responsible for the implementation of speed limits on the corridor and associated roadways however the posted speed limits will only be our recommendation.
7.3 Emergency Response

Situations regarding an emergency response often represent circumstances of a life, property or environment danger. Usually, local councils shall provide the rigorous and qualified traffic staff to control essential emergencies such as roadside accident emergency, search and rescue operations, or transportation infrastructure repair.

The objectives of considering emergency response:

- During or after a transport emergency, the negative impacts acting on humans, property or environment can be minimized.
- To promote and improve an express and effective emergency response and recovery.
- A good way to provide aid to security services

The appropriate standard plans as well as traffic management plans will be required to adjust and coordinate the site conditions.
7.4 Risk Management

Risks are widespread in transportation, and are highly dependent on transportation agencies to provide a strategic risk management plan. The strategic aim of risk management is to prevent and analyse the possibility or uncertainty of risks occurring.

There are seven categories of risk managers involved: local agencies, federal agencies, state agencies, travellers, public, carriers and shippers (Huang B et al. 2004).

In accordance with Australian Standard AS/NZS ISO 31000:2009 “Risk Management – Principles and Guidelines”, during risk management process, five steps will be followed:

1. Identify hazards.
2. Assess and prioritize risks
3. Decide on control measures including hierarchy of control
4. Implement control measures
5. Monitor & review/evaluate

Dhillon, BS (2011) has reported that in road traffic, risk is a function of four elements:

1. Exposure – the number of moment involved in the system by a given population density components affect exposure to risk
   - Demographic factors
   - Land use patterns – affect travelling length or mode.
   - High speed traffic condition for road users
2. Probability of crash components affect probability of crash
   - Inadequate speed
   - Drunk driving, fatigue driving and young age driver
   - Low visibility or drive in darkness
   - Braking or maintenance required vehicles
   - Probability of injury
3. Components affect probability of injury
   - Inadequate speed
   - Not wear seat belt
   - Drunk driving or fatigue driving
   - Roadside objects
4. Outcome of injury
• Traffic delay during accidents
• Difficultly elieverancing people from serious traffic accident

Based on these four influencing risk factors, traffic speed is the most important factor in the consideration, reducing speed will lower the probability of crashes and injuries. Then driving conditions of drivers and land use patterns shall be another significant factor which has an indirect relationship with traffic speed. Then traffic control devices will be the most appropriate manner to assist road conditions.
7.5 Traffic Control Plans

The traffic control plans are necessary to improve any sorts of services that disturb the free traffic flow. The control plans will include traffic control devices, temporary speed controls and plant and equipment movement that provide safe movement for both vehicle and pedestrians. Some of the goals of Traffic Control Plan are:

- Providing a safe and effective working environment followed by road users to travel through the work area during construction.
- Ensuring effective traffic control plans with inspection at all times.
- Ensuring any sorts of activity that hinders the traffic flow during peak hour.

Likewise, the following components are included under the Traffic Control Plans

- **Activity Area**: It an area where the constructions work takes place.
- **Termination Area**: It is an area that is used to return traffic flow to the normal road.
- **Transition Area**: It helps to move traffic flow from the normal flow to the desired path.
- **Buffer Space**: It is an area that is used to separate traffic flow from the work activity area providing recovery space for an errant vehicle.
- **Termination Area**: It is an area that is used to return traffic flow to the normal road.
- **Advanced Warning Area**: It signifies the signs and other devices to inform drivers to be caution.
7.6 Temporary Speed Limits

The reduced temporary speed limit provides safe a working environment for workers as well as the safe traffic flow through the construction area for general road users. The proposed speed limit restrictions and strategies will be only implemented through consulting with DPTI (Traffic Control Section) and local council. Likewise, the sign post will be used at an appropriate location to inform all road users.
7.7 Plant and Equipment Movement

The plant and equipment that will are used during the construction will be equipped with necessary warning devices according to the AustRoads guidelines. Warning lights will be installed on all the equipment to make sure all the road users are aware of construction on the roadwork is taking place during daytime followed by an additional traffic controller with illuminated red wand (if necessary) during poor light conditions or at night. Likewise, the traffic will be permitted to use the whole or portion of the existing road. In that case, all plants and equipment will be removed from the path of vehicles at a clearance of at least 6 meters.
7.8 Traffic Control Devices

The following devices will be used during construction see refer to Error! Reference source not found.
8. Water & Services Investigation

8.1 Overview

With the construction of an underpass or overpass scenario, a drainage system is required to maintain a safe driving surface for road and rail traffic. The type of drainage system required will be dependent on the nature of the engineering structure that is chosen, the location, and the design ARI. This report will detail drainage options for each of the scenarios and produce an estimation of the costing of each respectively.

The existing services in close proximity must also be considered for the design of each scenario. There are 8 known companies that have services in the area surrounding the South Road, Outer Harbor rail line location. The online service Dial Before You Dig has identified the affected services in the target area as AAPT, Amcom, APA, Electranet, Optus, SA Power Networks, SA Water and Telstra. As not all companies are registered with Dial Before You Dig other services may be affected however all major services are included. Many of these services are underground and will require relocation due to change in grades to rail and road in each of the scenarios. As many of the services are not being redesigned but redirected/relocated, cables and pipes shall be selected to match existing services as recommended by the company which the service belongs to.

In order to produce a stormwater system and relocation of services design, first the options available must be explored.
8.2 Contour Map Analysis

The following contour map was used to perform contour analysis of the surrounding area of the intersection. The red lines clearly show port road and the black lines show the railway line. The blue arrows are indications of the flow path of surface water. It is clear to see that on the South Eastern side of the railway the topography naturally brings surface water away from the railway. The area of concern is the Western residential area that naturally brings the water towards the track. This will be of concern for the rail underpass scenario and will need to be considered in the detailed design stage.

Figure 8-1 Contour map of subject area
8.3 Road Drainage

8.3.1 Pipe Types
There is a diverse range of types of pipes that can be utilised in this project. As described by DPTI of part 1035 of rail drainage guidelines, some of the more common types include reinforced concrete, fibre reinforced concrete and steel.

Reinforced concrete pipe most commonly used material with high strength, durability and effective cost. Also it is used on a wide scale and its non-flammable property unlike other plastic pipes.

Fibre reinforced concrete utilises fibres to control cracking due to plastic shrinkage and to drying shrinkage, whilst reducing the permeability of the concrete to avoid bleeding of water.

Steel pipes are light weight, easy to install, and have low maintenance with high adaptability to various field conditions.

The Table 8-1 shows the minimum strength requirement for each of the pipes.

<table>
<thead>
<tr>
<th>Pipe Material Type</th>
<th>Minimum Strength Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reinforced Concrete - Slotted and unslotted</td>
<td>4</td>
</tr>
<tr>
<td>Fibre Reinforced Concrete - Slotted and unslotted</td>
<td>4</td>
</tr>
<tr>
<td>Steel Slotted - perforated and unslotted</td>
<td>N/A</td>
</tr>
</tbody>
</table>

8.3.2 Pit Types
There is a range of pit types that can be utilised in this project. Some of these include sump drains, side entry pits (SEP) and junction pits (JP).

8.3.3 Sump Drain
A sump drain is located on the lowest elevation of the road surface. It is a small pit that is covered with a grating cover that allows water to fall into the pit. From here the water is taken into the connecting pipe network. These pits are often used in underpass situations, like the Gallipoli underpass located further down South Road. It is quite possible that these pits will again be used if another road underpass design is chosen.
8.3.4 Side Entry Pit
Side entry pit (SEP) are most commonly used on general roadsides. Side entry pits are located on the kerb and gutter channel that is designed to collect stormwater from a road surface. From here the water is fed into the underground piping network.

8.3.5 Junction Pit
A junction pit (JP) is a stormwater pit that is used for joining two or more upstream pipes which are located at different grades. The use of junction pits may be required in underpass situations where the pipe network will be much deeper than the surrounding network.

8.3.6 Gutters Design
A kerb is an important consideration when designing a road. The purpose of a kerb is to provide a safe walking path on the side of the road whilst also providing a gutter for surface water on the road to travel to the closest pit and pipe system. For this location on South Road it has been decided that a standard kerb design would be acceptable in the majority of scenarios. Hence Figure 8-2 is the intended gutter design which has been taken from the DPTI guidelines.

![Figure 8-2 Kerb gutter](image)
8.4 Railway Drainage

8.4.1 Surface Drains
Surface drains are the most commonly used drains for railways. This is because they are generally cheaper and easier to implement and maintain. Some types of surface drains include cess and catch drains.

8.4.2 Cess Drains
A cess drain is an open channel drain that starts on the inside of the cess and brings water away from the tracks. This drain can then direct the water to natural water courses and/or to an existing stormwater network. A typical cess drain is of trapezoidal or rectangular cross section. These open channels are designed to carry a flow larger than the design peak flow rate (due to the design life and ARI) and usually allow for small build-ups of silt and other flow restricting materials.) Cess drains can be made cheaply from many materials ranging from soils, stones, boulders or more expensively with concrete. For the purpose of the feasibility study, concrete would be the most likely option to use.

8.4.3 Catch Drains
Catch drains are also open channel drains that catch water travelling downhill towards the track due to the topography of the area. Because a rail overpass will be elevated, these are only applicable for road or rail underpass scenarios depending on the contour analysis. Catch drains are often lined channels, but can also be made from half round pipes or dish drains.

8.4.4 Subsurface Drains
Subsurface drains are used whenever surface drains cannot be used due to restrictions in design or surroundings. Some restrictions can include:

- Platforms
- Cuttings
- Junctions
- Multiple tracks
- Bridges
- Water table is near earthwork level

Some types of subsurface drains that may be considered are: Sump, Pipe and Aggregate drains.
8.4.5 Sump Drains

Similarly to a road sump drain, a rail sump drain is a pit that is installed underneath the railway tracks. This pit collects the water from the tracks and will usually be used in conjunction with a piping network. Pipes of appropriate size will carry the water away from the sump and into the stormwater network. Sumps are usually spaced from 20-50m apart and are usually a minimum of 600mm x 600mm plan view (greater than 1m depth) or 450x450 (depths less than 1m) and are of concrete material. Sumps also have a heavy duty cast iron grate cover which also allows water to enter the chamber.

8.4.6 Aggregate Drains

Aggregate drains are comprised of crushed rock, gravel or concrete. This is a permeable layer that allows water to soak through the tracks to natural watercourses. Aggregate drains are only acceptable for small flows and if required for larger flows, will need a pipeline to assist in the drainage.

8.4.7 Connection Types

As stated previously, most services are not being redesigned but mainly redirected/relocated, cables and pipes shall be selected to match existing services as recommended by the companies who own the service.

Types of connections for each of the services include:

- Fibre optic cable
  - Splicing
  - Connectors
- Cables
  - Splicing
  - Connectors
- Power Cables – High Voltage, Low Voltage
  - Terminal
  - Bi-manchet
- Pipes – Water, Waste Water, Stormwater
  - Pipe Connectors

8.4.8 Clearances

Table 8-2 taken from Standard Specification for Urban Infrastructure Works 3-10 Edition 1 shows the minimum cover for relevant services.
Table 8-2 Minimum cover for services underground

<table>
<thead>
<tr>
<th>Item</th>
<th>General</th>
<th>Under Roads</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Mains</td>
<td>600</td>
<td>750</td>
</tr>
<tr>
<td>Water Services</td>
<td>450</td>
<td>600</td>
</tr>
<tr>
<td>PVC Irrigation Pipes and Control Tubes or Cables</td>
<td>450</td>
<td>600</td>
</tr>
<tr>
<td>Telecommunication</td>
<td>450</td>
<td>600</td>
</tr>
<tr>
<td>Gas</td>
<td>650</td>
<td>750</td>
</tr>
<tr>
<td>Electricity Supply Conduits (Except 50mm diameter conduits inside lease boundaries which shall have 600mm minimum cover)</td>
<td>850 Low Voltage</td>
<td>950 Low Voltage</td>
</tr>
<tr>
<td></td>
<td>1100 to invert for High Voltage</td>
<td>1050 High Voltage</td>
</tr>
<tr>
<td>Other Conduits (unless specified by Service Authority)</td>
<td>750</td>
<td></td>
</tr>
<tr>
<td>Stormwater</td>
<td>600</td>
<td>600</td>
</tr>
<tr>
<td>Sewers</td>
<td>600 (general)</td>
<td>900 (minor sealed roads)</td>
</tr>
<tr>
<td></td>
<td>750 (road verges)</td>
<td>1200 (unsealed or major roads)</td>
</tr>
</tbody>
</table>
8.5 Design Options

8.5.1 Scenario 1 Rail Overpass

8.5.1.1 Stormwater

This scenario looks into the railway overpass. From a stormwater perspective this option would not require a great deal of modification to the existing system, because South Road is not being changed or affected, so the existing drainage system for the road is maintained. This means the existing pit and pipe network will not have to be altered until the eventual upgrade of South Road to accommodate the 30 year plan for greater Adelaide. One consideration here is to keep in mind that eventually the road will be upgraded and hence adequate space for the upgraded stormwater network will have to be provided in the overpass design. Looking into the railway structure of the overpass, a stormwater drainage design will have to be implemented to keep the water from accumulating on the railway tracks. The traditional surface drains may not be applicable on a rail overpass, and so subsurface drainage will most likely need to be used. The minimum design ARI will be 50 years, as according to the DPTI standards Volume 2 – Train System (CP2) "Drainage" CP-TS-958. The options that will be considered include sump and/or piped drainage which will discharge into the existing or upgraded storm water pipe network. Determination for the volume of water that is required to be drained and hence the design for the storm water network will be calculated using the Rational Method, adopting the design ARI of 50 years.

8.5.1.2 Above Ground Services

This option is concerning a railway overpass that crosses over South Road which remains at grade. Refer to the geotechnical team rail overpass specifications in feasibility study stage; the length of the overpass railway is approximately 800m which crosses over South Road and Queen Street. The heights from the ground surface level to the top (fencing) of the overpass structure will be at least 10m.

The overpass will affect existing power poles, overhead power lines and fire hydrants along Day’s Terrace, Euston Terrace and South Road.

Relocation or removal of water hydrants must achieve the standard of Fire Hydrant Installations - AS2419 which include fire hydrant spacing and fire safety policy stated by the state government. According to the standard of Fire Hydrant Installations - AS2419 relocation of a fire hydrant requires a 10m clearance distance from the building and electrical equipment which is necessary to prevent damage under radiant heat from the fire and the event of structural collapse due to fire and also to avoid a potential electrical hazard.
The overhead power line and power pole can be relocated using underground power line or remove the influenced services and upgrade surrounding services to accommodate for the increase in demand from removing part of the system. The option to replace the above ground power lines and poles to underground power cables is the most likely option as it is aesthetically pleasing and cost effective.

### 8.5.1.3 Below Ground Services

A rail overpass has the benefit of little to no relocation of any services underground as no excavation is required. However it must be checked to ensure no services are in the vicinity of any piling required by the geotechnical team for the rail overpass. Companies such as AAPT, Amcom, Electranet, and Optus have no services in the target area at all for a rail overpass. However companies such as APA, SA Power Networks, SA Water and Telstra do have underground services which will have pipes and cables underground, below the proposed rail overpass.

If relocation of man hole or maintenance shafts is required, a new location along the pipe line may be sought providing is falls within an acceptable distance between each shaft/hole.

### 8.5.1.4 Advantages of Rail Overpass

The following is a list of advantages for Scenario 1: Rail Overpass:

- Road staying at same elevation, hence existing kerbing and pitting can be used.
- South Road stormwater system (pipe network) does not need to be upgraded until the upgrade of South Road.
- Very little surface area change and hence run off coefficient will likely remain unchanged.
- Quantity of runoff into system is mostly unchanged.
- Aesthetically pleasing to move services underground
- Minimal or no excavation costs for services
- Minimal or no underground service relocation
- Minimal delays to traffic on South Road due to service relocation

### 8.5.1.5 Disadvantages of Rail Overpass

The following is a list of disadvantages for Scenario 1: Rail Overpass:

- Stormwater runoff system for train overpass will need to be implemented.
- Train overpass requires a great deal of space which will cause the tracks stormwater system to be large.
- May need to increase pipe sizes in existing stormwater system to handle extra flow coming from overpass runoff.
- Traditional surface drains may not be applicable on the overpass scenario
- Sub surface drains likely.
- Significant relocation of above services to underground
- Railway ramps may interfere with some inspection points, valves, maintenance shafts and manhole covers

![Figure 8-3 Location of inspection points which may be affected](image-url)
8.5.2 Scenario 2 Rail Underpass

8.5.2.1 Stormwater
This scenario looks into the railway underpass. From a stormwater perspective this option would not require a great deal of modification to the existing system for the road, because South Road is not being changed or affected, the existing drainage system for the road is likely to be maintained. This means the existing pit and pipe network will not have to be altered until the eventual upgrade of South Road to accommodate the 30 year plan for greater Adelaide. One consideration here is to keep in mind that because the railway is going under the road, existing stormwater piping may need to be modified as to provide sufficient space for the rail to pass underneath the road. This may mean the relocation of the waste water reticulation and water reticulation mains, which are currently running underneath South Road at the railway intersection. Looking into the railway structure of the underpass, a stormwater drainage design will have to be implemented to keep the water from accumulating on the railway tracks. The traditional surface drains may or may not be applicable on a rail underpass and will have to be investigated further, with consideration to space requirements. Subsurface drainage will also need to be considered. The minimum design ARI will be 50 years, as according to the DPTI standards Volume 2 – Train System (CP2) "Drainage" CP-TS-958. The options that will be considered include surface drains: cess, catch, mitre, and subsurface drains: sump and/or piped drainage which will discharge into the existing or upgraded storm water pipe network. Determination for the volume of water that is required to be drained and hence the design for the stormwater network will be calculated using the Rational Method, adopting the design ARI of 50 years. Because of the reduction in elevation of the water pipes, a pump design will need to be implemented to remove the water and get it to a detention basin or into the surrounding stormwater network.

8.5.2.2 Above Ground Service
The depth of excavation for construction of the rail underpass is proposed to be 7.68 m with a width of 16.565 m. The underpass will disrupt existing power poles and public lighting along the railway. Public lighting requires that the design satisfies the requirements of the AS/NZS 1158 - Lighting for roads and public spaces.

8.5.2.3 Below Ground Service
A rail underpass will require significant earth works and planning for the relocation of underground services which would be affected by an underpass. There are a number of services affected by the proposed rail underpass.
APA have gas mains running along South Road which fortunately do not cross the train tracks however they run parallel to the tracks down Euston Terrace and Day Terrace either side of the tracks as seen in Error! Reference source not found.. This could mean if the underpass is to encroach onto Euston and Day Terraces the gas mains may be affected by the rail underpass plans; however this could be avoided due to mains being located on the farthest side of the road compared to the rail line. This should be sufficient space for the planned underpass as it takes up approx. 17m.

SA Power Networks have a number of services which will be affected by the proposed underpass, as shown in Error! Reference source not found., Error! Reference source not found. & Error! Reference source not found. there are a number of underground cables which involve high voltage, low voltage and communications cables which either cross over the tracks on South Road or run directly underneath the current rail line in the case of the communications cable.

SA Water has multiple systems located underground where they will interfere with an underpass. Wastewater systems and water supply systems run extensively throughout all the surrounding roads and south road itself as can be seen in Error! Reference source not found., Error! Reference source not found. & Error! Reference source not found.. These systems will need to be relocated along with many of the other services in the target area.

Telstra have communications cables running on most roads in the area with major network cables running under south road which is represented by the red lines in Error! Reference source not found.. These cables will have to be relocated along with many of the other services in the target area.

**8.5.2.4 Advantages to Rail Underpass**

The following is a list of advantages for Scenario 2: Rail Underpass:

- Road staying at same elevation, hence existing kerbing and pitting can be used.
- South Road stormwater system (pipe network excluding the two mains running under the intersection) will not need to be changed until the upgrade of South Road.
- Very little surface area change and hence run off coefficient will likely remain unchanged.
- Quantity of road runoff into system is mostly unchanged.
- Minimal costs for relocation existing services
- Minimal impact for above ground service relocation
- Minimal impact to traffic on South Road due during service relocation
- Minimal delays to South Road traffic compared to road underpass
8.5.2.5 Disadvantages to Rail Underpass

The following is a list of disadvantages for Scenario 2: Rail Underpass:

- Stormwater runoff system for train underpass will need to be implemented.
- Train underpass requires a great deal of space which will cause the tracks stormwater system to be large.
- May need to increase pipe sizes in existing stormwater system to handle extra flow coming from underpass runoff.
- Traditional surface drains may or may not be applicable on the underpass scenario.
- Reduced elevation of tracks will cause water path to flow down into the underpass changing the watercourses and require piping of huge depth comparative to the current stormwater system.
- Relocation of any existing stormwater piping under railway for a considerable distance.
- Railway will be at a depth and may be below the water table which would raise more issues such as moisture ingress.
- Significant planning in the relocation of underground services
- Significant earthworks involved in relocation of services
- Disruption to services for extended periods of time
8.5.3 Scenario 3 South Road Underpass

8.5.3.1 Stormwater
This scenario looks into road underpass. From a stormwater perspective this option would require modification to the existing stormwater system for the road. Because South Road is being modified and will be travelling under the railway, the existing drainage system for the road will need to be changed. This means the existing pit and pipe network will need to be altered taking into account the eventual upgrade of South Road to accommodate the 30 year plan for greater Adelaide. The existing stormwater piping will need to be modified as to provide sufficient space for the road to pass underneath the rail. This will mean the relocation of the waste water reticulation and water reticulation mains that are currently running underneath South Road at the railway intersection. These mains will need to be relocated deeper under the new South Road. It is suggested that these pipes be redesigned to accommodate the upgrade of South Road to save future changes. Looking into the railway structure above the underpass, a stormwater drainage design will have to be implemented to keep the water from accumulating on the railway tracks. The traditional surface drains may or may not be applicable on the underpass structure and will have to be investigated further, with consideration to space requirements. Subsurface drainage will also need to be considered. The minimum design ARI will be 50 years, as according to the DPTI standards Volume 2 – Train System (CP2) "Drainage" CP-TS-958. The options that will be considered include surface drains: cess, catch, mitre, and subsurface drains: sump and/or piped drainage which will discharge into the existing or upgraded storm water pipe network. Determination for the volume of water that is required to be drained and hence the design for the storm water network will be calculated using the Rational Method, adopting the design ARI of 50 years. Because of the reduction in elevation of the road and thus water pipes, a pump design will need to be implemented to remove the water and bring it to a detention basin or into the surrounding stormwater network.

