Cockle Bay Park Development

Western Distributor Impact Assessment

DPT and DPPT Operator Pty Ltd

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Contents

1 Introduction

This report has been prepared to accompany a detailed State Significant Development (SSD) Development Application (DA) (Stage 2) for a commercial mixed use development, Cockle Bay Park, which is submitted to the Minister for Planning and Public Spaces pursuant to Part 4 of the Environmental Planning and Assessment Act 1979 (EP&A Act). The development is being conducted in stages comprising the following planning applications:

- Stage 1 – Concept Proposal setting the overall 'vision' for the redevelopment of the site including the building envelope and land uses, as well as development consent for the carrying out of early works including demolition of the existing buildings and structures. This stage was determined on 13 May 2019, and is proposed to be modified to align with the Stage 2 SSD DA.
- Stage 2 – detailed design, construction, and operation of Cockle Bay Park pursuant to the Concept Proposal.

1.1 The Site

The site is located at 241-249 Wheat Road, Sydney to the immediate south of Pyrmont Bridge, within the Sydney CBD, on the eastern side of the Darling Harbour precinct. The site encompasses the Cockle Bay Wharf development, parts of the Eastern Distributor and Wheat Road, Darling Park and Pyrmont Bridge.

The Darling Harbour Precinct is undergoing significant redevelopment as part of the Sydney International Convention, Exhibition and Entertainment Precinct (SICEEP) including Darling Square and the W Hotel projects. More broadly, the western edge of the Sydney CBD has been subject to significant change following the development of the Barangaroo precinct.