8.5.3.2 Above Ground Services
This option requires a deep excavation for construction of the underpass. A depth for the road should be about 10m and the width of the underpass structure is 35m. The design construction may affect existing water hydrants, power pole, power line, public lighting and substation on Port Road and South Road intersection.

The overhead power line and power poles can be relocated using an underground line or even to remove the influenced services and upgrade the surrounding services to accommodate for the increase in demand. The option to replace the above ground power lines and poles to underground power cables is the most likely option as it is aesthetically pleasing and cost effective.
The underpass will disrupt public lighting and water hydrant, public lighting requires that the design satisfies the requirements of the AS/NZS 1158 - Lighting for roads and public spaces; and water hydrant requires that the design satisfies the requirements of the AS 2419 Fire Hydrant Installations for roads and public spaces.

8.5.3.3 Below Ground Services

A road underpass will require planning for the relocation of underground services which would be affected by an underpass. There are a number of services affected by the proposed road underpass.

APA have gas mains running on south road which do not cross the train tracks however they run parallel to the tracks down Euston Terrace and Day Terrace either side of the tracks as seen in Error! Reference source not found.. As South Road would be required to be almost at its maximum clearance under the rail line by Euston and Day Terrace the gas mains which are directed along these roads will be required to be redesigned to be able to continue at Euston and Day.

SA Power Networks have a number of services which will be affected by the proposed underpass, as shown in Error! Reference source not found., Error! Reference source not found., Error! Reference source not found. & Error! Reference source not found. there are a number of underground cables which involve high voltage, low voltage and communications cables which either cross over the tracks on South Road or run directly underneath the current rail line in the case of the communications cable.

SA Water has multiple systems located underground where they will interfere with an underpass. Wastewater systems and water supply systems run extensively throughout all the surrounding roads and south road itself as can be seen in Error! Reference source not found., Error! Reference source not found. & Error! Reference source not found..

Telstra have communications cables running on most roads in the area with major network cables running under South Road which is represented by the red lines in Error! Reference source not found.. These cables will have to be relocated along with many of the other services in the target area.

The road underpass provides a slightly better solution to relocating the services in comparison to the rail underpass. The underpass allows for greater access and in most cases services run parallel to the road, for this reason it would make sense to re-ly all affected services under the road underpass. Optus, AAPT, Electranet have services located near Port road which will be affected by the underpass due to the requirement for the road to begin laid underneath; AAPT may be able to slightly redirect their cable and manhole pit closer to the nature strip in the middle of Port road to
overcome this. Optus may be able to continue across South Road as shown in Error! Reference source not found. however will need to come down with the underpass.

### 8.5.3.4 Advantages of Road Underpass

The following is a list of advantages for Scenario 3: Road Underpass:

- Rail staying at same elevation, hence existing drainage system for rail away from South Road can be used.
- Quantity of road runoff into system is mostly unchanged.
- Additional cut and fill significantly less than rail underpass

### 8.5.3.5 Disadvantages of Road Underpass

The following is a list of disadvantages for Scenario 3: Road Underpass:

- New stormwater runoff system for road underpass will need to be implemented.
- May need to increase pipe sizes in existing stormwater system to handle extra flow coming from underpass runoff.
- Reduced elevation of road will cause water path to flow down into the underpass changing the watercourses and require piping of huge depth comparative to the current stormwater system.
- Relocation of any existing stormwater piping under roadway for a considerable distance (approximately 200m).
- Road will be at a depth and may be below the water table which would raise more issues such as moisture ingress.
- Significant relocation of underground services
- Large disruption to South Road and Port Road traffic whilst service work is undertaken
8.5.4 Scenario 4 Combined Road Underpass & Rail Overpass

8.5.4.1 Stormwater
This scenario looks into the combination of a rail overpass and road underpass. Similar to the road underpass (Scenario 3), from a stormwater perspective this option would require modification to the existing stormwater system for the road. Because South Road is being modified and will be travelling under the railway, the existing drainage system for the road will need to be changed. This means the existing pit and pipe network will need to be altered taking into account the eventual upgrade of South Road to accommodate the 30 year plan for greater Adelaide. The existing stormwater piping will need to be modified as to provide sufficient space for the road to pass underneath the rail. This will mean the relocation of the waste water reticulation and water reticulation main that is currently running underneath south road at the railway intersection. These mains will need to be relocated deeper under the new South Road. Because of the fact that the rail is also being elevated, the road will not need to be as deep as the pure road underpass, and hence these mains will not need to be as extremely deep. However, like the pure road underpass (Scenario 3), it is suggested that these pipes be redesigned to accommodate the upgrade of South Road to save future changes. Looking into the railway structure on the overpass, a stormwater drainage design will have to be implemented to keep the water from accumulating on the railway tracks. This drainage design will likely be very similar to the pure railway overpass (Scenario 1) and thus traditional surface drains may or may not be applicable on the structure. Consequently surface and subsurface drainage will need to be considered with respect to spatial requirements. The minimum design ARI will be 50 years, as according to the DPTI standards Volume 2 – Train System (CP2) "Drainage" CP-TS-958. The options that will be considered for the combination scenarios include surface drains: cess, catch, mitre, and subsurface drains: sump and/or piped drainage which will discharge into the existing or upgraded storm water pipe network. Determination for the volume of water that is required to be drained and hence the design for the storm water network will be calculated using the Rational Method, adopting the design ARI of 50 years. Similarly to the road underpass (Scenario 3), the reduction in elevation of the water pipes will require a pump design to be implemented to remove the water from below the road and take it to a detention basin or into the stormwater surrounding stormwater network.

8.5.4.2 Above Ground Services
This option shows that the specification of each part is similar to the issues also faced by the rail overpass (Scenario 1) and the road underpass (Scenario 3). This means there will be more relocation of services and the solutions for this case are similar as the solutions for road underpass and railway underpass sections.
8.5.4.3 **Below Ground Services**

A combination of an underpass and overpass allows the cut taken from the underpass to be used as the fill for the ramps of the overpass providing it is of good enough quality. However, this solution still poses a similar problem to the road underpass solution as it requires a great deal of service relocation. Possible solutions to overcome the underpass obstacle will be similar to the road underpass solution (Scenario 1) in which many of the services can continue to be dropped down with the road level.

8.5.4.4 **Advantages of Combination Method**

The following is a list of advantages for Scenario 4: Combination Method:

- Relocation of the water mains underneath South Road will not need to be as deep as pure underpass scenario.
- May not take as much space as single underpass or overpass scenarios, and hence not as significant stormwater runoff action required.
- The underpass does not have to go as deep as the pure underpass scenario hence it will not be as close to Port road which means services such as AAPT and Electranet will not be affected as in the road underpass scenario.

8.5.4.5 **Disadvantages of Combination Method**

The following is a list of disadvantages for Scenario 4: Combination Method:

- New stormwater runoff system for road underpass will need to be implemented.
- May need to increase pipe sizes in existing stormwater system to handle extra flow coming from underpass and overpass runoff.
- Reduced elevation of road will cause water path to flow down into the underpass changing the watercourses and require piping of huge depth comparative to the current stormwater system.
- Relocation of any existing stormwater piping under roadway for a considerable distance (approximately 200m).
- Road will be at a depth and may be below the water table which would raise more issues such as moisture ingestion.
- Stormwater runoff system for train overpass will need to be implemented.
- Train overpass requires a great deal of space which will cause the tracks stormwater system to be large.
May need to increase pipe sizes in existing stormwater system to handle extra flow coming from overpass runoff.

Traditional surface drains may not be applicable on the rail overpass scenario.

Sub surface drains for railway likely.

High impact of traffic to road and rail while service work is undertaken

Expensive costing due to relocate the substation and other services

Significant relocation of above ground services compared with other scenarios

Significant relocation of underground services

Significant disruptions to both road and rail

8.5.5 Proposal Scenarios

The following section describes the stormwater proposal and maps the proposed relocation of services for each of the four design scenarios.

8.5.5.1 Rail Overpass

- Proposed sump and pipe network to take water along the side of the bridge, down into the stormwater network.
- Check to see if the increased low permeability surface area requires adaption to handle increased flow at input pits, pipes or junctions.
- Relocation of SA Power network underground communications cable to Euston or Day Terrace.
- Above ground power lines converted into high voltage cables underground
- New street lighting as old lighting part of power poles.
- Relocation of underground services for communications cables required as seen in proposed relocation sketches in Figure 8-5 below
- As seen below the communications cables are to be relocated under Euston Terrace due to the rail overpass will block access to these cables in case of maintenance but also may be affected by piling for the proposed overpass.
- SA Water and Telstra are not affected by this proposed solution.
If cost becomes an issue on the rail overpass, an alternative scenario is to leave many of the existing power poles in their current locations and only converting to underground power lines where the overpass affects them. This is not as aesthetically pleasing however it will reduce the cost. Further details of alternative 1 are outlined in the costing section.

8.5.5.2 Rail Underpass

- Possible relocation of the water mains (stormwater and sewer) to a position under the new South Road but above the railway (in the bridge structure).
- Catch drains on surrounding area to stop water running down-hill into underpass.
- Proposed subsurface sump and pipe drainage system.
- Pump design to take low elevation water back to normal water mains level.
- Check to see if the increased low permeability surface area requires adaption to handle increased flow at input pits, pipes or junctions.
- Concern for width of underpass in relation to Gas mains on Day and Euston Terrace. No space for relocation of mains providing to the properties on Day and Euston Terraces. Should be sufficient space.
Proposed width of underpass is 17m wide as shown above it is approximately 35m from pipe line to pipe line as represented above, the gas main is on the very edge of the property line which does not allow for any movement without encroaching onto the properties. As can be seen in Figure 8-5 and Error! Reference source not found., Error! Reference source not found. & Error! Reference source not found. many of the services run parallel to South Road hence a rail underpass will obstruct these and require significant relocation.

Many of the services affected by the proposed rail underpass run perpendicular to the train line, this is significant in that if a direct relocation is sought, there will be a large amount of earthworks required to drop the pipes and cables down below the underpass. This also raises the issue of access.
to these services if maintenance is required. The earthworks required would be outside the scope of the underpass and would result in the closure of south road for a period of time.

A more indirect solution must be sought for the rail underpass to be feasible this can be done by redirecting all services parallel with the rail line until it is at level again and cross under the train line and back to south road. The indirect approach will still require a large amount of earthworks and new pipe/cable as the underpass is not at road level for roughly 400m either side of the rail/south road intersection.

### 8.5.5.3 Road Underpass

- Relocation of the water mains (stormwater and sewer) to a deeper position under the new South Road.
- Adequate road cross fall to bring water from the middle of the road.
- Adequately sized gutters on side road.
- Adequately sized pits (likely sump pits) on gutters that lead into the water mains.
- Catch drains on surrounding area possible to stop water running downhill into underpass.
- Pump design to take low elevation water back to normal water mains level.
- Check to see if the increased low permeability surface area requires adaption to handle increased flow at input pits, pipes or junctions.
- Cess drain on railway above underpass.
- Relocation of South road underground services to remain under South road underpass as access is still possible from the road.
- Gas mains running to Day and Euston Terraces relocated to service roads which remain at level.
- All services may be dropped down to continue under South Road. The Gas mains seen below are to continue on the service roads which remain at level; this will allow the mains to continue on to Euston and Day terrace.
- All services may be dropped down to continue under South Road. The Gas mains seen below are to continue on the service roads which remain at level; this will allow the mains to continue on to Euston and Day terrace.
- All services may be dropped down to continue under South Road. The Gas mains seen below are to continue on the service roads which remain at level; this will allow the mains to continue on to Euston and Day terrace.

All services may be dropped down to continue under South Road. The Gas mains seen below are to continue on the service roads which remain at level; this will allow the mains to continue on to
Euston and Day terrace

Figure 8-6 Road underpass gas main to be redirected

Optus communications cable is able to be dropped down to travel below the underpass as it is not affected by drops in level as water pipes are.

Figure 8-7 Optus cable location to be dropped underground
8.5.5.4 Rail Overpass/Road Underpass Combination

- Proposed cess drains running along the railway to take the water along the side of the bridge, down into the stormwater network.
- Check to see if the increased low permeability surface area requires adaption to handle increased flow at input pits, pipes or junctions.
- Relocation of the water mains (stormwater and sewer) to a deeper position under the new South Road.
- Adequate road cross fall to bring water from the middle of the road.
- Adequately sized gutters on side road.
- Adequately sized pits (likely side entry pits) on gutters that lead into the water mains.
- Catch drains on surrounding area possible to stop water running down hill into underpass.
- Pump design to take low elevation water back to normal water mains level.
- Relocation of South Road underground services to remain under the road underpass
- Overhead power lines relocated to underground cables
- New street lighting as old lighting part of power poles.
- Gas mains running to Day and Euston Terraces relocated to service roads which remain at level.

As seen above the communications cables are to be relocated under Euston Terrace due to the rail overpass will block access to these cables in case of maintenance but also may be affected by piling for the proposed overpass.

SA Water and Telstra are not affected by this proposed solution.

All services may be dropped down to continue under South Road. The Gas mains seen below are to continue on the service roads which remain at level; this will allow the mains to continue on to Euston and Day terrace

Optus communications cable is able to be dropped down to travel below the underpass as it is not affected by drops in level as water pipes are.

For imagery explaining please refer to Figure 8-4, Figure 8-6 & Figure 8-7
8.6 Costing

The following table displays the costs of each scenario with respect to the recommended design. It is clear to see a rail overpass is much cheaper than the other scenario which is mostly due to the fact that the water mains below South Road are unaffected. Detailed costing table is displayed in Error! Reference source not found.

Table 8-3 Total costs for water & services

<table>
<thead>
<tr>
<th></th>
<th>Rail Overpass</th>
<th>Rail Underpass</th>
<th>Road Underpass</th>
<th>Combination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stormwater</td>
<td>$198,000.00</td>
<td>$847,050.00</td>
<td>$1,141,800.00</td>
<td>$1,261,840.00</td>
</tr>
<tr>
<td>Below Ground Services</td>
<td>$59,527.00</td>
<td>$381,900.00</td>
<td>$202,340.00</td>
<td>$261,867.00</td>
</tr>
<tr>
<td>Above Ground Services</td>
<td>$120,201.60</td>
<td>$13,409.60</td>
<td>$32,209.40</td>
<td>$127,740.60</td>
</tr>
<tr>
<td>Total</td>
<td>$377,728.60</td>
<td>$1,242,359.60</td>
<td>$1,376,349.40</td>
<td>$1,651,447.60</td>
</tr>
</tbody>
</table>
8.7 Recommendations

Looking from a purely stormwater and services point of view, a rail overpass (Scenario 1) is recommended option. Some factors that have influenced this decision are:

- Requires significantly less service relocation
- Requires little to no changing of existing stormwater road network
- Cheap relative to other scenarios.

The main reasons for not recommending a Rail underpass (Scenario 2) are:

- Extensive relocation of services.
- Expensive stormwater design (sump and pipe network, and relocation of mains)
- Pump design needed to bring low elevation water to normal elevation.
- High cost comparatively.

The main reasons for not recommending a Road underpass (Scenario 3) are:

- Extensive relocation of services.
- Expensive stormwater design (Earthworks, piping and guttering)
- Pump design needed to bring low elevation water to normal elevation.
- High cost comparatively.

The main reasons for not recommending the Combination Method (Scenario 4) are:

- Extensive relocation of services
- Expensive stormwater design (Earthworks, piping and guttering)
- Pump design needed to bring low elevation water to normal elevation.
- High cost comparatively.
- Includes collective disadvantages of every other scenario.
9. Geotechnical Investigation

9.1 Overview

This report details the results of a feasibility stage of geotechnical investigation for the proposed grade separation of South Road, Croydon and Outer Harbor rail line. The work was established for Project Services, in consultation with Department of Planning, Transport and Infrastructure (DPTI), consulting with the different teams and engineering departments for the project.

During the construction, geotechnical engineering ideally deals with the soils, structural backgrounds and mechanics and all disciplines relating to civil engineering designs. According to choosing the most beneficial project for the client, the geotechnical experts have analyzed different aspects of geotechnical methods for the project. The decision making for the South Road planning is entirely dependent on cost budgeting and feasibility or the suitability of the area or community interest.

The aim of the investigation is to provide information on the following:

- Subsurface conditions including groundwater.
- Excavation conditions.
- Earthworks.
- Site preparation.
- Unsuitable soils, reuse of cut for fill, and workability.
- Stable temporary and permanent slope batters.
- Shrink-swell movements.
- Settlements.
- Site & soil reactivity according to AS2870-1996.
- Geotechnical retaining wall design parameters.
- Suitable upper level footing options and allowable bearing pressures.
- Ultimate end bearing and shaft adhesion pressures for bored piles and shaft piles.
- Sub-grade California bearing ratio (CBR) values for pavement thickness design.
- Topsoil suitability.
- Pavement Damage and design.

The initial scope of work was to use a total of 8 test bores for the South Road Planning for South Road and the Railway. This scope of work was reduced to 4 bores for investigation since there is an access restriction of Port Road in scope of project and also due to dense vegetation and substation that is located adjacent to port road.
This investigation comprised the drilling of 4 test bores, followed by geotechnical and analytical laboratory testing, engineering analysis and reporting for the South Road project. It is understood that investigation and reporting has been undertaken on separate sections in this part of the report.
9.2 Site Investigation

The process of site investigation includes:

- Site visit
- Desktop study
- Sampling
- Probing & Sounding
- Testing
- Proof Loading

On 24th March 2012, a site visit was undertaken by three experienced geologists. DPTI has provided us with bore log data that was conducted by Coffey Engineering and URS for the railway. Based on the location of the boreholes, the soil samples were tested and methods of generic investigation were done according to the listed below:

- Existing Surface and Topography
- Permeability
- Stratigraphy
- Stiffness
- Boulders
- Bedrock

9.2.1 Existing Surface and Topography

During the site visit, photographs were taken on the site and shown in the Error! Reference source not found. through to Error! Reference source not found. which shows the existing road condition. As a lot of trucks are passing over the road, the pavement seems to be damaged and needs to be improved from the South Road/Torrens Road intersection to Port Road. Some cracks can be seen in the pavement. South Road needs to be widened for future pedestrian and cyclist needs as well as the need for a road re-alignment to the western side. Based on the Figure 9-1, we can see that the road seems to be flat, (ie not much cut and fill is needed to be done) as grade does not have a superelevation more than 2% which is within allowable limits from surveyors results.
9.2.2 Permeability of Soil

An accurate determination of the soils co-efficient of permeability value “k” can have a major influence on the design of a deep basement system and on the success or failure of that system once implemented. The South Road silty clays have low permeability materials and can generally be considered to provide a groundwater cut off layer. However when gravels, sands or silts are present the “k” value of each material will determine the quantity and rate that groundwater will enter the excavation. This will in turn determine the extent to which the retaining wall will be required to reduce or cut-off groundwater. There are a number of methods to determine the “k” value such as:

- Rising, falling and constant head tests in boreholes and in the laboratory.
- Groundwater pumping tests on site.
- Particle Size Distribution (PSD) analyses and tri-axial cell tests in the laboratory.

It is advisable to get specialist advice on the particular test suitable for a particular site and geology. It is also advisable to carry out a number of different types of tests and to compare the results obtained.
9.2.3 Stratigraphy
It may seem to be an obvious comment that the accurate determination of the stratigraphy to an appropriate depth below the basement level is essential. Embedded retaining walls may penetrate to double the basement depth or greater. Low-strength or high permeability layers may exist at depths below the basement level. The presence of bedrock may restrict the use of some common basement retention systems such as sheet piling or CFA piling. Therefore, sufficient stratigraphical information to sufficient depth is a vital component of a successful basement retaining wall design.

9.2.4 Stiffness
The stiffness of the soil plays a major role in the deflections realised in basement retaining walls. The soils in Adelaide and across the state present particular challenges when attempting to accurately determine their stiffness. The boulder content of the glacial soils can preclude either Cone Penetration Testing (CPT) in gravels or standard "U100" sampling techniques in clays.

For clay deposits, it may be worth investing in high quality "Geobor-S" borehole drilling to obtain high quality relatively undisturbed samples. These can then be tested in specialised tri-axial cells to assess the stiffness of the material.

The stiffness of gravel layers in Australia is normally assessed from the Standard Penetration Test (SPT). Groundwater in boreholes can sometimes cause the gravel to "boil" and thus loosen and yield a low SPT value. Measures should therefore be taken to avoid or reduce boiling. This can be achieved by keeping the borehole casing topped up with water to equalise the groundwater pressures.

9.2.5 Boulders
Based on the AS 1726, the Australian Site Investigation describes that the size of boulders must not be more than 200mm which is shown in Table A1, pg 10 of AS 1726. Boulders up to 1m in diameter are not unusual in some soils types. It is important that the size and quantity of the boulder content is adequately reflected in the site investigation report as this can have a significant bearing on the ability of various piling plant to penetrate to the required depth. An example of a boulder is shown Figure 9-2.
9.2.6 Bedrock

The presence or possible presence of bedrock needs to be investigated as part of a site investigation. If the presence of bedrock is confirmed then detailed consideration will need to be given to:

- Type of rock
- Strength
- Degree of weathering
- Angle of bedding planes
- Faults & folds

Many “standard” site investigations can represent incorrect bedrock because incorrect methods were specified or the methods used were not altered as the site investigation proceeded. Many site investigations can be based mainly on “Shell & Auger” borehole drilling. This technique has only limited ability to penetrate boulders and cannot penetrate much into bedrock. Boreholes sometimes terminate on “Presumed Rock”. In many instances, these boreholes will actually have terminated on a boulder and rock head can be many metres below. Therefore, this term should not be used to identify rock level. Bedrock can often comprise of an upper weathered/fractured zone and a lower more intact deposit. Depending on the strength of the rock and the degree of weathering/fracturing, various piling methods will have different capabilities to penetrate rock and the following points can be used as a guide:

- Sheet piling cannot penetrate into bedrock.
- CFA piling can penetrate weathered rock to a limited depth and generally cannot penetrate intact rock.
• Bored piling using appropriate rock augers or core barrels can penetrate both weathered and intact rock. However as the rock strength increases the rate of penetration will decrease.

• Down-The-Hole-Hammer (DTHH) techniques can readily drill intact rock to provide rock-socket piles.

The requirement to penetrate both weathered and intact rock can arise from the following:

• The basement level may be below rock head level.
• A rock socket may be required to provide sufficient pile toe restraint.
• A groundwater cut-off may be required through the weathered and into the intact rock.
• The basement wall may need to accommodate certain vertical loads. This can sometimes require extending piles into rock.

The most common ways to investigate bedrock, each with advantages and disadvantages, are:

• Rotary coring.
• Open hole/DTHH techniques.
• Geophysical techniques.

Site reactivity is dependent upon the contaminant depth, type of soils and phase solute concentration which is discussed based on AS 2870: Slabs and Footings Design.
9.3 Soil Properties

Soil is an important factor for the construction industry, because there are plenty of factors that affect soil properties. Soil properties consist of moisture content, pH value, and density and etc. Different environment leads to strength and stiffness of soil instability which will have a significant impact on buildings in the future.

The influence of water content, organic matter content, aggregate size and the interaction of these factors on the tensile strength of natural aggregates of a sandy loam and of a clay soil were studied. Tensile strength of a soil depended mainly on water content. For example, if the water table at the surface was undetected it would be possible to overestimate the shear strength of the soil at depth.

The correct measurement of the strength and stiffness of the soil is very important for the rail line. Strength refers to the solids parts of rock mass and the overall strength will be affected by joints, fractures and bedding planes. The soil property of the site is shown in the soil testing results which describe the characteristic of the soil.
9.4 Soil Classification

Soil can be classified in one of a number of soil groups on the basis of grading and the particles type and the plasticity of the friction of the materials passing through the sieve of 425 µm. This can be done by two different processes on the basis of elimination that is field test or the rapid method or laboratory. The process of soil classification is also carried out by the visual-tactile (see-touch) examination. The classification of unified soil is based on the visual-tactile examination and laboratory testing. The group symbol for the soil classification and identification characteristic are shown in Table 9-1 & Table 9-2

Table 9-1 Course grained soils description (AS 1726)

<table>
<thead>
<tr>
<th>Major divisions</th>
<th>Particle size, mm</th>
<th>Group symbol</th>
<th>Typical name</th>
<th>Field identification Sand and Gravels</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOULDERS</td>
<td>200</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COBBLES</td>
<td>63</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>course</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GRAVELS</td>
<td>5</td>
<td>GW</td>
<td>Well-graded gravels, gravel-sand mixtures, little or no fines</td>
<td>Wide range in grain size and substantial amounts of all intermediate sizes, not enough fines to bind coarse grains, no dry strength</td>
</tr>
<tr>
<td>medium</td>
<td>3</td>
<td>GP</td>
<td>Poorly graded gravels and gravel-sand mixtures, little or no fines, uniform gravels</td>
<td>Predominantly one size or range of sizes with some intermediate sizes missing, not enough fines to bind coarse grains, no dry strength</td>
</tr>
<tr>
<td>fine</td>
<td>2.36</td>
<td>GM</td>
<td>Silty gravels, gravel-sand-silt mixtures</td>
<td>‘Dirty’ materials with excess of non-plastic fines, zero to medium dry strength</td>
</tr>
<tr>
<td>course</td>
<td>0.6</td>
<td>GC</td>
<td>Clayey gravels, gravel-sand-clay mixtures</td>
<td>‘Dirty’ materials with excess of plastic fines, medium to high dry strength</td>
</tr>
<tr>
<td>fine</td>
<td>0.2</td>
<td>SW</td>
<td>Well graded sands, gravelly sands, little or no fines</td>
<td>Wide range in grain size and substantial amounts of all intermediate sizes, not enough fines to bind coarse grains, no dry strength</td>
</tr>
<tr>
<td>fine</td>
<td>0.075</td>
<td>SP</td>
<td>Poorly graded sands and gravelly sands; little or no fines, uniform sands</td>
<td>Predominantly one size or range of sizes with some intermediate sizes missing, not enough fines to bind coarse grains, no dry strength</td>
</tr>
<tr>
<td>fine</td>
<td>0.02</td>
<td>SM</td>
<td>Silty sands, sand-silt mixtures</td>
<td>‘Dirty’ materials with excess of non-plastic fines, zero to medium dry strength</td>
</tr>
<tr>
<td>fine</td>
<td>0.0075</td>
<td>SC</td>
<td>Clayey sands, sand-clay mixtures</td>
<td>‘Dirty’ materials with excess of plastic fines, medium to high dry strength</td>
</tr>
</tbody>
</table>
Table 9-2: Fine grain soils description (AS 1726)

<table>
<thead>
<tr>
<th>SILTS &amp; CLAYS</th>
<th>ML</th>
<th>Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity</th>
<th>Dry* Strength</th>
<th>Dilatancy†</th>
<th>Toughness‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>(bound limit &lt;30%)</td>
<td></td>
<td>None to low</td>
<td>Quick to slow</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CL, CI</td>
<td>Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays</td>
<td>Medium to high</td>
<td>None to very slow</td>
<td>Medium</td>
</tr>
<tr>
<td></td>
<td>OL †</td>
<td>Organic silt and organic silty clays of low plasticity</td>
<td>Low to medium</td>
<td>Slow</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>MH</td>
<td>Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts</td>
<td>Low to medium</td>
<td>Slow to none</td>
<td>Low to medium</td>
</tr>
<tr>
<td></td>
<td>CH</td>
<td>Inorganic clays of high plasticity, fine clays</td>
<td>High to very high</td>
<td>None</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>OH †</td>
<td>Organic clays of medium to high plasticity, organic silts</td>
<td>Medium to high</td>
<td>None to very slow</td>
<td>Low to medium</td>
</tr>
<tr>
<td>HIGHLY ORGANIC SOILS</td>
<td>Pe ‡</td>
<td>Pers and other highly organic soils</td>
<td>Identified by colour, odour, spongy feel and generally by fibrous texture</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
9.5 Soil Testing

9.5.1 Laboratory Testing
The laboratories testing the boring samples are to be submitted from the strata to analyse the sample and progress the work. The laboratory testing is carried out in accordance to the Australian standard AS1290 and AS1289.

9.5.2 Classification Tests
The tests are to be performed on the samples, which is obtained for the verification of the field classification. The tests performed according to the Australian standard and the results obtained from the test are reasonably establishing the satisfaction without duplication.

9.5.2.1 Sieve Analysis
The sieve analysis shall be performed to determine the grain size and the descriptive properties of the sample in accordance with AS1290; this process is widely used for the classification of the soils. The data obtained from the grain size distribution curve can be used to find the stability of soil and also helps to predict the soil water movement and also known as dilatancy.

9.5.2.2 Liquid Limit and Liquidity Index
Liquid limit test consist of the determination of moisture content at which the soil passes from the plastic to the liquid state in accordance to AS1289.3. The liquid limit testing process is carried out by the visual-tactile examination. The process is used in classification system to characterize the fine-grained soils and also the use for identification of soil use as a fill material.

9.5.2.3 Plastic Limit and Plasticity Index
The plastic limit is the water content at the point where the soil is changing from a liquid to solid state. Plastic limit test is used to determine the plasticity index of the sample in accordance to AS1289.3. The plastic limit test is also integral part of the Atterberg test used in the classification system to characterize the fine-grained soils and also the use for identification of soils used as a fill material.

9.5.2.4 Shrinkage Limit
The shrinkage limit test is necessary for the classification of soil. These tests shall be performing on the large sample to prepare for the plastic and liquid limit test. This test is done in accordance to the AS1289.3.
9.5.3 Special Tests

9.5.3.1 Moisture Content Tests
The moisture content test is performed to determine the amount of water in the soil. This test is done in accordance to AS1289.2. The moisture content test should be done primarily as it is a limiting factor for the other test.

9.5.3.2 Consolidation Test
The consolidation test (Figure 9-3) is performed to check the settlement of the soil, when soil is loaded. This test is done in accordance to AS1289.6. The consolidation test shall be done to avoid the non-elastic or the plastic settlement of the soil after the construction, which may lead to the structural failure.

![Figure 9-3 Consolidation Test](image)

9.5.3.3 Unconfined Compression Test
The unconfined compression test shall be performed in accordance to AS1289.6. This test is used to determine the compressive strength of the soil. The unconfined test is also useful to determine the moisture content, unit weight, visual description of soil, average strain at failure and average rate of strain to failure of the soil.

9.5.3.4 Tri-axial Test
The tri-axial test (Figure 9-4) of the sample shall be done in accordance to the AS1289.6. This test is performed to determine the shear strength parameters of the soil by plotting the Mohr circle. To conduct the tri-axial test it is necessary to have the initial and final moisture content of the soil.
9.5.3.5 **Direct Shear Test**

The direct shear test (Figure 9-5) is also used to determine the shear strength parameter of the soil, which is used to find the failure mode of the soil in two-dimensional or planer. This test shall be performed in accordance to AS1289.6.

9.5.4 **Detailed Testing Results**

In Table 9-3 Example of soil test result BH2 soil sample, it shows an example of results from a soil test. Hence we require the test for determining the dry strength, plastic limit, elastic limit, atterberg limit, diluting and undrain shear strength test (using CPT or PPT) for stability of soil.
9.5.4.1 Sample soil of BH2

Table 9-3 Example of soil test result BH2 soil sample

<table>
<thead>
<tr>
<th>Major division</th>
<th>Group symbol</th>
<th>Depth (mm)</th>
<th>Dry strength</th>
<th>Plastic limit</th>
<th>Elastic limit</th>
<th>Atterberg limit</th>
<th>Dilatancy</th>
<th>PPT(Kpa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandy clay</td>
<td>SC</td>
<td>0 -2m</td>
<td>medium to high dry</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Very quick</td>
<td>180</td>
</tr>
<tr>
<td>Clay</td>
<td>CL</td>
<td>2-8m</td>
<td>Medium to high</td>
<td>&lt;20%</td>
<td>&lt;30%</td>
<td>Below A-line shown in Figure 9-5</td>
<td>Slow</td>
<td>300 to 550</td>
</tr>
<tr>
<td>Silty clay</td>
<td>CH</td>
<td>8 - 13.5m</td>
<td>High to very high</td>
<td>&gt;40%</td>
<td>&gt;50%</td>
<td>Above A-line shown in Figure 9-5</td>
<td>Non</td>
<td>150 to 300</td>
</tr>
</tbody>
</table>

9.5.4.2 The Plasticity Chart

Figure 9-6 Plasticity chart with all hole soil samples
9.5.4.3 *Summary and Recommendation of Soil Testing*

For this south road and outer Harbor rail line project, our geotechnical team had to perform some soil tests on a soil sample from the site. The method of testing on the soil is described in detail in the above section; the geotechnical team will only be testing for the plastic limit, liquid limit, atterberg limit, cone penetration test, direct shear test, permeability head test, seepage control on soil, tri-axial test, moisture content and consolidation which is part of determining the soil stability and strength.
### 9.6 Borehole Description

There are four point boreholes in the map as follow BH2, BH214, 215 and 218. The soil testing is based on the BH2. The bore holes tested in the geological survey are near the rail line. The result of the first bore hole (BH2 shown in the Figure 9-7) showed a sandy top soil to a depth of approximately 39 meters, the soil composition consist of sand clay, silty clay and CH. This is thick enough to cause problems during construction. The BH2 was also laboratory tested for geological results.

Another borehole (BH215 and 218 shown in the Figure 9-7) is located within 30m of the rail line, to the south and north respectively. The BH215 and 218 has a sandy top soil to a depth of approximately 30 meters, the soil composition includes fill clay sand and clayey sands. The final point (BN214 shown in the Figure 9-7) is located approximately 100m south of the rail line. BH214 has a sandy top soil to a depth of approximately 30 meters, the soil composition includes fill clay sand and clayey sands.
Figure 9-7 Arial photograph of borehole locations
9.6.1 Boring and Sampling

9.6.1.1 Borehole Sampling Techniques
The list below shows all the types of borehole sampling techniques:

- Standard Penetration Tests
- Split-Spoon Samples
- Sample Handling
- Sample Identification
- Groundwater Readings and Backfilling Bore Holes

9.6.1.2 Boring Methods
The boring methods are shown below:

- Mobilization
- Remobilization
- Hand Borings
- Truck Drilling
  - Truck-Mounted Borings with Split-Spoon Sampling
  - Truck-Mounted Rock-Core Borings
- Skid Drilling
  - Skid-Mounted Borings With Split-Spoon Sampling
  - Skid-Mounted Rock-Core Borings
- Floatation Equipment
- Floating Equipment for Machine Borings
- Soundings
- Casing
- Field Geotechnical Engineer

9.6.1.3 Soil Sampling
The technique for soil sampling is as below:

- Undisturbed Samples
- Additional Split-Spoon Samples
9.6.2 Field Record

All material encountered in each bore shall be carefully examined and visually classified at the time of boring, and a written record (boring log) should be prepared. The boring log shall be on a sheet 8-1/2-by-11 inches in size, and shall show the following information:

- Project designation and project location;
- Boring number;
- Final location of boring by reference to station, offset, and survey line;
- Method of boring, type drill rig and sampling;
- Date of boring and weather;
- Ground elevation measured utilizing a transit or level instrument and referencing to a USC&GS Benchmark or other points of known elevation;
- Numerical thickness and depth of various soil layers to be shown in feet below ground surface or by elevation;
- A complete description of each soil layer including color, moisture, consistency or density, and visual grain-size classification;
- The elevation of free water during the drilling, at completion of drilling and 24 hours later;
- Any additional information obtained during the boring shall be shown;
- Blows per 6-inch increment of drive of split-spoon sampler, sample number, and depth of top and bottom of samples taken;
- Percent recovery on split-spoon and undisturbed samples, rock cores, etc.;
- County;
- Driller;
- Inspector.

When rock is encountered and cored, the boring log shall also include the following remarks:

- Numerical thickness and depth of rock unit;
- A complete description of each rock unit including colour, texture, significant mineralogy, degree of weathering etc.;
- Percent recovery and RQD values (rock quality designation);
- A description of joints, fractures, and bedding planes (i.e., degree of openness, spacing, inclination, etc.);
- Location of core fracturing;
- Type and size of core barrel and depths where casing is used;
• general descriptions of penetration rate, with significant changes in rate noted;
• zones of drilling fluid loss;
• Zones of water gain (when air is the drilling fluid);
• Any unusual occurrences such as sudden drop of drill rods, change in colour of return wash water, etc.

Fill or embankment material depth limits should be shown on all boring logs, as well as the classification of the soil comprising the fill or embankment. This information should be checked for accuracy by referring to original construction plans to determine the original embankment height.

The boring logs shall contain all necessary information required to plot the final geotechnical profile, and such information shall also serve as the basis for determining pay quantities.
9.7 Regional Geology

The study area lies on the Pooraka formation, which is described as mottled clay, reddish brown coloured Pleistocene alluvial deposit with weakly developed calcareous pedogenic horizons that underlies river terraces and alluvial fans. The landscape is generally flat, with soil variations in depth where the dominant soil type is red-brown clay or sandy clay soils with low lime sand, as well as minor soil type of silts, sands, gravels and organic deposits. Figure 9-6 shows the soil type and geological map of the study area.

The ground slopes are usually less than 5% and the vegetation typically comprises partly cleared eucalypt, evergreen tree, bushes and four seasons leaf tree. The soils range from shallow to moderately deep (less than 1m thick) and are hard setting, mottled textured clay soils. The soils are typically moderately reactive with highly plastic subsoil, have a low soil fertility and poor soil drainage. The soils are often deep, layered sediments overlying bedrock or relict soils. The main limitations of this soil landscape are the risk of erosion and dry soil.
9.8 Soil Profile

The soil profiles of each bore logs data are shown below. The soil profiles are showing the excavated properties and at what depths that change.

Figure 9-9 Soil profile of BH2

Figure 9-10 Soil profile of BH218
Figure 9-11 Soil profile of BH215

Figure 9-12 Soil profile of BH214
9.9 Groundwater Description

Based on the rail structure design which is shown in Electrical and Mechanical Clearance, the depth of excavation for construction of the underpass of the rail should be 7.68m while the width of the underpass structure is 16.565m. For the depth of excavation for construction of underpass for South Road should be 5.8m with a width of 70.8m. Therefore, both depths of the underpass are above the ground water table.

Table 9-4 Groundwater level on site

<table>
<thead>
<tr>
<th>Piezometer Borehole</th>
<th>Ground Water Reduced Level (m)</th>
<th>Datum, AHD(m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BH214</td>
<td>12.5</td>
<td>3.5</td>
</tr>
<tr>
<td>BH215</td>
<td>12.5</td>
<td>3.5</td>
</tr>
<tr>
<td>BH218</td>
<td>12</td>
<td>4.5</td>
</tr>
<tr>
<td>BH2</td>
<td>13.2</td>
<td>2.5</td>
</tr>
</tbody>
</table>

These levels indicate that there is a gradual fall in the level of the water table to the east and north-west, towards the drainage channel. This is consistent with expectations that the ground water table is a subdued reflection of the surface topography. The ground water level may be affected by piling depth.
9.10 Excavation

Excavation is needed for grade separation of South Road and Outer Harbor rail line, especially with the construction of the underpass. The construction method of excavation depends upon a number of factors:

- Nature of subsoil – affect type of machine used and the necessity of soil protection.
- Size of excavation – affect type of machine used and method to excavate.
- Scale of work – large volume of excavation may involve complicated phasing arrangement and work planning.
- Ground water condition – affect degree of protection (watertight sheet piling or dewatering maybe required.
- Surrounding condition – impose certain restrictions and precautions (e.g. diversion of a government drain, or underpinning work to the nearby building foundation).

9.10.1 Removal of Soil

There will be a great amount of excavated soil produced during the process of excavation.

Suitable planning for the removal of the excavated material should be made in advance in order not to cause disruption to work and incur extra costs. Soil removal can be done by the following ways:

- Using manual method, e.g. by wheel barrow.
- Using bucket and lift to ground level by crane.
- Using hoist rack (opening has to be provided in the basement/excavation pit first).
- Using gantry crane (opening has to be provided in the basement/excavation pit first).
- Using conveyor belt.
- Using excavating machine to removal soil may be in stepped position in case of very deep pit.
- Using dump truck but access provision has to be provided in advance (such as a temporary ramp or the permanent vehicular access into a basement).

9.10.2 Excavation Plants

Advantages of using mechanical plant in excavation:

- Work done quicker.
- Avoid dangerous condition of work by human workers, e.g. existence of ground water or collapse of soil.
- Achieve greater depth.
- Use fewer manpower and work done in lower cost (for larger scale work only).

Disadvantages of using mechanical plant in excavation:

- Involve larger running and maintenance costs.
- Require a larger operating area.
- Access provision to working area.
- Less flexible in work planning.
- Idling time increase cost of work.

9.10.3 Deep Excavation

For the construction of the underpass for this project, there is a large amount of soil needed to be excavated because of the depth of the underpass, so deep excavation will be considered. Deep excavation, unlike a shallow one, often requires protection of the sides of the cut using suitable supports. Besides this, the problem of ground water cannot be avoided. There are methods to overcome this, such as:

There are few methods of excavation can be and they are as listed below:

- Dumpling Method.
- Diaphragm Walling.
- Using Cofferdams.

9.10.3.1 Dumpling Method

This is used where there is a street in the proximity. The method (Figure 9-13) is used to construct a series of retaining walls in a trench, section by section, around the site perimeter, leaving a centre called a "dumpling".

When the perimeter walls are in place, excavation may start at the centre of the dumpling, until exposing a section of the wall. Then the wall may be side supported by struts, shoring or soil anchor etc., again section by section in short length, until the excavation is all completed.

This method does not require much heavy mechanical equipment and thus cost of work is relatively lower. It can excavate up to a maximum depth of about 3m. Sometimes in very poor soil or in waterlogged ground, interlocking steel sheet pile may be driven to confine the area to be excavated. After that excavation can be done in section and properly supported similar to that mentioned above.
By use of sheet piling, excavation may reach of maximum about 15m. However, the cost of work will be increased.

9.10.3.2 Diaphragm Walling

This method (Figure 9-14) needs to construct a R.C. retaining wall along the area of work. The wall is designed to reach a very great depth; a mechanical excavating method is employed. Typical sequence of work includes:
- Construct a guide wall.
- Excavation for the diaphragm wall.
- Excavation support using bentonite slurry.
- Inert reinforcement and concreting.
- Joining design for diaphragm wall.