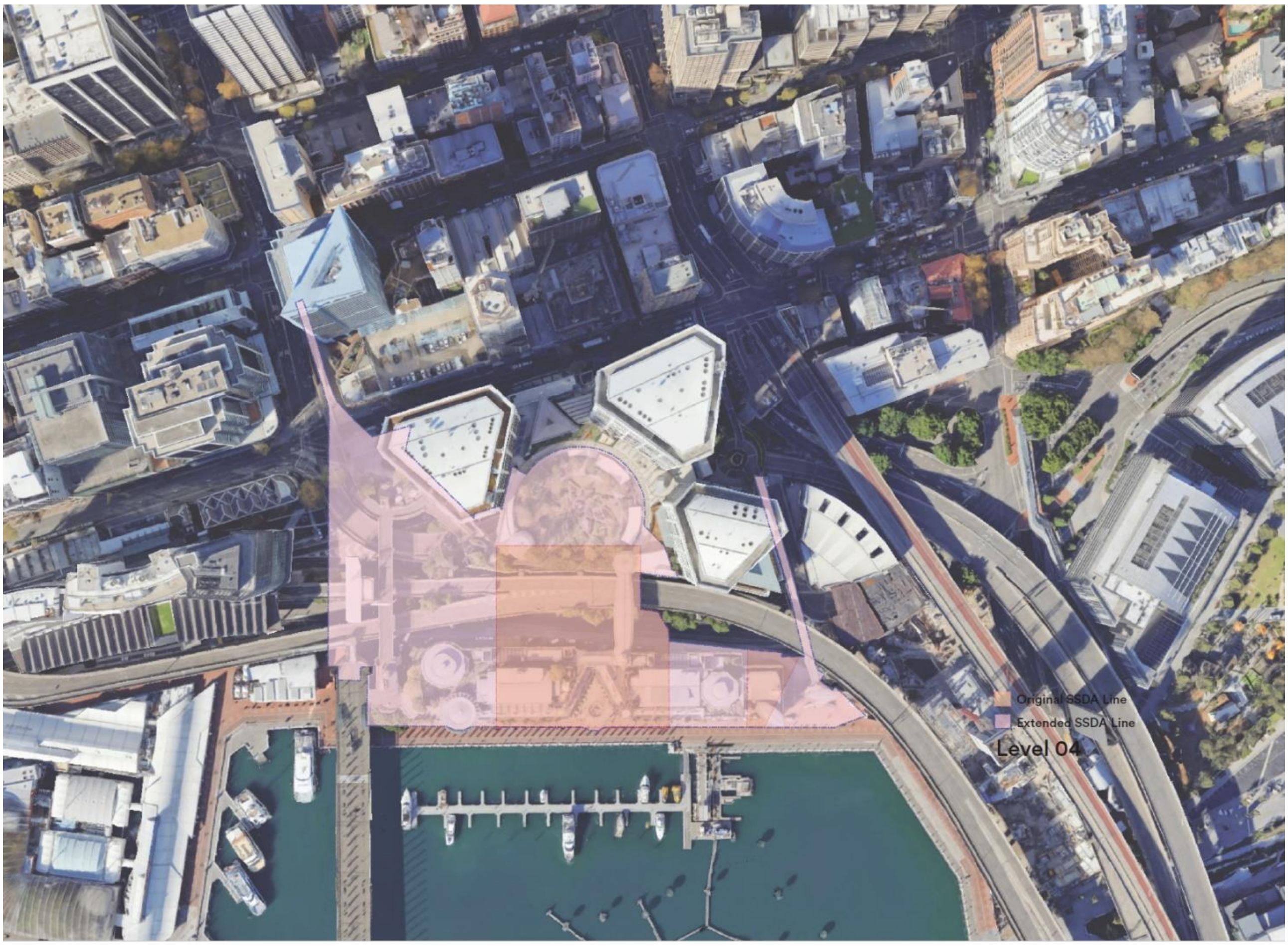

Figure 1 – Location Plan

1.2 Purpose of report

This report has also been prepared in response to the following Stage 1 (SSD 7684) conditions of consent summarised in Table 1.

Table 1 – Concept approval of Conditions of Consent

Item	Description of Requirement	Section Reference (this report)
C23	Western Distributor Impact Assessment (WDIA)	
C23 (a)	Fire safety	2.1
C23 (b)	The provision of adequate lighting	2.2
C23 (c)	Reflectivity of the external façade	2.4
C23 (d)	Air quality over / in the Western Distributor	2.5
C23 (e)	Prevention of falling objects	2.6
C23 (f)	The ability of the Western Distributor to continue to allow for the transportation of dangerous goods	2.3
C23 (g)	Maintenance of the road reserve / corridor width	4.1
C23 (h)	Design, location and impact of structural supports / columns / piers	3.1
C23 (i)	Access for maintenance and repair	4.2
C23 (j)	Impact on the structural integrity and durability of the Western Distributor	3.2
C23 (k)	Maintenance of appropriate clearance in accordance with RMS requirements	3.3
C23 (l)	Methodology of construction over the Western Distributor	5
C23 (m)	Responsibility for elements of the development that interfaces with RMS infrastructure and long term maintenance	4.3
C23 (n)	Major works authorisation deed(s)	6
C23 (o)	Road network safety and the safety of the landbridges in case of earthquake	3.4
C23 (p)	Emergency response management during construction, site emergencies and incidents	5.1

The purpose of this report is to assemble and present the various materials required of the Western Distributor Impact Assessment (WDIA) in an easily accessible format, which considers the development's relationship to, and design construction, operational and maintenance impact on, the Western Distributor.

2 Design assessments

2.1 Fire safety assessments

The addition of the landbridge over the road network has the effect of altering the way a fire event will behave on this portion of the Western Distributor.

Western Distributor fire safety assessments have been undertaken in two parts:

1. fire modelling, including computational fluid dynamics (CFD) modelling, for a fire event involving a Heavy Goods Vehicle (HGV), which is addressed in this Section 2.1, and
2. a Dangerous Goods Vehicle (DGV) risk assessment, which is addressed in Section 2.3

For the HGV and combustible liquid tanker fire assessments, the tenability of the modified space on the Western Distributor, as well as the modified effects of a fire events on the road network and surrounding infrastructure, has been assessed for a fire event under the landbridge.

This fire safety assessment addresses the fire safety below the landbridge between the portals for a fire generated by a typical heavy goods vehicle (HGV), as well as a DGV tanker fire on the Western Distributor. The fire scenarios assessed a peak Heat Release Rate (HRR) of 157MW for the HGV, and 250MW for the DGV tanker fire, which are consistent with the representative HRR suggested by NFPA 502 as a typical design fire size without fixed water based firefighting systems.

The results from the HGV and tanker fire assessment conclude that tenable conditions are maintained within the acceptance criteria for heat, smoke and the ability for road users to safely egress from the site.

The full fire assessment report is provided in Appendix A.

The full Dangerous Goods Vehicle (DGV) risk assessment, which addresses the ability of the Western Distributor to continue to carry all DGV Classes is covered in Section 2.3 of this report.

2.2 Lighting assessment

A lighting assessment under the proposed landbridge has been undertaken to determine the lighting design characteristics for the roadway extents beneath the landbridge. The aim of this investigation was to provide preliminary information on the underpass lighting design appraisal for the carriageways, impacts and commentary on the interfacing elements after the landbridge, as well as to describe the information required to provide a holistic design assessment throughout subsequent design development stages.