**Construct a guide wall** – guide wall is two parallel concrete beams running as a guide to the clamshell which is used for the excavation of the diaphragm wall.

**Excavation for the diaphragm wall** – In normal soil conditions excavation is done using a clamshell or grab suspended by cables to a crane.

**Excavation support** – excavation for the diaphragm wall produces a vertical strip in soil which can collapse easily. Bentonite slurry is used to protect the sides of soil and is a naturally occurring clay which, when added to water, forms an impervious cake-like slurry with very large viscosity. The slurry will produce a great lateral pressure sufficient enough to retain the vertical soil.

**Reinforcement** – reinforcement is inserted in form of a steel cage, but may require to lap and extend to the required length.

**Concreting** – concreting is done using tremie. As Concrete being poured down, bentonite will be displaced due to its density is lower than concrete. Bentonite is then collected and reused. Usually compaction for concrete is not required for the weight of the bentonite will drive most of the air voids in concrete.

**Joining design for the diaphragm wall** – Diaphragm walling cannot be constructed continually for a very long section due to tremendous soil pressure. The wall is usually constructed in alternative sections. Two stop end tubes will be placed at the ends of the excavated trench before concreting. The tubes are withdrawn at the same time of concreting so that a semi-circular end section is formed. Wall sections of this type are built alternatively leaving an intermediate section in between. The interior sections are built similarly but without the end tube. At the end a continual diaphragm wall is constructed with the sections tightly joined by the semi-circular groove.
Figure 9-14 Construction sequence of diaphragm wall

9.10.3.3 **Cofferdams**

A cofferdam (Figure 9-15) may be defined as a temporary box structure constructed in earth or water to exclude soil or water from a construction area, such as for foundation or basement works.

Use of cofferdam suitability for excavation of larger scale can be of:

- **Sheet pile cofferdam** – Also known as single skin cofferdam. Interlocking type steel sheet pile is used and can use for excavation up to 15m. Sheet pile in this case acts as a cantilever member to support the soil therefore adequate depth of pile or suitable toe treatment may be required. In addition, cofferdams are needed to be braced and strutted or anchored using tie rods or ground anchors. Making use of sheet pile to form a cofferdam to support excavation is very useful.

- **Double skin cofferdam** – This works similarly like the sheet pile to form a diaphragm. However, the diaphragm is double-skinned using two parallel rows of sheet pile with a filling material placed in the void between. This creates somewhat a gravity retaining structure and increase the ability to counteract the soil behind. However, more working space is required.

Figure 9-15 Photograph of cofferdams technique
9.11 Pile Foundation

9.11.1 Description
As with other types of foundations, the purpose of a pile foundation is to transmit a foundation load to a solid ground and to resist vertical, lateral and uplift loads. A structure can be founded on piles if the soil immediately beneath its base does not have adequate bearing capacity. Piles provide bearing capacity in terms of “skin friction” and end bearing capacity. As the names imply, it provides resistance from the friction between the soil and the surface of the piles, also from the base of the piles. It is shown in Figure 9-16.

9.11.2 Classification of Piles

9.11.2.1 Materials

9.11.2.1.1 Timber
Timber is the most suitable option for long cohesion piles and piling beneath embankments. The timber should be in good condition and should not contain any infestations. Normally, for timber piles of length less than 14 meters, the diameter of the tip should be greater than 150 mm. If the length is greater than 18 meters, the tip with a diameter of 125 mm is acceptable. It is essential that the timber pile is driven in the right direction and should not be driven into firm ground as it would damage the pile. Timber piles can be protected against decay and putrefaction by staying below the water table. The part where it is above the water table, it should be protected by pressure creosoting.

9.11.2.1.2 Concrete
Concrete piles can be precast or cast in-situ. Precast concrete are easily connected together in order to reach the required length. However, precast has an additional cost of transporting them from the
factory to the site. Long piles can be difficult to transport and handle. Concrete piles can also be reinforced or pre-stressed with steel to help withstand both handling and driving stresses, with the latter requiring less reinforcement.

9.11.2.1.3 Steel
Steel piles (Figure 9-17) are suitable for handling and driving in long lengths. Their relatively small cross-sectional area combined with their high strength makes penetration easier in firm soil. They can be easily cut off or joined by welding. However, if the pile is driven into a soil with low pH, then there is a risk of corrosion. Coal-tar epoxy or cathodic protection can be applied to slow or eliminate the corrosion process.

![Types of steel piles](image)

**Figure 9-17 Types of steel piles**

9.11.2.1.4 Composite
Piles can be a combination of different materials in the same pile. For example, the timber pile is protected by the concrete or steel where it is not submerged in ground water. Reinforced concrete and pre-stressed piles are also composite piles.

9.11.3 Foundation Methods

9.11.3.1 Displacement Piles
Soil is displaced radially as the pile shaft penetrates the ground. Granular soils tend to become compacted by the displacement process, and clay soils may heave, with little immediate volume change as the clay is displaced. Pile with smaller cross-sectional area, such as ‘H’ steel pile are termed low displacement piles, and the effects of compaction or soil heave are reduced. This can be advantageous if long lengths of pile are to be driven through granular deposits, if the piles are at close centres, or if clay heave is a problem.

Displacement piles are generally driven with drop hammers, where a weight approximately equal to that of the pile is raised a suitable distance in a guide and released to strike the pile head. This type of method is disadvantageous in noise sensitive areas as it causes loud noise. Figure 9-18 shows an example of constructing a driven pile.
The following piles can be classified as displacement piles and shown in table below:

<table>
<thead>
<tr>
<th>Large displacement piles</th>
<th>Small displacement piles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timber piles</td>
<td>Tubular concrete piles</td>
</tr>
<tr>
<td>Precast concrete piles</td>
<td>H-Piles</td>
</tr>
<tr>
<td>Closed-end steel pipe piles</td>
<td>Open-end pipe piles</td>
</tr>
<tr>
<td>Jacked down solid concrete piles</td>
<td>Thin-shell type</td>
</tr>
</tbody>
</table>

### 9.11.3.2 Non Displacement Piles

With the excavation of a borehole in the ground, a pile can be produced by casting concrete in the void. Some soils, such as stiff clays, are particularly amenable to the formation of piles in this way, since the borehole walls do not require support. In unstable ground, such as gravels, the ground requires temporary support, from casing, bentonite slurries or a polymer fluid. A different technique, which is still essentially non-displacement, is to intrude a grout or fluid concrete from a continuous flight auger (CFA) that is rotated into the ground, and hence produce a column of concrete which can be reinforced when the auger is pulled out. The three non-displacement methods are therefore:

- Bored cast-in-place-piles
- Partially pre-formed piles
- Continuous flight auger (CFA) piles (Figure 9-19)
Non-displacement piles are preferred in a noise sensitive environment, as they are less noisy than displacement piles. Furthermore, they create less vibration than displacement piles as well. Figure 9-4 shows the process of constructing a CFA pile.

**Figure 9-19 Process of continuous flight auger (CFA)**

### 9.11.3.3 Pile Cap

A pile cap (Figure 9-20) is a block of reinforced concrete that connects the piling to the structure above for load transfers. The piling could be single or group piles depending on the bearing capacity it is required to carry. Figure 9-4 shows an example of a pile cap connecting the structure and the piling.

**Figure 9-20 A pile interlinking pilling and loads**
9.11.4 Recommendation

As the soils relative density in this area is generally stiff to hard, it is not advisable to use large displacement piles as it could be hard to penetrate to the desirable depth. Using small displacement piles might not have the desired load capacity. It is recommended to use the non-displacement continuous flight auger (CFA) method for deep piling in this project. As the soil is stiff, there is no need for any temporary casing, unless there is intrusion into the ground water. In this case, a temporary casing or bentonite slurry can be put in place to slow the intrusion of groundwater in time for the application of fluid concrete. CFA also produces minimum noise and vibration compared to driven piles, and thus minimising disturbance to the public. CFA is also readily available in South Australia. Therefore, CFA would be a better choice.
9.12 Retaining Wall

9.12.1 Crib Gravity Retaining Wall
There are many types of retaining wall such as crib gravity retaining walls, gabion gravity retaining walls, masonry gravity retaining walls and etc.

9.12.1.1 Crib Gravity Retaining Wall
Crib walls (Figure 9-21) are made up of interlocking individual boxes made from timber or pre-cast concrete. The boxes are then filled with crushed stone or other coarse granular materials to create a free draining structure. There are two basic types of crib walls:

- Timber,
- Reinforced pre-cast concrete.

Crib walls use the dead weight of the soil to their advantage. Crib walls are comprised of short interlocking beams of concrete or timber, stacked to form rectangular hollow walls, which are subsequently filled with soil.

Figure 9-21 Crib gravity wall

Crib walls infill material shall be dense, hard, durable and clean materials as specified and approved by the project engineer. The most commonly used materials are from stone-quarries or riverbeds. The materials must have a minimum weight as specified on the design documents, be non-friable, non-washable and non-porous.

The guidelines recommendation designs are given by:

- Los Angeles Value (B) grading AS 1141.3 < 20%.
- Aggregate Wet/Dry Strength (AS1141.21)
- Dry Strength shall not be less than 200kN
- Wet Strength shall not be less than 100kN.
- Wet/Dry strength variation shall not be greater than 50%.
- Rock size shall be between 10mm to 50mm.
- The loose fill density of the stone infill shall be generally being in the order of 1.5t/m³.

**9.12.1.2 Gabion Gravity Retaining Wall**

Gabions are multi-celled, welded wire or rectangular wire mesh boxes, which are then, rock filled, and used for construction of erosion control structures and to stabilize steep slopes. They are used as:

- Retaining walls,
- Bridge abutments,
- Wing walls,
- Culvert headwalls

![Figure 9-22 Gabion wall](image)

The Gabion blocks are simply stacked up on top of one another. Water readily drains from the backfill through the large void spaces in the gabions. Geo fabric often needs to be placed between the wall and the soil to stop migration of fines from the soil. It is recommended to be used for riverbanks as it has resistant to flowing water and dissipate energy.

Example of gabion gravity retaining wall is shown in Figure 9-22.
9.12.1.3  **Masonry Gravity Retaining Wall/Cantilever Wall**

Cantilever walls are the most common structure used to hold back soil or other earth material. This soil which is known as backfill, is retained in positions that it would not normally be in, and would collapse under the influence of gravity without the retaining wall or if the structure failed. A cantilever wall is constructed from reinforced concrete and is built with a stem and base slab that is thinner than in other types of retaining walls. The base is comprised of a heel, which lies underneath the soil, and a toe that sits on the outer part of the wall base.

Cantilever construction is most effective when walls are less than 25 feet (about 7.6 meters) in height. A cantilever wall consists of cantilever footings, structural steel, tie beams, and concrete. A retaining wall is better to be built with a large toe as it provides better stability.

Example of masonry gravity retaining wall/cantilever wall is shown in Figure 9-23.

![Figure 9-23 Cantilever wall](image)

9.12.1.4  **Mechanically Stabilized Earth (MSE) Walls**

- Supported by soil instead of the other way around unlike other retaining wall.
- MSE is divided into three categories which is panel wall, concrete block wall, and temporary earth walls.
- The price for this wall varies from $25 per square foot to $45 per square foot.
- Most of the time used for Overpass Bridge.

The MSE wall is shown below:
9.12.1.5 **Sheet Pile Walls**

- Used to build continuous walls for waterfront structures and for temporary construction wall heights which is greater than 6 m if used with anchors.
- Can be made of steel, plastics, wood, pre-cast concrete.

The sheet pile representation is shown in Figure 9-25:

9.12.1.6 **Reinforced Concrete Block Walls**

- These walls do not rely on their mass to retain the soil. Rather, they rely on their flexural strengths to retain the soil.
- They are supported by penetration into the soil or by anchoring systems.
9.12.1.7  **Contiguous Pile Wall**

- Used as deep excavation supporting system.
- These piles were designed as cantilever retaining systems without provision of anchors.
- Lack of inadequate space at town centres goes for deep vertical excavations, which require supports that are designed to consume minimum construction space.
- Diameter and spacing of the piles is decided based on soil type, ground water level and magnitude of design pressures.
- Centre to centre spacing of piles is kept slightly greater than the pile diameter.
- Secant bored piles which are a part of contiguous pile wall are formed by keeping this spacing of piles less than the diameter.
### 9.12.2 Advantages & Disadvantages of Retaining Walls

The advantages and disadvantages of retaining walls are tabulated in Table 9-6.

<table>
<thead>
<tr>
<th>Type of Retaining Wall</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
</table>
| Crib Gravity Retaining Wall    | • Ease of construction  
• High strength, good stability and safe.  
• Low cost.  
• Able to be used for all kind of slopes. | • More space needed.  
• Cannot be used in passive soil. |
| Gabion Gravity Retaining Wall  | • Easy to transport and install   
• Various sizes to suit different design limit.  
• Little maintenance required.  
• Resist breakage and separation due to flexibility.  
• Allows natural drainage if there is seepage from soil. | • Can be dangerous to public.  
• Size of rock is required.  
• Limited to small drainage areas.  
• More expensive  
• May lead to heavy wear or tear due to bed load movement.  
• More slopes are needed and takes more space. |
| Cantilever Wall(Underpass)     | • Unobstructed open excavation.  
• Do not require installation of tiebacks below adjacent properties.  
• Offer a simpler | • Max excavation is needed.  
• Not recommended to use cantilever walls next to adjacent buildings. |
<table>
<thead>
<tr>
<th>Construction Procedure</th>
<th>Control of lateral wall displacements depends on the mobilization of passive earth resistance.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>For deeper cantilever excavations, the wall stiffness may have to be considerably increased.</td>
</tr>
<tr>
<td></td>
<td>Limit the available space within the excavation.</td>
</tr>
</tbody>
</table>

### Mechanically Stabilised Earth Wall (Overpass Bridge)

- Most economical
- Most commonly constructed.
- Requires small space.
- Attain a greater traffic capacity in smaller right-of-ways.
- Cannot be used for all type of soil.

### Sheet Pile Wall

- Provides higher resistance to driving stresses.
- Light weight
- Can be reused on several projects.
- Provides a long service life above or below the water table.
- Easy to adapt the pile length by either welding or bolting.
- Not advisable to use for low strength soil.
- Cannot be used in hot condition places.
- Has geologic and geomorphic failure.
<table>
<thead>
<tr>
<th>Reinforced Concrete Block Walls</th>
<th>Contiguous Pile Wall</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Their joints are less apt to deform during driving.</td>
<td>• Traditional piling equipment’s can be resorted for their construction.</td>
</tr>
<tr>
<td>• It embraces various shapes.</td>
<td>• Considered more economical than diaphragm wall in small to medium scale excavations due to reduction in cost of site operations.</td>
</tr>
<tr>
<td>• It can be assumed to be more or less monolithic.</td>
<td>• Restricts ground movements on the</td>
</tr>
<tr>
<td>• Connections are homogenous with rest of the frame.</td>
<td>• Perfect alignment of piles is often difficult to achieve at site, and this in turn is found to affect the dimension and alignment of the Capping beams.</td>
</tr>
<tr>
<td>• It is easily used for two way structural systems</td>
<td>• Some concrete and steel area remains under-utilized.</td>
</tr>
<tr>
<td>• It is not necessary to pay for crane on site.</td>
<td>• Anchored easily loose if erosion occurs.</td>
</tr>
<tr>
<td>• Construction can proceed independently of weather conditions.</td>
<td>• A lot of equipment and staff is needed.</td>
</tr>
<tr>
<td>• Better working conditions.</td>
<td>• Easily rust.</td>
</tr>
</tbody>
</table>
9.12.3 Effect of Ground Movement on the Retaining Wall Structure

Ground movement is normally affected by the pore water pressure, permeability of soil and the shrinkage and expansion of soil due to the changes in weather condition and even by liquefaction of soil. Thus, this applies to the piling as well. According to ASTM D6230, the ground movement are normally tested using method as shown below:

- Inclinometers - measuring deformation along the pipe and inclination of the probe with respect to the line of gravity.

9.12.4 Recommendation

Density of soil generally changes from stiff to hard, and it is not advisable to use large excavated walls as it could be hard to penetrate to the desirable depth. It is recommended to use mechanically stabilized earth walls for the overpass bridge in this project and cantilever walls for the underpass. MSE walls are economical and give good traffic conditions when used for the overpass but are not desired for the underpass and it does not have the ability to support soil which has high dilatancy. It is recommended to use contiguous walls for the underpass as it uses less space and gives a better factor of safety than other walls. Both walls are commonly used also in South Australia. Thus, both walls are incorporated and designed based on AS 4678: Retaining wall standard.
9.13 Pavement Design

9.13.1 Overview

The most common types of pavements are rigid and flexible pavements. In this case, flexible pavement was suggested for the design pavement along South Road. A flexible pavement structure is generally composed of unbound granular and/or stabilized materials and/or asphalt. Flexible pavement can be constructed in stages (staged construction) and, in many cases; repair of underground services is simpler than rigid pavements. Based on the study area, the length of the pavement along South Road is approximately 650m. The width of the pavement (for both directions) is approximately 33m including the future upgrade for three lanes. For the design project, the width of the pavement considered is only two lanes in each direction which is 13.3m (total width of the pavement is 26.6m). Moreover, the depth or thickness of the pavement is approximately 550mm (subgrade not included).

As shown in the figure below, the flexible pavement layers transmit the vertical or compressive stresses to the lower layers by grain transfer through contact points of granular structure. Besides that, the vertical compressive stress is at a maximum on the pavement surface directly under the wheel load and is equal to contact pressure under the wheels. Due to the ability to distribute the stress to a large area in the shape of truncated cone the stresses get decreased in the lower layer. Top layer has to be strongest as the highest compressive stresses. To be sustained by this layer, in addition to wear and tear, the lower layer have to take up only lesser magnitude of stress as there is no direct wearing action die to traffic loads, therefore inferior material (low quality material) with lower cast can be used in the lower layers.

![Figure 9-28 Distribution of pressures under single wheel loads](image)
The five types of common material use in pavement design are unbound granular materials, modified granular materials, stabilized materials, asphalt, and concrete. In this case, the material that will not be used for the flexible design pavement is concrete. Figure 9-29 shows the pavement structure of a flexible pavement.

![Figure 9-29 Flexible pavement structure](image)

9.13.2 Assumptions

- Wearing Surface – Asphalt (AC10H) [40 – 200mm thick].
- Base – Asphalt, Granular working platform or insitu stabilization (AC14HN) [150mm thick].
- Sub base – Granular, CTCR or insitu stabilization [150 – 200mm thick].
- *Asphalt thickness variable, usually 250-350mm.

For the flexible pavement, two types pavement was suggested which are the full depth asphalt pavements and the deep strength asphalt pavement with granular lower base. The traffic load was assumed as heavy or severe therefore, bound materials such as Asphaltic Concrete (AC) and/or Cemented Treated Crushed Rock (CTCR) are suitable for strengthening the pavements. AC is a graded aggregate, bound together into a coherent mass with bitumen. CTCR is a low content concrete. In addition, the asphalt thickness that ensures adequate fatigue life is usually more than 200mm. Thick layer of asphalt will help to improve fatigue life and rutting properties. Heavy trafficked roads have design traffic loadings greater than or equal to 5x10^6 ESA.
### Table 9-7 Purpose of various road components

<table>
<thead>
<tr>
<th>Pavement component</th>
<th>Purpose</th>
</tr>
</thead>
</table>
| **Wearing Surface**         | - Provide a smooth riding surface  
- Provide a safe, economical and durable all-weather surface  
- Minimize vehicle operating and maintenance costs  
- Minimize the rate of pavement wear and maintenance costs  
- Reduce moisture infiltration into the pavement  
- Provide suitable properties for the local environment (e.g. noise reduction, dust suppression, skid resistance and surface texture)  
- Delineate traffic lanes and shoulders, traffic islands, bicycle paths, traffic calming devices and changes in road class  
- Visually enhance the road environment for road users and adjacent residents |
| **Base**                    | - Provide the bulk of the structural capacity in terms of load-spreading ability by means of shear strength and cohesion  
- Minimize changes in strength with time by having low moisture susceptibility  
- Minimize the ingress of moisture into the pavement by having adequate shrinkage and fatigue properties  
- Assist with the provision of a smooth riding surface by having volume stability with time and under load |
| **Subbase**                 | - Provide a stable platform for construction of the base and wearing surfaces  
- Assist in providing adequate pavement thickness so that the strains in the subgrade are kept within design limits  
- Provide adequate erosion resistance to prevent pumping and erosion upon moisture entry into the pavement structure |
| **Subgrade**                | - The naturally occurring material upon which the pavement is constructed  
- An important subgrade or selected subgrade maybe placed over the natural subgrade |
### Table 9-8 Advantages & disadvantages of flexible pavement

<table>
<thead>
<tr>
<th>Flexible Pavement</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advantages</strong></td>
<td><strong>Disadvantages</strong></td>
</tr>
<tr>
<td>Low installation/completion cost</td>
<td>Low flexural strength</td>
</tr>
<tr>
<td>Road can be used for traffic within 24 hours</td>
<td>Low life span</td>
</tr>
<tr>
<td>Ability to easily open and patched</td>
<td>Maintenance or rehabilitation every 10-15 years</td>
</tr>
<tr>
<td>No thermal stresses are induced as the pavement have the ability to contract and expand freely</td>
<td>Strength of the road is highly dependent on the strength of the sub grade</td>
</tr>
<tr>
<td>Repair underground service is simpler</td>
<td>Damaged by oils and certain chemicals</td>
</tr>
<tr>
<td>Suitable for heavy traffic (depends on the thickness of each layer in pavement)</td>
<td>Deteriorates rapidly; crack and potholes are like to appear due to poor drainage (and if heavy vehicular traffic)</td>
</tr>
</tbody>
</table>

### Table 9-9 Structural & functional requirements for pavement layer

<table>
<thead>
<tr>
<th>Pavement Layer</th>
<th>Structural Considerations</th>
<th>Functional Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wearing surface (Rigid &amp; Flexible Pavements)</td>
<td>• Deformation resistance</td>
<td>• Roughness</td>
</tr>
<tr>
<td></td>
<td>• Durability (including ageing)</td>
<td>• Skid resistance / surface texture</td>
</tr>
<tr>
<td></td>
<td>• Strength</td>
<td>• Surface drainage characteristics</td>
</tr>
<tr>
<td></td>
<td>• Propensity for cracking</td>
<td>• Noise characteristics</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Reflectivity</td>
</tr>
<tr>
<td>Base</td>
<td>• Deformation resistance</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Durability</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Strength</td>
<td></td>
</tr>
</tbody>
</table>
### Table 9-10 Distress mode for rigid and flexible pavements

<table>
<thead>
<tr>
<th>Pavement Type</th>
<th>Distress Mode</th>
<th>Likely Causes</th>
<th>Materials Affected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexible</td>
<td>Rutting</td>
<td>Traffic associated:</td>
<td>All but sound cemented materials</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Densification, shoving, breakdown</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cracking</td>
<td>Traffic associated:</td>
<td>Asphalt, cemented materials, granular materials</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Single or low repetitions of high loads</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Many repetitions of normal loads</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Non-traffic associated:</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Thermal cycling</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Reflection of shrinkage cracks from underlying materials</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Swelling and shrinkage of</td>
<td></td>
</tr>
<tr>
<td>Roughness</td>
<td>subgrade materials</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------</td>
<td>--------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Variability of density</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Material properties</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Consolidation and settlement</td>
<td>All materials</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Moisture variation (Shrinkage/swelling of subgrade)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
9.14 Design Option

For our feasibility planning project, the geotechnical team will be making geotechnical based designs according to the suggestion of design of four scenarios.

The scenarios were discussed in detail in sections according to the point of feasibility and economical point of view as well with the details of costing of every option for geotechnical which is shown in the appendices section which might be a clear idea to the client about their preferences.

9.14.1 Scenario 1 Rail Overpass

This option will involve piling for the support of the railway overpass, pavement design and maintenance work. Besides that, this option does not require any excavation or retaining walls. The costing for this option is shown in Error! Reference source not found.

9.14.1.1 Piling

In this case, the team recommends use of a non-displacement continuous flight auger (CFA) method for piling. This type of piling is suitable for underpass and overpass structure. CFA is a type of bored piles that produces minimum noise and vibration compared to driven piling. The depth of the piling varies from 9m to 30m. The size of the pile cap, number of piling, and the size of piling depend on the combination or total load of the structure. Therefore, the result of the number of piling and piling dimensions was assumed. CFA method of piling was discussed further in section 9.11.3.2 which is a part of non-displacement pile. The piling cost was included under dig for column pillars.

9.14.1.2 Pavement Design

For the pavement design, the thickness of the pavement is widely dependent on the traffic load at South Road. Hence, heavy or severe traffic load was assumed, therefore the approximate thickness of the pavement 550mm. The type of pavement considered by the team will be flexible pavement (either full depth asphalt pavements or the deep strength asphalt pavements with granular lower base). The length of the design pavement along South Road will be approximately 650m as shown in the study area in Figure 9-28. Pavement design was discussed in details in section 9.13.
9.14.1.3 Rail Overpass Specifications

Figure 9-30 above shows the design for the overpass for the railway at South Road. The length of the overpass railway is approximately 765m which passes over South Road and Queen Street. Based on the railway design guidelines, the minimum heights clearance from the ground surface level to the lower deck (platform) of the overpass is 5.8m. Besides that, the team also discussed that the heights from the ground surface level to the top (fencing) of the overpass structure will be at least 10m. In this design, there will be four columns and walls to support the entire load of the overpass structure. The width of the design pavement along South Road will be about 33 m for both directions and total of 6 lanes where 2 lanes were considered for future construction. The slope of the overpass structure is 2% which has an angle of 1.145 degrees. From the calculated angle and the approximate heights of 7m, the run (horizontal distance) will be 350m approximately.'
Figure 9-31 Map 1 study area for Scenario 1

Starting elevation of the rail overpass

Starting elevation of the rail overpass
9.14.2 Scenario 2 Rail Underpass

The above option will involve excavation works, piling works, construction of retaining walls and analysis of slope stability from a geotechnical point of view.

Excavation works will involve the use of excavating machineries for removal of soil and dump trucks for transporting of soil to soil dumping grounds which is described in section 9.10. Before any excavation works are carried out for the rail line, a set of contiguous piles on both sides are to be installed to act as retaining wall for the underpass. The piles have to go deep about 11m, just above the water table, as the required excavation depth is 8m. The piles will be installed using the same technique as the deep foundation, which is the continuous flight auger (CFA). Once the piles have dried up and stabilised, excavation works can begin. On the sides where the underpass is increasing or decreasing in elevation, reinforced concrete blocks can be put in place as retaining walls instead of contiguous piles using the dumpling method as discussed in the excavation section. This will save much cost, however, using concrete blocks as retaining wall is only recommended for depth up to 3m. Figure 9-32 show the longitudinal section of the rail underpass and Figure 9-34 shows the cross section.

Once the excavation works are completed, compaction can then be done on the foundation to construct a shallow footing for the railway. Slope stability will be analysed at the sides of the underpass using computer software called “Galena”. The costing for this option is shown in Error! Reference source not found.
According to the rail structure design which is shown in Electrical and Mechanical Clearance, the depth of excavation for construction of the underpass for the rail line should be 7.68 m and the width of the underpass structure is 16.565 m.

The total length of rail underpass for Scenario 2 is 717 m.
Figure 9-35 Aerial map for excavation point for rail underpass
9.14.3 Scenario 3 Road Underpass

The above design option involves excavation work, excavation bracing, removed soil dumping, check for ground movement, piling work, retaining wall work, slope stability maintenance and analysis, filling of void spaces within the retaining wall, compaction, pavement design and maintenance work.

For excavation work, we are decided to use dumpling method as a part of excavation method and this method is described in details in section 9.10.3.1. The depth of excavation and width of excavation is shown in the sketch below. The excavation will be carried out within Torrens road till after Port Road and shown in the aerial figure below. Excavating bracing also need for temporary support after excavation for large lump of soil removal. The removed soil is transferred by truck to the proposed location which might be at the beach or near an embankment. Most importantly, ground movement must be checked for soil stability purposes.

For piling and retaining walls, we decided to use contiguous pile walls for the structural support and as the depth of piling vary from 9 m to 30 m. The wall also acts as a pile and retaining structure which is commonly used to cut cost on the excavation and piling. This option is discussed with further details in sections 9.12 & 9.13. The geotechnical team also proposed that for an excavation that is 13 m, a reinforced concrete block will be used to keep the soil in place which acts as a retaining wall rather than using contiguous pile which is cost effective as well. Slope stability was analysed using computer software (Galena) and slope maintenance will be done as well which includes the seepage and this will be based on the outcome from “Galena”. The refilling of suitable soil in the void spaces back of retaining wall to control seepage. Compaction was carried out and making the filling and soil in place. Pavement design is needed but the thickness of the pavement is widely dependent on the traffic load at South Road and the pavement design was discussed further in details in section 9.13. After fully finishing the underpass, we also must take into account the maintenance work on the pavement for every 5 years that is included as a part of our service. The costing for this option is shown in Error! Reference source not found..
According to the Austroads standard, the depth of excavation for construction of underpass for road should be about 10 m and the width of the underpass structure is about 33.0 m.

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**Figure 9-36 Cross section of excavation for South Road underpass**

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**Figure 9-37 Cross section of excavation and geotechnical work**
Figure 9-38 Top view of excavation of underpass
The total length of south road underpass for Option 3 ranges from 700 m to 2 000 m. The length is dependent on the design that is proposed from structural and geotechnical team.
9.14.4 Scenario 4 Combined Road Underpass and Rail Overpass

The final design option which is stated above involves excavation work, excavation bracing, removed soil dumping, check for ground movement, piling work, retaining wall work, slope stability maintenance and analysis, filling of void spaces within the retaining wall, compaction, pavement design and maintenance work, dig for the column pillars, installation of bridge abutments, layering of pebbles across the track. The costing for this option is shown in Error! Reference source not found.

Piling is needed for this option as large loads are being supported, but for the columns, piling is needed as a footing acting as a toe for the heavy load which has a resisting moment to the structure. The piling method that was adapted was CFA method which Continuous Flight Auger, (CFA). This piling is described in detail in section 9.11.3.2 and also pile cap is needed. Contiguous piling is used for the retaining wall for the underpass and MSE wall is needed for the overpass structure of rail line but the geotechnical team was proposing to install a reinforced concrete wall which also acts as a retaining wall for an excavation less than 3 m.

The excavation method that can be used for this option will be dumpling method or even diaphragm wall method whichever that is feasible in the area of the site and the traffic condition. This excavation method is shown in section 9.10.3.2 & 9.10.3.3.

The slope stability was analysed after excavation and this is done by using “Galena”. Thus, excavation bracing is needed to keep the soil in place for a temporary support. Compaction will be done after all earthwork, piling and retaining wall. Pavement design and construction is done according to the traffic data which is given by the transportation team for this option. Pavement is not needed for the train track and slab track will be installed and layering of pebbles will be done. Maintenance work for the work will also be done every 5 years. Pavement design that is chosen for this option is flexible pavement and described in detail in section 9.13. Austroads standard will be referred for the design option. The excavation work and related foundation work will be carried out within the study area which is shown in Figure 9-37.
Figure 9-40 Sketch of excavation for Scenario 4
Figure 9-41 Map of study area for Scenario 4
9.15 Costing

The list of costs for each scenario is laid out in table. For a more thorough breakdown please refer to Error! Reference source not found..

<table>
<thead>
<tr>
<th>Option</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 1</td>
<td>$4,192,338</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>$6,945,816</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>$8,792,561</td>
</tr>
<tr>
<td>Scenario 4</td>
<td>$11,924,902.5</td>
</tr>
</tbody>
</table>
9.16 Recommendation

In relation to the geotechnical department, based on all the options that were discussed, we recommend the outer harbor rail line overpass (Scenario 1) should be constructed. This is because it has an effective cost and the most feasible design but the only disadvantage is the excavation needed in Queen Street, it may cause disruption for the café along Queen St which is close to the Croydon train station. Hence, this option will not cause any traffic problems at south road where the heaviest vehicle are travelling and will not be possible for excavation machinery. Some of the future consideration also was undertaken such as the making excavation for 3 lane widths at each side with additional lanes for bicycle lanes and pedestrian paths. The decision making is entirely dependent on further discussion with the rest of the team part of the company with consideration of the surrounding community.
10. **Structural Investigation**

10.1 **Overview**

In order for the grade separation of South Road and the Outer Harbor rail line to take place, some form of bridge will have to be constructed. The design of the bridge will depend heavily on which of the four design options are chosen, and will obviously have an impact on the construction time and cost of the project.

The structural team at Edge Engineering has performed an investigation into the aspects of the bridge design in order to determine the most feasible bridge solution for this project. This study will cover only conceptual work of the structural design, providing a starting point for the detailed design and allowing an estimate of the total cost to be performed.
10.2 Scope

A great deal of research and investigation has been undertaken by Edge Engineering in order to determine the most feasible bridge design.

As this project will be taking place in a built up area, in close proximity to residential, commercial and industrial properties, a thorough site investigation was undertaken in order to gain a good understanding of the available space and any areas that might be of concern during the construction of the bridge.

The site visit was followed by an investigation into the potential bridge types that could be constructed. The type of bridge chosen could have a large impact on the cost and construction time of the project, and it is therefore important that all options are thoroughly investigated. A number of bridge styles were explored, and the advantages and disadvantages of each considered, allowing the most feasible bridge style to be chosen.

The possible materials that could be used in the bridge design were also researched. The material used in the bridge will have a large effect on the final design, as they will impact both the cost and the structural properties of the bridge.

Elements of the final bridge design were then investigated. Several potential beam styles were looked at, including super T concrete beams, concrete box girders and concrete and steel I beams. The beams are one of the most critical parts of the bridge, and the style of beam chosen will have a huge impact on the rest of the design. It is therefore crucial that the potential beam styles are thoroughly researched and the best style is chosen for the particular bridge.

The deck and column designs were also looked at. The design of these elements will depend on the geometry of the bridge along with type and amount of traffic that is expected to use the bridge. These factors will in turn be influenced by the design option that is chosen for the project. As they are both important features of the bridge, a great deal of care must be taken to ensure the most economical and appropriate designs are chosen. The elements chosen in this study will provide a starting point for the final bridge design.

Finally a feasible bridge option for each of the design options was developed, and an estimate of the cost was calculated.
10.3 Site Investigation

At the moment south road and the outer Harbor rail line intersect at the same grade (E on Figure 10-1) meaning traffic along south road gives way to trains which causes delays to the traffic along south road. South road at the moment is two lanes each way crossing the rail line and the rail line consists of two standard gauge rail lines side by side. Surrounding the intersection are industrial buildings, a power sub-station, several roads arterial and minor and residential housing.

Currently there is a warehouse situated on the south eastern corner of the intersection (Figure 10-1 at A, Figure 10-2). This building lies within 10m of the train line and within 5m of south road. Being so close it will play an important part of the final outcome. The option to acquire the warehouse would allow it to be demolished and taken out of the equation, but this exercise would prove very costly and have negative effects on the community. Therefore it is likely the outcome will have to work around this building. Having a road underpass and widening south road would mean south road would have to be widened on the western side of the train line. The rail overpass wouldn’t affect the building as the bridge dimensions would only be contained to the current rail corridor.
There are some other warehouses located to the north east of the intersection (point B on Figure 10-1 and Figure 10-2). These warehouses are far enough away not to be in the way of the widening of south road and the underpass. The rail overpass would also be unaffected by these buildings. However these buildings may be affected during the construction stages.

The residential houses along the western side of south road (C at Figure 10-1 and Figure 10-4) will have a big impact on the final designs. For the widening of south road, the road will need to be widened onto that land; therefore this land will have to be used. The land is already owned by the DPTI (see Figure 10-6) which means the only extra cost will be the demolishing of the houses on the property.
If the rail overpass option is taken up the properties along the rail line will need to be considered. On either side of the rail line on the western side there are many properties with residential homes. Immediately next to the rail line there is dense trees and shrubs (D at Figure 10-1 and Figure 10-5) to separate the rail line corridor to the road. Although the width of the rail bridge won’t affect these properties they will have to be monitored during construction of the bridge to make sure they aren’t damaged by the vibrations caused by machinery.

All of the properties mentioned will need to be monitored during the construction of the underpass or overpass. During construction work the vibrations caused by machinery may cause structural damage to surrounding buildings. Therefore Inspections of properties should be carried out before
construction works begin to cover legalities. Also steps will be undertaken to prevent damage to these surrounding structures which will be discussed once the final outcome is decided.

Figure 10-6 Map showing ownership of land (source DPTI)
10.4 Materials

With the development of new bridge structures, it is required that bridge materials should have higher intensity. The materials of the bridge mean those taking main loads. Nowadays timber, steel, reinforced concrete, composites and all other sorts of materials have been utilized in bridge construction. It is the characteristics of the material itself that decide whether or not to use it. As steel and reinforced concrete are the main materials used in bridge construction today, only they have been considered.

10.4.1 Steel

Steel is one of the strongest bridge materials available. Steel bridges could be constructed in long spans because of the superior performance of the material itself. It is 10 to 100 times stronger than concrete and weighs less. The higher the strength, the smaller the proportional difference between the yield strength and the tensile strength, and this means that high strength steels are not as ductile as those with normal strength, nor does fatigue strength rise in proportion to the tensile strength. Steel components are able to be produced in a short period in industry and they have the advantage of being easy to repair. However, steel bridges require a lot of maintenance and it is very expensive compared with other materials.

10.4.1.1 Advantages of Steel

- Capable of long spans
- Low weight
- Great ductility
- Easy to repair

10.4.1.2 Disadvantages of Steel

- Require a lot of maintenance
- Expensive

10.4.2 Reinforced and Pre-Stressed Concrete

Reinforced concrete is a construction material used in almost all construction works. It is the most widely used material in bridge construction because of its affordability and strength. In fact, concrete is much cheaper than steel because it is made from easily obtainable materials. Good concrete attains high compressive strength and resistance against most natural attacks, though not against de-icing saltwater, or CO2 and SO2 in polluted air. It would be comfortable for bridge users because it will cause less noise than other materials. Reinforced concrete has excellent durability
and could be produced in large quantities in industry. But, reinforced concrete is heavy in itself so that it could not be adapted in some long-span case.

Prestressed concrete is a method for overcoming concrete's natural weakness in tension. It could take advantages of high-stress concrete and reinforcement, in order to reduce the number of bars to reduce self-weight. It usually needs advanced production skills and it requires a high quality and therefore professional equipment is necessary.

10.4.2.1 Advantages of Concrete
- Affordable
- High compressive strength
- Easily produced
- Less noise

10.4.2.2 Disadvantages of Concrete
- Short span
- Low tensile strength
10.5 Bridge Research

There are three main types of bridges that could potentially be used for this project. The suitability of the bridge will depend on the cost, geotechnical condition, bridge span length or height and method of construction. The detailed descriptions for three types of bridges are shown below.

10.5.1 Truss Bridges

A truss is mostly composed of triangulated framework elements. Because the triangulated framework elements are very strong, the truss elements are capable of two transferring large tensile and compressive forces to their supports, and therefore make excellent frames for bridges. Truss bridges were commonly used in the late 19\textsuperscript{th} and early to mid-20\textsuperscript{th} century, because of their relatively simple design, which meant they could be analysed very easily without modern tools. Early truss bridges were commonly constructed from timber because of its wide availability, however more modern design are usually constructed from steel due to its high strength.

![Truss Bridge](image)

Figure 10-7 Truss bridge

Due to their efficiency, truss bridges can be used across a wide range of bridge spans, the variety of truss designs allow the bridge to be customized for a particular project. For short to medium spans,
parallel cord trusses such as Warren trusses, Pratt trusses or Howe trusses are used to minimize fabrication and erection costs. For longer spans, multiple truss types may be used.

Truss bridges do have several disadvantages. They are considered expensive today, and can be quite labor intensive to construct. They also require a great deal of costly maintenance. Truss bridges are often seen as lacking in aesthetic appeal, which could be of concern and due to their high costs, they are much less common today, with existing truss bridges slowly being replaced with more modern designs.

10.5.1.1 Advantages of Truss Bridges
- Suitable for short to medium spans
- Good strength with fewer materials

10.5.1.2 Disadvantages of Truss Bridges
- Expensive to construct and maintain
- Lack aesthetic appeal

10.5.2 Beam Bridges
Beam bridges are the simplest types of modern bridges. The structure is comprised of series parallel beams simply supported by an abutment or pier at each end. A deck is then constructed on the top of the beams. As beam bridges are simply supported, no moment is transferred at the supports. The result of this is that large bending moments occur in along the beams that must be considered during the design. Beam bridges can be constructed out of a wide variety of materials including wood, reinforced concrete or steel. There are also a number of beam styles that can be used in the construction of the bridge, each with their own advantages and disadvantages.

Figure 10-8 Beam bridge
Beam bridges can be quite cheap relative to other bridge designs as they can be made mainly out of concrete. They can sustain high loads over shorter spans and can also be quite easy to construct, with many of the components being precast off site and then simply lifted in to place during construction. This can dramatically reduce the construction time and will require less skilled labour, reducing costs.

Over longer spans, beam bridges do not fare as well, and will require the construction of piers. They are also not particularly aesthetically pleasing. Space during construction could also pose an issue, as cranes will most likely be required to raise the bridge components into place.

10.5.2.1 Advantages of Beam Bridges
- Relatively cheap
- Can support high loads over short spans
- Easy to construct

10.5.2.2 Disadvantages of Beam Bridges
- Do not perform well over longer spans
- Lack aesthetic appeal

10.5.3 Arch Bridges
The arch bridges are one of the oldest types of bridges still in use. They are composed of a curved arch spanning between the abutments at each end. This curved arch allows the vertical forces applied to the bridge to be partially converted into horizontal forces at each end. By dissipating the forces horizontally, the tensile forces in the bridge can be greatly reduced. Arch bridges can be constructed from a wide variety of materials. Traditionally they were constructed from stone; however they are now commonly made from steel or precast concrete.
A major advantage of arch bridges is the fact that they greatly reduce any tensile forces by transforming them into compressive forces. This allows them to overcome concretes major weakness, its poor performance in tension. They are also capable of spanning rather long distances without any piers. Arch bridges are often viewed as an aesthetically pleasing style of bridge.

Unfortunately, due to their shape, arch bridges can be quite difficult to erect. If constructed from concrete, the pieces of the arch have to be precast off site specifically for an individual bridge. The pieces then have to be carefully lifted into place, to ensure they are balancing each other. They also require more material to build than some other types of bridges. As they require more skilled labour and materials, arch bridges can be more costly than alternative bridge styles.

**10.5.3.1 Advantages of Arch Bridges**
- Reduce tensile load
- Capable of spanning long distances

**10.5.3.2 Disadvantages of Arch Bridges**
- Difficult to erect
- Can be more expensive
After investigating several potential bridge styles, a beam bridge appears to be the most suitable style for this particular project. They are relatively cheap and can support high loads. They are also easy to construct and require less skilled labour to erect than the other bridge styles considered. The bridge will be constructed mostly from reinforced concrete; however the beams could be either steel or concrete depending on which style of beam is chosen.
10.6 Beam Bridge Design Considerations

10.6.1 Beam Types
There is a range of different beam types that can be considered for our bridge construction. As a beam bridge has been chosen as the most appropriate choice, beams relating to this kind of bridge design will be explored. There are four beam types that need to be considered: I beam, plate girder, box girder and super T girders. Each beam type has their advantages and disadvantages and it will be these factors that will influence the final beam choice.

10.6.1.1 I Beams
The simplest beam type for bridge construction is the I beam. As the name suggests, the I beam is a beam with a cross section in the shape of an I. This cross section allows for high strength and provides an efficient form of carrying both bending and shear loads. The ideal span for this beam type is short. With the span for this bridge being large in terms of I beam design, the depth of the beam will be larger than the standard fabrication depths, therefore if an I beam design was chosen, the beams would have to be specially manufactured. One method in reducing this depth is the implementation of haunched I beams. The haunched I beam has varying depths across the section (as can be seen in Figure 10-11) in order to improve the cost effectiveness while still meeting the structural demands. Both the I beam and the haunched I beam can be manufactured out of steel or precast concrete.

![Figure 10-10 Typical steel I beam](image-url)
10.6.1.1 Advantages of I Beams

The advantages for the use of I beams are their light weight, off site manufacturing and reduced skilled labour needed on site. The I beam, in particular the steel I beam, is lightweight in comparison to the other options. This allows the support structures to be designed for smaller loads thus increasing the economics of the design. Another advantage of the I beams for this project is that they are fabricated off site reducing the need for onsite skilled workers. An advantage to using the steel I beam is that it has a greater flexibility over the length of the bridge span also.

10.6.1.2 Disadvantages of I Beams

The I beam does come with some disadvantages also. Due to the large span of the bridge (in I beam terms), the depth of the beam will be very large. Having a large depth is economically undesirable and even though the haunched I beam can reduce this depth slightly it would not be enough to counter this economical downfall. Also as such large depths are not standard manufacturing depths; the beams would have to be manufacture for the project specifically, again resulting in an increase of cost. If a steel beam is chosen, there is the problem of high maintenance costs as a result of direct weather exposure. With the large spans of the beams, heavy machinery will be required to transport the beams as well as to lift them in place, adding to the cost of construction.

10.6.2 Plate Girders

Plate girders are another alternative that need to be considered. A plate girder is a combination of separate structural steel plates that are welded together to form an I beam section or a Z section depending on the application. There are three methods in which the plate girder can be applied to the bridge; deck-type plate girder bridge, half-through plate girder bridge and a multi span plate girder bridge.

The deck-type plate girder bridge has a deck which is supported by two or more plate girders. The half-through plate girder bridge has a deck which is supported between two plate girders. The deck
usually sits on top of the bottom flange to form a U-shape cross section. Finally, the multi-span plate girder bridge can be multiple spans of the other two types in order to make a more economical solution for large span bridges.

Figure 10-12 Typical plate girder design

10.6.1.2.1 Advantages of Plate Girders
Due to its similarity to the I beam, the advantages of the I beam also apply for the plate girder. The plate girder has some additional advantages surrounding ease of design and design resultants. The design process of a plate girder bridge is relatively straight forward in comparison to other bridge designs making the design process easier. Also the girders themselves are designed individually which ensures the best possible design option is used.

10.6.1.2.2 Disadvantages of Plate Girders
As was the case in the advantages, the I beam’s disadvantages also apply to the plate girder. However, the plate girder also has the additional disadvantage of plate requirements. Depending on supply at the stage of construction, the structural steel plates may need to be sourced from other locations increasing the already high cost of construction.

10.6.1.3 Box Girders
The third alternative that needs to be looked at is the box girder. A box girder is pre-stressed concrete that forms an enclosed tube, usually in the shape of a rectangle or trapezoidal cross section, with multiple walls. If chosen for our design, the box girders would be fabricated off site in a fabrication yard. The box girder design uses incremental launching method to install the girders which places new segments of the bridge onto the completed portions until the bridge is complete.
10.6.1.3.1 Advantages of Box Girders

The advantages to the box girder are its resistance to torsion, some size factors and its load baring capabilities. The box girder has a high resistance to torsion; especially in comparison to the I beam which is beneficial in the design process. The size of the girders is also an advantage in the sense that they are larger and have sturdier flanges allowing for longer span lengths. This would reduce the requirement of additional columns along the span of the bridge in the case of the railway overpass option. The box girder can also carry a larger load that an I beam of equivalent weight. This becomes an important asset in the design process allowing for more cost effective supports to be design as a result of this weight baring capability.

10.6.1.3.2 Disadvantages of Box Girders

The box girder has several disadvantages mainly surrounding cost issues. The fabrication process of a box girder is of high expense, it is the largest of the 4 beam types. The fabrication and onsite construction requires a higher level of skilled construction than the other methods thus cost the project more. The box girder also requires regular maintenance. This can be an issue both cost wise and due to the confined spaces in which the maintenance works would need to work in. With the size of the girders, large machinery will be need for transportation to the site and for placement of the girders into the bridge. There is also the potential for corrosion with in the box girder if there is cracking in the decking.

10.6.1.4 Super T Girders

Another alternative is the use of Super T girders. In 1993, the super T girder was designed by VicRoads and has become a nationally standardised design over the past 20 years. The super T’s are
reinforced precast prestressed concrete girders that can span up to 38 metres. With the national standardisation, the girders have standard depths of 750, 1000, 1200, 1500 and 1800mm with standard flange widths of 1800, 2000, 2200, 2400 and 2500mm. As the girders are precast, they are constructed off site and delivered to the site ready to be implemented into the bridge construction. The onsite construction of the super T girders is as simple as lifting and securing the girders into place.

10.6.1.4.1 Advantages of Super T Girders
The advantages of using super T girders in bridge construction are that they are a fast, safe and economical alternative to steel beams. As they are precast and constructed off site, the onsite construction time for super T girders is fairly small. The girders are reinforced prestressed concrete which gives them incredibly high strength making them a safe design option. As the girders have little exposed metal, they require little maintenance from corrosion resulting in lower cost of maintenance. The girders themselves are generally cheaper to construct than steel beams providing a more economical alternative. Also as little to no formwork is required for onsite construction, the overall project can be cheaper.
10.6.1.4.2 Disadvantages of Super T Girders

The disadvantages of using super T girders are their weight, size and need for large scale machinery for delivery and onsite placement. The super T girders are extremely heavy in comparison to steel beams. This results in the need for an increase in capacity of the supporting structures which may result in inflated project costs. There are several issues surrounding the size of the super T girders. The span of the girder is large so large trucks are required for delivery. However, for the railway overpass, the span of the girders is insufficient to span the entire of the bridge, therefore in order to use this method of construction, a minimum of another column would have to be used, resulting in larger costs. Due to the size and weight of the girders, large cranes would be required to place them in place during the construction process.

10.6.1.5 Summary

Choosing an appropriate beam type for the bridge design is dependent on the design option that is chosen. For the railway overpass, a box girder design would be chosen while for the road underpass and the railway underpass, a super T girder design would be chosen.

A box girder design was chosen for the railway overpass for several key reasons. Although, it is an expensive design, the other 3 designs were not capable of solving the problems that the box girder design can. With the other designs, a column or multiple columns would have been placed on the road in order to support the beams. This is undesirable and highly costly. The box girder was capable of the longest span which is ideal for the span of at least 75 metres that would come with the railway overpass option. This reduces the need for additional columns which improves the cost effectiveness of the design. In addition, as the bridge can be constructed incrementally, the road closure requirements (one lane in each direction must stay open at all times) can also be fulfilled.

For the road underpass and the railway underpass, a super T girder design would be chosen for cost effectiveness reasons. The beam types were narrowed down to the I beam, plate girder and super T girder designs for these design options as the span of both was approximately 30 metres and a box girder would not be appropriate nor cost effective for this span. The super T's advantages therefore out weight the effectiveness of the remaining designs. The fast, safe and economical construction of the super T girders along with the low maintenance requirements make it ideal for both these design options.

10.6.2 Piers

A pier is as a structure that supports the bridge at specified intervals beneath the bridge deck. They carry vertical loads from the weight of the deck and the traffic on the bridge, as well as horizontal...
loads from thermal expansion. Generally a pier has one footing to support it, and bent may have two or more columns and each column has individual footings.

### 10.6.2.1 Types of Piers
There are a number of different pier styles and layouts commonly used in bridge construction. A single pier, or multiple piers arranged in a row can be used depending on the space available. Multiple slender piers are often preferable, as they would have extra flexibility which would allow more of the horizontal forces to be transferred to the abutments.

![Figure 10-15 Single and multiple column piers](image-url)

A web wall can be added between to piers ton increase stability; however this will require more material and space, resulting in a more expensive pier design. A headstock can also be constructed at the top of the pier, to allow the load from multiple beams to be transferred to a single column.

![Figure 10-16 Pier with headstock](image-url)
10.6.2.2 Summary
Due to limited space, the most feasible pier for this project would be a single pier with a headstock. The pier and headstock would both be constructed from reinforced concrete due to its high compressive strength. The type of pier chosen depends highly on the expected loads on the bridge and as these have not yet been calculated it is possible that another pier style may be more suitable. If so, this will be determined in the design stage.

10.6.3 Bridge Deck
The bridge deck is an important part of the bridge design. Having the right deck is vital as it needs to be able to cope with the loads on the bridge but not be too heavy as to add to many loads to the columns. Different deck types can come from cement, Timber and steel.

For the rail overpass and south road underpass the bridge deck will have the same decking just at different lengths. Included on the deck will be the rail line, pedestrian and cyclist access and barriers for protection. The decking will be concrete as steel and timber would prove to be impractical due to higher costs and maintenance. The exact depth of the concrete base will be finalised in the design stage but for costing purposes it will be taken as 200mm thick.

For the rail underpass there will be a road bridge which will need to have asphalt for the road, barriers and footpath for pedestrians. Again for the deck base concrete will be strongly considered but may change according the geotechnical design of the road base. The final deck designs will be finalised during the design stage.

10.6.4 Abutments
Abutments are the structures located at each end of a bridge. Their task is to transfer the vertical loads from the bridge deck and the horizontal loads due to creep and thermal expansion to the foundation of the bridge as well as retaining the embankment. They are typically constructed from reinforced concrete as they take a great deal of compressive force and very little tensile force. There are several types of abutments commonly used in bridge construction, each with their own advantages and disadvantages.

10.6.4.1 Types of Abutments
Abutments are classified by their positions with respect to the approach embankment. Common types are full height (also known as closed abutments), stub, or spill through (also known as open abutments). Integral and mechanically stabilized abutments also exist and are more recent styles of abutments. Four major styles of abutments were investigated in order to determine their feasibility for the project.
10.6.4.2 Stub Abutments

Stub abutments (also called seat abutments) are located at the top of embankments and are relatively short. They are usually founded on piles or on top of a gravel fill. A back wall spanning horizontally behind the abutments is used to retain the fill. Stub abutments are constructed after the embankment, which simplifies the fill compaction process, except for the area behind the back wall. As they do not extend the full height of the embankment, they experience the lowest lateral earth pressure of all abutments.

![Stub abutment](image1)

10.6.4.3 Full Height Abutments

Full height abutments have walls which extend the full height of the embankment, and must therefore be constructed prior to the embankment. This can make fill compaction difficult close to the abutments due to the confined space. As they extend the full height of the embankment, they experience the highest lateral earth pressures. There are several styles of full height abutments available including: cantilever, counter-fort, crib and soldier pile.

![Full depth abutment with return wing wall](image2)

Cantilever abutments consist of a vertical arm fixed to a horizontal base. Lateral earth pressures are resisted by the cantilever of the arm and the footing. Horizontal pressures are transferred to the footing by the stem, which in turn provides resistance from the dead weight of the abutment.
Counter-fort abutment walls are similar to the cantilever style abutments with the addition of counter-forts or triangular cross walls which connect the vertical walls to the base. The counter-forts provide additional resistance to the bending moments in the stems.

Soldier pile abutments consist of a number of steel piles which support horizontal lagging, usually constructed from steel or timber, to retain the embankment. The piles function as cantilevers with a bridge seat attached to the top.

**10.6.4.4 Spill through Abutments**

Spill though abutments are essentially stub abutments supported on columns. They must be constructed before the embankment. They experience lower lateral earth pressures than full height abutments as there is no solid structure preventing horizontal movement of the soil; however they make fill compaction difficult, especially between the columns. As they do not retain the slope, they are not suitable for areas near road or railways.
10.6.4.5 **Integral Abutments**

Integral Abutments are cast monolithically with the bridge deck. They are supported by a single row of piles and encase the deck beams. Integral abutments generally have a lower maintenance cost than other abutment styles and, as there is no joint between the bridge deck and natural earth, they result in a smoother ride.

![Diagram of Integral Abutment](image)

**Figure 10-21 Integral abutment**

10.6.4.6 **Summary**

Each of the abutments investigated have their own advantages and disadvantages, and not all would be suitable for this project. The most feasible abutment design for this project appears to be a full height cantilever wall. As a retaining wall will have to be constructed for three of the four design options, to allow for either the road or the rail to pass safely beneath the bridge, constructing the cantilever abutment as part of the retaining wall appears to be the simplest option. For the rail overpass option, a cantilever abutment with return wing-walls to retain the embankment would be most feasible.
10.7 Design Options

10.7.1 Scenario 1 Rail Overpass

One of the available options to separate south road and the outer Harbor train line is to build an overpass for the train to go over south road. Having the rail going over south road brings many advantages however, there are also some disadvantages.

Advantages of having a rail bridge is that it will cause minimal disruption to road traffic during construction however, the down side to this is that the rail line will have to be closed, although it may be possible to arrange the electrification of the rail to coincide with the construction of the bridge so that extra disruption won’t occur at a later date.

Constructing a rail bridge means that the bridge will only have to accommodate two rail lines rather than if it was a road bridge, which would require 6 lanes of traffic. The rail bridge will experience heavier loads than a road bridge but this will be investigated in the design stage so that the correct materials will be selected.

During the design stage the exact dimensions of the bridge will be calculated but traditionally a rail bridge will require less space than an underpass therefore less land will have to be acquired.

The bridge will be designed to go over the future expanded south road. The height of the bridge will have to be high enough to cater for trucks and busses. According to the Australian bridge standard the height of the bridge will be 5.8m high and the width of the bridge will have to cater to two standard gauge rail lines. Its final length will be determined in the design stage, with the length being determined by the future width of south road and the gradient of the rail lines. As the gradient of the rail line will have to be very small; a maximum of 2%, the bridge will be quite long. The final length would be decided in the design stage but its length may affect Queen Street which will cause extra costs and bring more disruptions which will need to be considered.

Due to the close proximity of the Croydon train station it will need to be decided depending on the final length of the bridge whether or not the station will be relocated or remain where it is. The decision of where the station will be located will be decided during the design stage, but if it was to be located on the bridge greater loads would have to be considered as well as widths. Access will have to be taken into consideration. Part of the bridge overpass could be used to allow pedestrians to safely cross south road. This would make the bridge wider and add loads but would allow pedestrians to safely cross south road without interrupting traffic flow. Safety barriers to protect pedestrians from trains will also have to be considered.
Overall the rail overpass with the correct design will cause fewer disruptions to south road but will be a long bridge which may increase costs.

10.7.1.1 Advantages of Rail Overpass
- South road could remain open during construction with minimal disruption
- Narrower bridge
- Construction work can coincide with the electrification of the outer Harbor train line
- Range of options structurally
- Less land acquisition required
- Will increase safety of the intersection

10.7.1.2 Disadvantages of Rail Overpass
- Closing the rail line
- Heavier loads
- Long bridge required

10.7.1.3 Feasibility of rail overpass
As the bridges that will be constructed for option 1 and 4 are the same, the costing will also be the same. In summary, the bridge required for these options would have a total span of 635 metres. Due to the train requiring a maximum slope of 2%, the bridge is not able to be brought down completely before Queen Street. Queen Street will have to be raised 0.8 of a metre to accommodate this. There will be 8 columns with a span of 75 metres between each column. The bridge will be 20 metres wide to allow for the dual way train service, a dual way cycling track as well as fencing and barriers that would need to be erected. Due to the large spans, both bridges will be constructed from precast concrete Box girders.

The prices have been taken from Rawlinson’s Australian Construction Handbook 2013 Edition

*Note: only material and maintenance costs have been taken into consideration

Several assumptions were made in the costing process as designs are not yet complete. It was assumed that the box girders would have a top flange width of 10m, bottom flange width of 8m, height of 3.75m (for a 20:1 span to depth ratio), web thickness of 0.15m and depth of 3m. It was calculated that 424 girder pieces would be required for these bridges. Also as no reinforcement calculations have been completed, it was assumed that 15% of the box girder would be steel reinforcement. The material costs of both the steel ($1250 per tonne) and concrete ($193 per m³) were combined to make the cost for a single box girder.
For the column, it was assumed that the column would have a diameter of 5 metres and height of 6 metres. It was also assumed that the cost for the reinforcement of the column would be equal to that of the cost of the concrete. Again, the steel ($1250 per tonne) and concrete ($193 per m$^3$) costs were combined to get the cost of a single column.

A cantilever abutment return wing walls will be constructed at each end of the bridge. Costing for this would be performed by the geotechnical team in the design stage.

As maintenance costs for a bridge of this length and style were not able to be obtained, based on the maintenance costs of the other design options, a yearly cost of $150,000 was assumed.
10.7.2 Scenario 2 Rail Underpass

This design option would have the rail line pass beneath South Road, while keeping South Road at its initial level. A path for the rail line would have to be excavated and a road bridge constructed across the top. Allowing the road to cross above the rail line would alleviate any current traffic issues due to the level crossing and as South Road would remain level, there will be no issues at the intersection with Port Road. The bridge will have to span at least 30m in order for it to cross the rail line, however the final length could be much greater than this, depending on the properties of the surrounding soil.

This option would require a significant amount of earth moving as the train line would have to be lowered enough to allow for the road bridge to be constructed above it as well as providing the minimum clearance required below the bridge. According to the Edge Engineering traffic team, the minimum height for a structure above the rail line is 9m. The bridge would then cross above the train line, while keeping South Road at a constant level.

The bridge would be required to support typical traffic loads along South Road, and would have to be wide enough to accommodate the future expansion of South Road. Including the service roads running alongside the main road, it would therefore be necessary for the bridge to be quite wide, increasing the final cost a great deal.

The total length of this bridge would depend a great deal on the properties of the surrounding soil, as they will affect the maximum possible slope of the cutting and therefore, the distance that must be crossed by the bridge. If the distance is short enough, it may very well be possible that a single span bridge could be constructed, with no piers required, which could reduce the cost and construction time. It is also likely this option would require both South Road and the Outer Harbor rail line to be closed for a period of time during construction. Detours and substitute buses would therefore have to be arranged, which is undesirable.

At this stage, lowering the rail line and constructing a bridge across it seems like a feasible option. It does have some disadvantages, however due to its short length it could prove to be significantly cheaper than some of the other design options considered.

10.7.2.1 Advantages of Rail Underpass

- Short span
- May not require piers
10.7.2.2 Disadvantages of Rail Underpass

- Large amount of earthwork required
- Wide bridge would be required
- Would require temporary closure of rail line and road

10.7.2.3 Feasibility of Rail Underpass

For this design option, Edge Engineering have concluded a concrete beam bridge would be the most feasible option. The bridge would span approximately 30m in order to cross the rail and have a width of 70m in order to allow for the expanded South Road as well as the service roads running along each side.

The bridge would be constructed from precast Super-T beams and as it only spans a short distance, would require no intermediate piers. For costing purposes, it was estimated that 30 1200mm deep Super-T beams would be required. Each beam has been estimated to cost approximately $45,000, resulting in a total cost of $1,350,000 for beams.

A full height cantilever abutment would be constructed as part of the retaining wall at each end of the bridge to provide support. A standard reinforced concrete deck would overlay the Super-T beam to provide a road surface for traffic and has been estimated to be 200mm thick. At $254/m$^3$, and with a deck area of 2250m$^2$ the total cost of the deck would be $114,300.

Steel guard rails were also included in the costing, allowing for one row of railing to run down each side of the bridge, this would require 140m of railing. At a cost of $190 per meter, the total cost of guard rails would be $26,600. This price could change if it is decided more guard rails should be used.

The total cost of materials for the construction of this bridge comes to a total of $1,490,900. Allowing for an approximate maintenance cost of $97/m$^2$ of deck area recommended by VicRoads, the cost of yearly maintenance would be $218,250.
**10.7.3 Scenario 3 Road Underpass**

For this design option a road underpass would be constructed with a rail bridge across the top. The rail bridge would remain at its initial level. The total length of the bridge mainly depends on the width of the underpass; it would need to be at least 30 meters long in order to cross South Road. As the bridge would be horizontal without any slope, it would be shorter than a rail bridge across the level road; the bridge could therefore be constructed more easily. The train would then be able to cross South Road without any interruption to traffic.

The underpass will be constructed in the middle of South Road across the rail way. It would be approximately 30 meters wide to allow for future expansions to South Road and would have a total distance of about 200 meters. The vertical distance from the bottom of bridge to the surface of underpass should be minimum 5.8 metres according to the Australian Standard, so that the trucks are able to pass beneath the rail way.

This design option will result in a significant reduction to the traffic delay on South Road and improve the safety for road users. The construction of an underpass along South Road would require...
less space to reach the required level. However, the long construction period will disrupt the traffic flow and rail schedules, and will have a greater effect on the minor roads which connect to South Road.

![Figure 10-23 Front view of typical underpass](image)

**10.7.3.1 Advantages of Road Underpass**
- Less land use
- No slope for railway bridge
- Underpass is more stable than an overpass
- Short bridge length

**10.7.3.2 Disadvantages of Road Underpass**
- Long construction period
- During the construction period, disruption to traffic flow and rail schedules will occur

**10.7.3.3 Feasibility of Road Underpass**
Having south road go under the outer Harbor rail line would require a bridge for the rail line. This bridge would be 33m long and 20m wide. The total deck area of the bridge will be 660m². On either side on the underpass there will be service roads that will remain at the current grade of the rail line.

On the bridge there will be two standard gauge rail tracks, paths for pedestrian and cyclist access. There will also be barriers on the outside of the bridge and barriers to separate the train from the pedestrian access.
The bridge will be supported by super T beams. Final dimensions of the beam will be decided in the design stage but preliminary dimensions will be 33m long, 2m wide and 1.2m deep. As the rail bridge will be 20m wide, 10 super T beams will be needed having 50mm gaps between beams. A cost estimate for the super T beams will be $45,000. Therefore the costs of the super T beams will come to $450,000.

The deck base will be concrete. The preliminary design will have the concrete 200mm thick. The deck area will be 660m$^2$. The price from Rawlinson’s Australian Construction Handbook 2013 Edition for the concrete decking is $254/m$^3$, therefore the cost for the concrete decking is $33,528.

On the bridge there will need to be barriers to separate the train from pedestrians and cyclists and barriers on the edge of the bridge to stop pedestrian from falling off the bridge. Therefore there will be four barriers 33m long totalling 132m. The cost per metre is $190 bringing the total cost of the barriers to be $25,080.

The structural cost for the bridge comes to $508,608. This cost excludes labour costs. Other costs for the road underpass will come from excavations cost and road installation costs. These costs will be worked out by the Geotechnical and Transport teams respectively.

The bridge will be supported by a full height cantilever abutment incorporated into the retaining wall at each end.

The maintenance for the bridge each year is approximated at $97/m$^2$ of deck. Thus the cost per year for undertaking the maintenance will be $64,020.

The final cost may change in the design stage but educated approximations were made so the materials cost should be close to the final price. The costs of labour will need to be estimated in the design stage.

The road underpass option comes out to be cheaper than the other options structurally. It will also require less land usage and significantly reduce delay along south road.
10.7.4 Scenario 4 Combined Road Underpass & Rail Overpass

This option explores the possibility of combining a road underpass and a railway overpass in order to create a more desirable solution. The main section of South road would become an underpass, while the service roads would stay at their current level. A railway overpass would also be constructed over the top of South road. This would eliminate the current traffic problems due to the train passing through. From pillar to pillar, the bridge would span at least 75 metres, with a total length of 635m in order to reach the required height with a 2% grade.

As with all options in this study, there are advantages and disadvantages that need to be taken into consideration. The main advantage to this design is that it solves the current traffic at the South Road level crossing. From a structural point of view, its advantages are that it provides a different alternative to current roadway structures around Adelaide, an aesthetically pleasing design and a design that would provide a different challenge to the conventional designers. While the disadvantages surrounding the bridge design are: the cost and social issues that would arise from building such a development.

Expanding on the above advantages, the greatest advantage of this structure is that it solves the current problem of train traffic interfering with the South road vehicle traffic. This construction allows both the rail and vehicle traffic to run uninterrupted which is the main aim of this project. From a structural point of view, the design provides an alternative to the current structures that have been built on the road ways of Adelaide. Having a different design around Adelaide would be aesthetically pleasing as well as providing the potential designers with an alternative to the conventional designs.

There are disadvantages that also need to be considered with this option. In terms of the bridge component, there are several issues. Due to the span of the bridge, several useful bridge design options will be ruled out. Working on the basis of an approximate 20:1 span to depth ratio, the bridge would require a depth of at least 3.75 metres which could be uneconomical. With such an uneconomical build for the bridge and the underpass also costing a large amount, the cost of this design is greater than any other option by a large amount. The building of the overpass will also cause lengthy closures for the railway which will inconvenience commuters. Building an overpass in such close proximity to the surrounding buildings also causes a privacy issue. To solve this problem, barriers would have to be built on top of the overpass to block the view from the bridge. These barriers will cause even greater bridge design issues with weight and mounting issues being at the forefront. The largest disadvantage from a structural point of view is due to the clearance required above the service roads. The height of the bridge that will be built will require a minimum clearance.
of 5.8 metres over the side road as per the Australian standards. This would mean that the overpass in this option would be the same design as it would be for a conventional overpass defeating the purpose of creating this alternate design.

In summary, this design provides several different alternatives to the conventional; however, when the advantages and disadvantages to the design are weighed up, the advantages are heavily outweighed by the disadvantages. This being the case, from a structural point of view, the option would not be an ideal option.

### 10.7.4.1 Advantages of Combination Method
- Narrow bridge
- Alternative to current structures
- Can coincide with rail electrification

### 10.7.4.2 Disadvantages of Combination Method
- Would require same length bridge as option 1
- Long bridge would be required

### 10.7.4.3 Feasibility of Combination Method
For this option we calculated a total construction cost of $2,356,932 with a maintenance cost of $214,020. As this option is similar to scenario one and Scenario 3 please refer to section 10.7.1 & 10.7.3.
10.8 Costing

Final total structural costs are shown below, for a detailed breakdown of the cost associated with this department please refer to Error! Reference source not found.

Table 10-1 Structural total costs

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<tr>
<th></th>
<th>Rail Overpass</th>
<th>Rail Underpass</th>
<th>Road Underpass</th>
<th>Combination</th>
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<tr>
<td>Total</td>
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<td>$1,490,900.00</td>
<td>$508,608</td>
<td>$2,356,932.00</td>
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10.9 Recommendations

After the thorough investigation into the feasibility of a number of different bridge styles that could be constructed to allow for the grade separation of South Road and the Outer Harbor rail line, structural engineers at Edge Engineering have been able to provide a feasible bridge style for each option.

A beam bridge constructed from pre-stressed concrete was found to be the most suitable bridge style for the project. As the bridge design would vary a great deal depending on the most feasible design option, a detailed investigation into the structural elements required for each bridge was performed.

An estimate of costing was also undertaken to give an idea of the approximate cost of each bridge design. Design option 3, the road underpass was clearly the most inexpensive option from a structural perspective, with an approximate cost of $508,608. Although this is the cheapest bridge design, it may not result in the cheapest design option. This will be decided by the total cost found by each team.
11. Urban Planning Investigation

11.1 Overview

The following section detailed by the Urban Planning team investigates the land, use of land and property, in the area identified around the intersection of South Road and the Outer Harbor Rail Line by DPTI. In more detail, it also investigates each of the four options identified by Edge Engineering regarding the impact they have on the road and the rail line, the aesthetics of each design and concerns the community may have regarding each option. This section of the report also investigates the impact on pedestrians, cyclists, transportation and property access.

The properties outlined in Table 11-1 and Table 11-2 include only those in the project area which lie directly on South Road. The majority of these are residential properties, whether privately owned or Government owned, however this stretch of South Road also includes a few industrial and commercial properties.

The majority of the houses along South Road in the project area were built between 1921 and 1945, however as shown in Error! Reference source not found., there are no heritage listed sites. As a result, heritage is not a concern for the planning, design and construction of this project.

<table>
<thead>
<tr>
<th>Western Side</th>
<th>Type</th>
<th>Quantity</th>
<th>Ownership</th>
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</thead>
<tbody>
<tr>
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<td>≈ 51 (21 state owned)</td>
<td>Private</td>
<td></td>
</tr>
<tr>
<td>Industrial</td>
<td>1</td>
<td>State Government</td>
<td></td>
</tr>
<tr>
<td>Reserves</td>
<td>1</td>
<td>State Government and DPTI</td>
<td></td>
</tr>
<tr>
<td>Commercial</td>
<td>9</td>
<td>Private</td>
<td></td>
</tr>
<tr>
<td>Public Institution</td>
<td>3</td>
<td>State Government</td>
<td></td>
</tr>
<tr>
<td>Vacant Lots</td>
<td>8</td>
<td>State Government</td>
<td></td>
</tr>
</tbody>
</table>
Table 11-2 Land uses on eastern side of South Road section

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<thead>
<tr>
<th>Type</th>
<th>Quantity</th>
<th>Ownership</th>
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</thead>
<tbody>
<tr>
<td>Residential</td>
<td>≈ 11</td>
<td>Private</td>
</tr>
<tr>
<td>Industrial</td>
<td>2</td>
<td>State Government</td>
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<tr>
<td>Reserves</td>
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<td>State Government and DPTI</td>
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<td>33</td>
<td>Private</td>
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<tr>
<td>Public Institution</td>
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<tr>
<td>Vacant Lots</td>
<td>8</td>
<td>State Government</td>
</tr>
</tbody>
</table>

The 30 year plan for Greater Adelaide has been the subject of extensive consultation with the community, local government and industry. The main focus of this plan is to return to some of Colonel Light’s original ideas for Adelaide and its surrounds. This is a concept in which there is a balance between nature and the city. This can be achieved through expanding the network of parks and greenways to encourage walking and cycling. (Government of South Australia, 2010).

Some fundamental concepts of the plan include:

- A connected transport system which will form the backbone of the urban environment;
- Walkable neighbourhoods;
- People living in the best places, near parklands, waterways and vibrant centres.

The plan specifies the need for Greater Adelaide to reduce its reliance on individual motorised transport to potentially lower the greenhouse gas emissions per capita, and create more liveable, accessible and connected communities. This can be done through projects such as this South Road and Outer Harbor rail line grade separation.

The Design must include the following to achieve part of this plan:

- Open spaces, especially parks and other vegetated areas.
- A design which has a sense of community connectedness
- A safe environment
- An area in which local businesses can thrive
11.2 Correspondences

This section of the report refers to the topics which are points of concern with similar outcomes which will impact more than one option presented in this feasibility study.

11.2.1 Public Transport

During the redevelopment of the Outer Harbor Rail line there will be disruption to the normal train services along this line. This will occur regardless of the selected outcome, although the extent will vary depending on the option. During the construction phase alternative services will be put in place to accommodate for the users of this line.

The project may consider relocating Croydon Station to one that is more convenient for the upgraded design and also for the community. It is possible that the station could be elevated to a new level for the rail line but stay in the same location, as this would allow for car parking space and does not impact on the ease of reaching the station any more than it currently does. If elevated, it is also possible that the current Queen Street precinct could be extended to run under the rail bridge.

11.2.2 Pedestrians

Pedestrian paths alongside South Road and the Outer Harbor Rail line will be incorporated into each option. By adding these new pedestrian paths, the community will be able to move around the area more freely without disrupting the traffic flow or putting lives at risk through the risky crossing of South Road. These pedestrian paths will help promote a healthy and vibrant community, as well as possibly increasing the financial profit for local business.

11.2.3 Cyclists

In the current state of South Road and the Outer Harbor Rail line there are no cycle paths along these sections. As with the pedestrian paths, cycle paths shall be added during the redevelopment alongside South Road and the Outer Harbor Rail line in each option. This means that cyclists will be able to ride in a safer environment and not be in the way of other vehicles on the road. A possible layout for new bike paths is shown in Figure 11-1
11.2.4 Property Access

Maintaining the same level of access for all properties within the project area, particularly those on South Road is a major concern, and will be given high priority. Access for each of these properties would not be required to be changed if South Road was to stay at grade level, however if South Road was to move, access roads would be introduced so as not to lose this access.

Currently traffic is unable to enter Euston Terrace from South Road due to its close proximity to the railway line and the high volume of traffic on South Road, however if the rail crossing was to be moved from grade level it is possible that this could be changed, and access could be improved.

11.2.5 Aesthetics

The visuals of a project are of a major concern to the community, and any option that this project chooses will require a structure somewhere, changing the current look of the existing area. Tunnels are the least obtrusive option; however any bridge structures can be turned into a feature. As mentioned above, it is possible that if the railway was to be lifted up, a new community precinct could be established beneath, whether this be in the form of a café, an open plaza, or even just a car park. This has been done before in various ways and locations, as can be seen in the photos below.
Figure 11-2 Pershing Square Cafe, New York, under the Park Avenue Viaduct (Dallas Fort Worth Urban Forum, 2010)

Figure 11-3 Vauduc Cafe, Paris (Vladuc des Arts Pictures, 2013)
Figure 11-4 Proposed Community Plaza under Elevated Freeway, San Francisco’s Central Corridor (SocketSite, 2012)

Figure 11-5 Car Parking under Alaskan Freeway, Seattle (Arbury, 2011)
11.2.6 Affected Businesses
The development of the Queen Street precinct is a major point of interest for the community, so the best design for this project will be one which least affects them, or which is used to enhance this area.

A challenge for the project team will be minimising disruption to the community during construction, however the long term benefits would greatly outweigh this small inconvenience. Not only will the transport network in the area be improved, but potential business opportunities will increase also.
11.3 Design Options

11.3.1 Scenario 1 Rail Overpass

Option 1 involves the separation of South Road from the railway line intersecting it, done by raising the railway line over South Road, which will remain at ground level. In doing this, safer conditions will be achieved for drivers, public transport users, pedestrians and cyclists. Road congestion will also be lessened providing a more reliable commute for users. South Road is a major Adelaide road passage and is a vital passage for commuters. In order to minimise disturbance on its users, major roadwork will be undertaken at night, keeping one lane open at all times.

11.3.1.1 Land Acquisition

In order to accommodate the development of option 1, in which the railway line will be elevated above South Road, there is some land that may need to be acquired. A large portion of the land which will have to be occupied is already DPTI owned, which is a positive in accommodating this option. However in order to account for the raising of the various framework and infrastructure required, land on the south east quadrant of the south road railway intersection will need to be attained. This particular area is shown in Figure 11-6.

Figure 11-6 South Road rail line intersection and property needing to be acquired in south-east quadrant

A large portion of the eastern side of the railway line is DPTI owned, and can be described as industrial. In contrast, the western side is more residential. Although the residential areas will not be immediately affected by the eventual outcome, property owners will need to be consulted as their land and property access may be impacted during the construction process.
In the implementation of any scenario, costing and economic feasibility is going to be an issue. Due to the immense span of the proposed railway overpass, and hence the large degree of structural framework which is to be enforced, this may cause the cost of the project to be excessive. As well as this, specific land will need to be acquired adding more cost, as mentioned earlier. The cost of acquiring industrial property in this area is approximately $300/m², and due to the approximate 4000m² which will need to be acquired, land acquisition will cost in the region of $1,200,000.

### 11.3.1.2 Road and Rail Line

The occupancy of South Road will be an issue in the process of elevating the currently intersecting rail line. It is important that the community be consulted and hence made aware of the potential impositions during construction. Due to the close proximity of Port Road, it is also a likely possibility that the intersection of Port Road and South Road may be imposed upon in this process.

As previously mentioned, the more easterly side of the rail line is amongst a more industrial area, while the western side is predominately residential. As such it may be a more community friendly and viable approach to initiate the majority of the structure on the eastern side, while limiting the amount of construction on the western side. In altering the railway line, the relocation of rail stations will also have to be considered, although the requirement that the minimum separation between rail stations of 800 metres must be kept in consideration. The shift of the current rail station, currently located approximately 150 metres from the South Road intersection between Day
Terrace and Euston Terrace, will be heavily dependent on the eventual length and elevation of the rail line.

One possible option for the train overpass is a span length of approximately 800m, as discussed by the structural team, which would require the current rail station to be moved. The likely options proposed include the insertion of the station on the future overpass, or moving the station from its current location so that it is still positioned at ground level. That would mean having the station situated approximately 400 metres away from South Road. Due to the substantial distance it would have to be moved this would not be a beneficial option for the community and the Queen Street precinct.

11.3.1.3 Aesthetics
In elevating the railway line to go above South Road, there can be a cause for concern amongst the community in terms of aesthetic appeal. Reconstructing the railway in this fashion will cause various structural frameworks to be erected. This may be an unwelcome feature. However in order to maintain the privacy of the residents from this elevated railway, this elevation could be partnered with a barrier or tunnel which can be made to be visually appealing with suitable help from architects. Elevating the railway will also open up space below for construction of parklands or landscaped areas, or could even enable an opportunity to develop more local businesses or a shopping precinct beneath the structure.

11.3.1.4 Community Concerns
The primary concern for the community in raising the railway line above South Road is the increased possibility of homeowners losing a degree of privacy due to train commuters being able to see into their property. This has the potential to be a large issue in the argument against option 1, however this can be combated by the construction of a barrier or tunnel, which will help maintain the privacy of residents, while also providing aesthetic benefits. An attractive solution can be designed with the help of other professionals such as architects.

Noise pollution is also a concern for the community and local residents. A train travelling on an elevated railway line may enhance any unwanted sound or vibration, and this is a problem that will need to be dealt with to minimise the impact on the community.

11.3.1.5 Pedestrian, Property Access, Transportation and Cyclists
Pedestrian walkways and access will be largely unaffected in the implementation of option 1 on South Road. On the upgrade of South Road, a 2 metre wide footpath will accommodate pedestrians, and a bicycle lane of 1.5 metres will be included. It is going to be a vital characteristic of the upgrade
to ensure pedestrians and cyclists will be catered for, and that they will be able to safely travel across South Road. Therefore it is proposed that a pedestrian walkway and a bike lane will be allocated on the same level as the train. Given that a width of approximately 20 metres is given for the train overpass this can be adequately imposed. Due to the high traffic rate of South Road, incorporating a lane for these users detached from the main road will particularly cater to the safety of users.

Appropriate access to the railway stations will need to be considered; a component of the project which is dependent on the location of the station, and hence the span of the railway overpass. The rail station is currently situated by Queen Street, and for it to stay at this location it would need to be elevated and placed on the overpass. In doing this, appropriate access will need to be included. This will include stairs for pedestrians, as well as the inclusion of a ramp or an elevator to enable an easy access approach for disabled commuters or parents with prams. A ramp will also cater to cyclists using the bike lane, which will be elevated with the train overpass. Upon the conclusion of the project, property access is also likely to be unaffected. However during the construction phase of the project, appropriate detours will need to be considered and implemented.
11.3.2 Scenario 2 Rail Underpass

The road underpass option would mean that South Road would be diverted under the rail line, whilst keeping the rail line at its initial level. A path for South Road will be excavated and a rail line bridge constructed across on top.

11.3.2.1 Land Acquisition

To build South Road under the existing rail line would require the road to be widened from what it is currently. Due to the close proximity of residential properties to South Road this would normally be a problem, however DPTI and the Local Government have been planning ahead, and have already been purchasing properties in the area. Figure 11-8 shows the properties which are already owned by DPTI and the Local Government.

![Figure 11-8 DPTI and Local Government Owned Parcels](image)

Having surveyed the surrounding residential and industrial properties, an approximate costing for land acquisition has been calculated. With residential properties being valued at $500 per square
metre, and industrial properties at $300 per square metre, the approximate total price for land acquisition along South Road in the project area has been valued at $2.1 million.

### 11.3.2.2 Road and Rail Line

The rail line will be left in its current state. There may be a possible platform upgraded to 7.8 metres wide by 120 metres long, in order to accommodate four passenger rail cars. If the South Road underpass is chosen to be the final design, it will offer a variety of benefits, including:

- Improved North-South road links and improved connections to public transport services
- Faster emergency response times for Fire, EMS and Police personnel by reducing delays when crossing the rail line
- More efficient North-South traffic flow
- Improved driver and pedestrian safety by eliminating an existing at-grade rail crossing at South Road.

With this process, a wider non-stop highway will be produced, as well as additional side access roads combined with bike lanes. The side access roads are to be used for entry to and from South Road to all the other roads in surrounding areas and also to allow access to Port Road.

There are also disadvantages that need to be considered for this option, issues which include the large amount of earth works required and the relocation of utility services along the road.

### 11.3.2.3 Aesthetics

A major focus of this project is to improve the general aesthetic of the underpass, while engaging with the local community and users to produce a design which has longevity. Community engagement is a critical aspect of any major road project.

### 11.3.2.4 Community Concerns

The main concern for community is the construction process. Issues such as road closures and safety are of paramount importance. This project will require a traffic management system for works to be undertaken safely, whilst ensuring traffic flows are well managed. Construction impacts will be minimised where possible, including noise, dust and vibrations.

In order to keep the community connected, public spaces with plenty of vegetation would be desired. It is preferable in any option that the park on Day Terrace as shown in Figure 11-9 is retained or upgraded to keep with the community values.
11.3.2.5  Pedestrian, Property Access, Transportation and Cyclists

This underpass option would allow the current public transport network to continue during construction, with the Outer Harbor train running as normal. The bus service along South Road will be able to run with much less travel time due to no longer needing to stop at the rail.

Cycle lanes are to be added along the length of South Road. As part of the 30 Year Plan for Greater Adelaide, it would also be preferable if cycle paths were added alongside the rail line. Pedestrian paths could also be added alongside the cycle lanes of both South Road and the rail line. Due to the large amounts of traffic along South Road, pedestrian crossings can be dangerous and disruptive to the flow of vehicles. An alternative solution would be to have pedestrians cross over South Road by the paths alongside the train line.

During the construction stage, there would be limited property access and disruption to traffic along South Road. On completion of the project, access to side streets will be through the side roads adjacent to South Road. Entry and exit points from South Road would be located at major intersections.
11.3.3 Scenario 3 Road Underpass

Option 3 involves the separation of South Road from the railway line intersecting it, keeping South Road at ground level, while lowering the railway line creating an underpass. In doing this, as in the case of the various other options proposed, safer conditions will be achieved for drivers, public transport users, pedestrians and cyclists, while road congestion will also be eased providing a more reliable commute for users. South Road is a major Adelaide road and is a vital passage for commuters. In order to minimise disturbance on its users, major roadwork will be undertaken at night, while one lane will be open at all times.

11.3.3.1 Land Acquisition

The Land acquisition requirements for option 3 are parallel to that of option 1. However as this particular construction is to involve the majority of works underground, landowners will have to be made aware of the works below the surface in order to avoid legal issues.

In the implementation of any scenario, costs and the economic factors of the feasibility is going to be an issue. Due to the scale of work that will need to be undertaken beneath the surface, the cost of excavation may be at the high end of the scale. This is due to the large amount of services under the surface such as water, sewer, electricity and gas. As well as this, as previously stated specific land will need to be acquired adding more cost. The cost of acquiring industrial property in this area is approximately $300/m², and as approximately 4000m² will need to be acquired, land acquisition for the project will cost in the region of $1,200,000.

11.3.3.2 Road and Rail Line

The road and rail line specifics for option 3 are very similar to those of option 1. Different from this however is the large amount of excavation required underneath South Road. This is likely to come at a great cost. The rail line going beneath the surface will have a span of approximately 75 - 80 meters; therefore the rail station located by Queen Street is able to stay in its location.

11.3.3.3 Aesthetics

Altering the construction of this road and railway intersection so that the railway line will be placed underneath South Road will have great benefits in terms of pleasing the community aesthetically. In its current position the railway line does not offer a great deal of visual appeal. Placing the line beneath South Road will hide what could be considered to be an eye sore. As well as this, space will be cleared on the surface allowing for the construction of recreational parks and landscaped areas, which can then be utilised by the public and surrounding community. As a result, placing the railway line beneath South Road has a multitude of benefits aesthetically.
11.3.3.4 Community Concerns
The community surrounding the area expressed concerns that placing the railway line beneath South Road so that it acts as an underpass, may encourage rather than deter unwanted anti-social behaviour. This behaviour includes graffiti or vandalism due to darkened areas, and to combat this increased lighting in these areas may be beneficial. As well as this, a large amount of soil excavation beneath South Road and various surrounding properties may need to be undertaken, raising concerns as to how this may affect these surrounding properties. Separating the railway line in this manner may also bring up economic concerns as it is a method which will most likely prove more costly, than for example raising the railway.

11.3.3.5 Pedestrian, Property Access, Transportation and Cyclists
The pedestrian, property access, transportation and cyclist specifics for option 3 are largely parallel to that of option 1. In order to cater to cyclists and pedestrians wishing to safely cross South Road, specific bicycle lanes will be attributed to them on the same level as the train underpass. This will require entrance and exit paths connecting the surface laneways below the surface allowing easy access. This option will allow the rail station to remain at ground level, thus proving to be slightly more accessible.
11.3.4 Scenario 4 Combined Road Underpass and Rail Overpass
This option incorporates lowering the main section of South Road under the rail line, while elevating the rail. The majority of the works will be undertaken at night, reducing the impact on road users. Soil taken from the road excavation can, if suitable, be used in the elevation of the rail.

11.3.4.1 Land Acquisition
The majority of the area around the rail line is owned by the government. There are a few commercial buildings that will need to be acquired in order for the widening of South Road for the underpass and the rail overpass. The current cost for commercial/industrial land in this area is approximately $300 per metre square, and there is approximately 4,000 m$^2$ combined on either side of the rail line that needs to be acquired by DTPI for these works to be undertaken. The cost is then approximated to be $1,200,000. The land that is most likely to be acquired for this redevelopment option is shown in Figure 11-10 below.

![Figure 11-10 Land to be acquired for Option 4](image)

11.3.4.2 Road and Rail Line
With the future upgrade of South Road, allowances need to be incorporated into this current project. A wider road than the current situation with added side access roads need to be allowed for, and this must be considered when designing the length of the railway line. As the grade of South Road is to be lowered, access to this road will be altered to its current state, although as it is not a
full underpass the traffic will most likely still be able to enter and exit using Port Road. The side access roads that are to be built along South Road will remain at grade and therefore these roads will be used for access to and from the side roads until the side roads meet major intersections at which there will be entry and exit points to and from South Road.

The rail line is to be elevated according to the Australian Bridge Standards, and therefore it will need to be elevated over Queen Street. This means that the current Croydon station will need to be relocated. The best option is to keep the station in position and to elevate the station to the height of the rail line. This will then be accessible to the public by a ramp which is part of the cycle and pedestrian paths alongside the rail line. An elevator and possibly stairs are also to be incorporated into the design, to ensure that the station is accessible to all users. By having the train line elevated over Queen Street, the traffic along this road will be able to flow more freely and could possibly increase the business to the Queen Street Precinct.

11.3.4.3 Aesthetic
Due to this option being a half lowered road and a half elevated rail, the visual impact will be quite different to the current look of the site. The impact may not be as harsh as the other options due to the road not having to be lowered/underground as deep as a full underpass. There will still be a barrier on the elevated railway, which can be architecturally designed to be more visually appealing to the community. Vegetation should also be added alongside the rail line as a noise dampener, but to also give a more visually appealing look to the area.

11.3.4.4 Community Concerns
Safety is a major concern to all within the community. Because of the elevation of the railway there will be guard rails put in place to minimise danger from objects falling and landing on South Road below. Lighting is another issue in the community, as inadequate lighting can lead to people within the community feeling unsafe. Adequate lighting is to be added along South Road through the underpass and also along the overpass section of the rail line, this will help in preventing activities such as vandalism and potential suicide.

The noise and vibration levels during both construction and the final use of the area are another concern to the community. During construction the source noise level (continuous) should not exceed 45dB (A) and source noise level (maximum) should not exceed 60dB (A) as stated in the South Australian Environment Protection (noise) Policy from 2007. After construction both general road and rail noise is exempt from the policy, though the elevated rail could cause an increase in the noise levels, as well as the vibration levels. Possible impacts of both the increased noise and
vibration levels include: general annoyance of community, sleep disturbance, increased heart rate, increased blood pressure, and impaired performance due to lack of sleep.

Another concern is that of the Queen Street Precinct and its future business. By elevating the train line over Queen Street it is possible that the area will change dramatically. As the current option is to elevate the station to the height of the train line but to leave it in relatively the same position, the current car park will still be utilised. It is believed that this will ensure that the current users of the station will continue to use this area and keep the business afloat. With the removal of the rail crossing over the road, there is potential for an increase in traffic through this area which could potentially help to improve the businesses in this area.

11.3.4.5 Pedestrians, Property Access, Transportation and Cyclists

Currently there are no cycle paths and very limited pedestrian paths along South Road. With the upgrade of the Outer Harbor Rail line and South Road, bicycle lanes will be added to the side roads along the length of South Road. Pedestrian paths will also be added; these paths will be paved along the side roads and also be added to access the Croydon rail station. As part of the 30 Year Plan for Greater Adelaide, DPTI would like to incorporate bicycle paths that follow along the route of the rail line. This would mean incorporating a bike lane to run up alongside the train line to the station and then down the other side, this would also be the pedestrian access to the station and for ease of crossing over South Road. An elevator should also be included in access to the station to make sure that it is accessible for all.

During the construction there will be a disruption to the normal usage of the rail line, to accommodate for this bus services will be put in place for the Outer Harbor line through the affected areas. Once the construction is completed the rail service will return to normal.

There will be little impact in the access to surrounding properties after the construction is complete. During the construction stage the side roads adjacent to the rail line, Euston Terrace and Day Terrace, may be reduced to one lane to allow for the works to be undertaken. Access to Queen Street may also be limited and at times traffic may need to be diverted.
11.4 Advertisement and Community Consultation

Since the Grade Separation of South Road and the Outer Harbor railway line is a big scale project, the communities in the area will be affected in at least one way. The communities from Croydon, Ridleyton, Brompton and West Hindmarsh are the ones which would be most affected. To keep the residents and general public around the area up-to-date with the development of the project, appropriate measures need to be taken. This involves advertising the project and community consultation.

11.4.1 Advertising of South Road & Outer Harbor Rail Line Grade Separation

There are a few ways of advertising the project to the community around the area. This includes local newspapers, flyers, postcards and posters regarding the project, and keeping the project updated on the local council website.

11.4.1.1 Local Newspaper

The local newspaper for the studied area is the Weekly Times Messenger, as can be seen in Figure 11-11, a map showing the location of local newspapers.
The advertising rate for the Weekly Times Messenger is provided in Table 11-3. Messenger papers are sold on a ‘per module’ basis. Each messenger page has 16 module spaces available (4 modules high by 4 modules wide. 92mm high x 63mm wide each module). For example, a quarter page in the Weekly Times would be 4 modules wide. This would total up to be $412.50 per module = $1650.00 per insertion including GST with full colour.

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The use of local newspaper is by far one of the best tools of advertising for the project. Based on the research done by the Circulation Audit Board (CAB), the Weekly Times were circulated 67,350 times and the readership survey done by Roy Morgan Readership Survey from April 2009 to March 2011 found that there are 66,000 readers for the Weekly Times.

11.4.1.2  Flyers, Postcards and Posters
Flyers, postcards and posters should be designed to be distributed to the community around the area. The information attached to the materials should explain the benefits of the project, up to date information about the ongoing project and also the cost. The materials should also contain contact
details for the project team so the community can contact them if they have any concerns. Posters could be posted at shops around the area.

The printing prices provided by Officeworks are listed in the table below. The pricing for the document prints are based on the colour, page size and number of pages.

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11.4.1.3 Local Council Website

The local council for the project area is Port Adelaide Enfield Council. The local council have a good up-to-date website that is informative for the residents within the local council area. This website should be used to advertise the South Road and Outer Harbor Rail Line Grade Separation Project.

The information regarding the project could be linked under the Project and Development section. A snapshot of the website and the direct link to it is provided below in Figure 11-12
11.4.2 Community Consultation

Community consultation is necessary to establish a formal communication session between stakeholders, the project team and DPTI. The parties involved during the consultation session would be a community consultant, a DPTI officer who is directly involved with the project and the stakeholders. The purpose of this consultation session is to answer any questions by the stakeholders regarding the project.

Meetings between the parties involved could be held at the community centres. The community centres that are nearby and available to the project team are the Enfield Community Centre, Hillcrest Community Centre, Kilburn Community Centre and LeFevre Community Centre. There are also halls and reserve areas within the council’s jurisdiction area that are available for hire at reasonable rates and these are listed on the council’s website. An example of the hire details are included in [Error! Reference source not found.].

Booth or kiosk stations could also be set up at the community centre. The booths are set up to give out flyers regarding up to date information on the project. Besides that, a suggestion box installed at the booths would be helpful to get feedback from the community around the affected project area. A dedicated email account and phone line could additionally be set up to make it easier for the stakeholders to communicate directly with the community consultants regarding their concerns.
11.5 Recommendation

The Urban Planning Departments recommendation revolves highly on community interest. There were a few aspects that were taken into consideration by the department to come up with a valid recommendation; aspects such as

- Land acquisition
- Property access and community concerns
- Aesthetics
- Pedestrians and Cyclists

In terms of land acquisition, most of the options are similar in cost at $1.2 million except for the option with South Road as an underpass, which is expected to be roughly $2.1 million. Costing for the project plays a vital role in considering the option that is most feasible for the project.

Generally, all of the options result in good property access around the area, as better flow of traffic would be introduced once the project is completed. With easier property access to the area, it would increase the opportunity for the local businesses to expand and thus be a great benefit to the community. There are a few community concerns with each of the options. With the rail line as an overpass or half rail overpass, there are concerns regarding the community losing their privacy and also any unwanted objects falling from the overpass below if the train station is elevated above. This concern could be avoided by creating a fence which could be architecturally design and this feature could be a great landmark for the community and is aesthetically pleasing compared to a normal overpass bridge. Besides that, another concern would be the increase of unwanted anti-social behaviour if an underpass is introduced as the solution. This could be avoided by having adequate lighting around the area to ensure unwanted anti-social activities are not happening around the area.

All of the options do take pedestrians and cyclists into consideration but with the rail underpass, it creates more safety concerns. Below is a table showing how the department has ranked each option studied in this feasibility stage.
Table 11-5 Options ranking based on department discussion

<table>
<thead>
<tr>
<th>Option</th>
<th>Land Acquisition</th>
<th>Property Access</th>
<th>Aesthetics</th>
<th>Pedestrians and Cyclists</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Railway line over South Road</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>10/12</td>
</tr>
<tr>
<td>South Road under railway line</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>8/12</td>
</tr>
<tr>
<td>Railway line under South Road</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>9/12</td>
</tr>
<tr>
<td>Half rail overpass – Half road underpass</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>8/12</td>
</tr>
</tbody>
</table>

Based on the table above, the Urban Planning Department have agreed to recommend that the railway line over South Road should be implemented for the South Road and Outer Harbor Rail Line Grade Separation Project.
12. **Benefits versus Costs**

The cost benefit analysis is a tool used to weight-up and quantify the benefits of a project. It theoretically shows which project option will reap the highest rewards per dollar spent. This is achieved by calculating the cost benefit ratio.

\[
\text{Benefit Cost Ratio (BCR) equation}\]

\[
\frac{\text{Monetised Benefits}}{\text{Monetised Costs}}
\]

A ‘Net Present Value’ will also be calculated in order to evaluate the total cost of the project over the 30 year period at today’s current monetary rate (ie. minus escalation).

\[
\text{Net Present Value (NPV) equation}\]

\[
\frac{\text{Total Present Value of Benefits}}{\text{Total Present Value of Costs}}
\]

Benefits are monetised from factors that will bring a benefit from the project doing ahead. Factors such as transport benefits, social benefits and environmental benefits affect the benefits that are created. Costs are determined by the sum of the costs running the whole life of the project.

### 12.1 Economic Appraisal

The basic assumptions for the economic appraisal of the project include:

- An economic assessment period lasting 30 years
- Construction to commence in 2016
- An escalation rate of 6.5%
- A discount rate of 7%

#### 12.1.1 Monetised Costs

The costs that will be included in this economic appraisal include:

- Construction costs
- Operation and maintenance costs

#### 12.1.2 Monetised Benefits

Benefits that will be included in this economic appraisal include:

- Benefits of major arterial roads being separated from grade total a present value benefit of $120 million
- Benefits of minor roads being separated from grade total a present value benefit of $2 million
- Also any additional benefits that are added to the surrounding areas increasing social aspects, shopping aspects and liveability will have a total present value of $2 million
12.2 Final Collated Cost for all Scenarios

Below in Table 12-1 you can see the costs for each department’s scenarios (1 through 4). It also contains the maintenance costs that attribute to each department. As can be seen, the only department that was able to calculate maintenance costs was the structural division. Geotechnical maintenance costs were incorporated into the department’s construction cost for a 10 year period. This was mainly because cost of doing repairs on bridges is well documented, whereas transport and water & service maintenance costs are harder to find, even though they do exist. Advertising costs have not been factored into this analysis as they would be redundant to the calculation. This is because the advertising costs are all the same for each scenario.

<table>
<thead>
<tr>
<th></th>
<th>Costs</th>
<th>Maintenance Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Transportation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scenario 1</td>
<td>$900,360.00</td>
<td>$-</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>$1,602,360.00</td>
<td>$-</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>$943,560.00</td>
<td>$-</td>
</tr>
<tr>
<td>Scenario 4</td>
<td>$2,423,160.00</td>
<td>$-</td>
</tr>
<tr>
<td><strong>Water &amp; Services</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scenario 1</td>
<td>$377,728.60</td>
<td>$-</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>$1,242,359.60</td>
<td>$-</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>$1,376,349.40</td>
<td>$-</td>
</tr>
<tr>
<td>Scenario 4</td>
<td>$1,651,447.60</td>
<td>$-</td>
</tr>
<tr>
<td><strong>Geotechnical</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scenario 1</td>
<td>$4,192,338.00</td>
<td>$-</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>$6,945,816.00</td>
<td>$-</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>$8,792,561.00</td>
<td>$-</td>
</tr>
<tr>
<td>Scenario 4</td>
<td>$11,924,902.50</td>
<td>$-</td>
</tr>
<tr>
<td><strong>Structural</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scenario 1</td>
<td>$2,356,932.00</td>
<td>$150,000.00</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>$1,490,900.00</td>
<td>$218,250.00</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>$508,608.00</td>
<td>$64,020.00</td>
</tr>
<tr>
<td>Scenario 4</td>
<td>$2,356,932.00</td>
<td>$214,020.00</td>
</tr>
<tr>
<td><strong>Urban</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scenario 1</td>
<td>$1,200,000.00</td>
<td>$-</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>$2,100,000.00</td>
<td>$-</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>$1,200,000.00</td>
<td>$-</td>
</tr>
<tr>
<td>Scenario 4</td>
<td>$1,200,000.00</td>
<td>$-</td>
</tr>
</tbody>
</table>

Below (Table 12-2) is the total summed construction costs of each scenario

<table>
<thead>
<tr>
<th>Table 12-2 Totalled construction costs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Scenario 1 Costs</strong></td>
</tr>
<tr>
<td><strong>Total Scenario 2 Costs</strong></td>
</tr>
<tr>
<td><strong>Total Scenario 3 Costs</strong></td>
</tr>
<tr>
<td><strong>Total Scenario 4 Costs</strong></td>
</tr>
</tbody>
</table>
12.3 Benefit for the Project

As stated by the client (DPTI) major and minor road benefits are seen in Table 12-3. The major road benefits come from separating the major freight corridor of South Road from the outer harbor rail line. The minor road benefits are applied to an option if back streets such as Queen Street which have a shopping and café district on them stay in use and do not become affected. Lastly any additional benefit has been added due to department innovations such as in scenario 1 & 4 where there is space under the rail bridge for a mixed land-use functional promenade which would ultimately add potential profits and connectivity to the already established precinct in that area. Scenario 1’s benefits entailed the major, minor, and additional road profits; scenario 2 entailed only the major road profit; scenario 3’s benefits entailed the major and minor road profits and scenario 4’s benefits were the same as scenario 1.

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major</td>
<td>$120,000,000.00</td>
</tr>
<tr>
<td>Minor</td>
<td>$2,000,000.00</td>
</tr>
<tr>
<td>Added</td>
<td>$2,000,000.00</td>
</tr>
</tbody>
</table>
12.4 Cost benefit analysis

Table 12-4 shows the Total Cost (incl. maintenance), Total Benefits, present value costs (PVC), Present Value Benefit (PVB), Net Present Value (NPV) and the Benefit Cost Ratios for each scenario over a 30 year period of time. The table shows that scenario 1 is the best option for this project as it yields the greatest benefit per cost, even though it has the highest net present value (NPV) of all scenarios.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Cost ($)</th>
<th>Benefit ($)</th>
<th>Present Value Cost (PVC) ($)</th>
<th>Present Value Benefit (PVB) ($)</th>
<th>Net Present Value (NPV) ($)</th>
<th>Benefit Cost Ratio (BCR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 1</td>
<td>13,227,358</td>
<td>3,472,000,000</td>
<td>6,893,405</td>
<td>1,431,490,532</td>
<td>208</td>
<td>262</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>19,492,436</td>
<td>3,360,000,000</td>
<td>10,168,263</td>
<td>1,385,313,418</td>
<td>136</td>
<td>172</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>14,549,618</td>
<td>3,416,000,000</td>
<td>9,162,286</td>
<td>1,408,401,975</td>
<td>154</td>
<td>235</td>
</tr>
<tr>
<td>Scenario 4</td>
<td>25,120,962</td>
<td>3,472,000,000</td>
<td>17,170,456</td>
<td>1,431,490,532</td>
<td>83</td>
<td>138</td>
</tr>
</tbody>
</table>

For a more in depth review of the cost benefit analysis please refer to Error! Reference source not found..
13. Final Recommendation

This Feasibility Study investigates the issues and benefits that will arise when four different design options are implemented for the South Road and Outer Harbor rail line grade separation. These four options include:

- Rail line overpass
- Rail line underpass
- South Road underpass
- Half rail overpass and half road underpass

Each sector of our company investigated the cost and benefits of these four options and recommended the best option according to their sector. The results of these recommendations are:

<table>
<thead>
<tr>
<th>Division</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural</td>
<td>Option 3</td>
</tr>
<tr>
<td>Geotechnical</td>
<td>Option 1</td>
</tr>
<tr>
<td>Urban Planning</td>
<td>Option 1</td>
</tr>
<tr>
<td>Transport</td>
<td>Option 1</td>
</tr>
<tr>
<td>Water and Services</td>
<td>Option 1</td>
</tr>
<tr>
<td>Environmental</td>
<td>Option 1</td>
</tr>
</tbody>
</table>

The recommendations listed above were based on the advantages and disadvantages of each scenario according to their specific sector and did not look at the overall big picture of the project. To analyse the feasibility of each scenario across the whole project a cost/benefit analysis was performed. This used the costs that were produced by each sector’s investigations above. The benefits are much harder to calculate as a monetised value has to be applied to a social economic factor. With this difficulty DPTI decided to give us the benefit values for each option that was investigated.

The result of the cost/benefit analysis produced a very close ratio between scenario one and three, however scenario one did have the best ratio of 262:1. Due to this large ratio compared to the other scenarios our final recommendation for this project is to have the Outer Harbor rail line over the top of South Road. This scenario has the most advantages for each sector as it can be seen in the table above with each sector recommending this option except for structural. The only reason structural did not choose this scenario was due to the higher costs as this option produces the largest bridge.
All in all the rail line overpass is the best option according to this feasibility study as it has the greater amount of advantages for each sector investigated and was the best option according to the cost/benefit analysis. EDGE Engineering believe the project as a whole is feasible to undertake as the benefits largely outweigh the costs which can be seen with the cost/benefit ratio produced in the previous section.
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Costing


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Urban Planning Department


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