The affected carriageways are the Western Distributor Northbound, Western Distributor Southbound, Harbour Street Northbound, Market Street Southbound, Sussex Street Southbound and Harbour Street Southbound. All elevated and at-grade carriageways fall under the same design considerations requiring new underpass lighting treatment to support the changed visual conditions. This includes full supporting threshold lighting, with varying requirements for threshold, interior and exit lighting. The lighting assessment demonstrates that compliant lighting conditions can be provided.

The full lighting assessment report is provided in Appendix B.

2.3 Dangerous Good Vehicles risk assessment

A detailed risk assessment process has been undertaken in consultation with TfNSW, EPA, FRNSW, Police and Ambulance to establish the ability for the Western Distributor to continue to carry dangerous goods.

The Dangerous Goods Vehicle (DGV) risk identification and assessment was undertaken based on a system safety approach in accordance with ASA Standard T MU MD 20001 ST System Safety Standard for New or Altered Assets in order to ensure that safety risks of DGVs using the Western Distributor, impacted by the proposed landbridge development, have been managed so far as is reasonably practicable (SFAIRP).

The DGV risk assessment documents the approach and outcomes for determining the safety risk identification and assessment pathway for Dangerous Goods Vehicles (DGVs) using the TfNSW road assets impacted by the proposed landbridge over the Western Distributor.

The conclusions of the DGV assessment are:

1. The landbridge structure is to be designed to provide 2 hours fire resistance against the modified hydrocarbon curve (HCinc). The modified hydrocarbon curve addresses the impact of a sharp heat rise on the structure and is reasonably practicable for the sections of the landbridge without additional water fire safety protection.
2. Based on industry guidelines and engineering practice at some of the surrounding underpasses, it is recommended that a fixed water-based firefighting system (FFFS) is installed above the Western Distributor. For any FFFS to be designed there are various reasonably practical criteria and limitations required to be considered within the detailed design to optimise the performance of the system and derive its benefit.
3. It is recommended that a qualified fire safety engineer should develop and document the fire safety strategy and fire safety measures in the schematic design stage. Any FFFS can then be evaluated in the context of the design performance and practicality of operating, installing and maintaining such a system above the Western Distributor.

Provision for a FFFS has been included in the SSDA Stage 2 documentation. The full Dangerous Goods Vehicles Safety Assessment Summary Report is provided in Appendix C.

The DGV Risk Assessment report was reviewed by all stakeholders and all comments addressed to arrive at its final recommendation that concluded that dangerous goods can still be operated on this route, subject to the further consideration of a Fixed Water-Based Fire system under the land bridge.

A range of different dangerous goods vehicles have been assessed. While it was concluded that most types of dangerous goods can continue to be transported on the Western Distributor, FRNSW is seeking that additional work be undertaken to assess fire events in relation to Class 2.1 (flammable gas) and Class 3 (flammable liquid) DGVs, to confirm the tenability conditions under the landbridge and the appropriate type of mitigation measures that could be implemented, including the provision of a fire suppression system. The work required to consider these dangerous goods fire events will continue to be progressed with FRNSW with technical support from TfNSW, through the assessment period.

2.4 Reflectivity assessment

A reflectivity assessment has been undertaken for roads in vicinity of the site, to verify that solar reflections from the facades of the proposed development do not cause unacceptable glare to drivers.

The assessed roads include the Western Distributor heading east from Anzac Bridge up to the site, and heading south from the Harbour Bridge to the site.

The upper west tower façade can reflect sun towards Anzac Bridge and tilted triangular panels on the upper west façade can reflect sun towards the section of the Western Distributor south of Darling Harbour at times during winter afternoons. However, in both cases the analysis has found that the intensity of reflections remains below the limit of acceptability set out in the Hassall methodology referenced in the assessment.

Conclusions from the reflectivity assessment determine that reflections towards the Western Distributor will not exceed the limit of acceptability of 500 cd/m^2 stipulated by Hassall as long as the façade glazing reflectivity will be kept within the limits noted in the report:

- Tower west façade glazing levels 5-9: 9.5%, with design configuration of solid spandrel and tilted glazing as per SSDA elevations. An equivalent outcome maybe developed with a higher percentage of titled and solid panels, and glass with reflectivity up to 12%;
- All other glazed facades: 20% specular reflectivity at normal incidence.

The full reflectivity assessment report is provided in Appendix D.

2.5 Air quality assessment

An air quality assessment has been undertaken to demonstrate that the vehicle emissions are adequately dispersed to a level that provides an air quality within an acceptable standard.

This study assessed air quality under the landbridge for Carbon monoxide (CO), Nitrogen Dioxide (NO_2) and visibility through a desktop assessment. The visibility parameters examined are $PM_{2.5}$ and PM_{10}, which represent a subset of particulate matter with sizes in the order of 2.5 and 10 microns respectively. Only these pollutants are modelled as they have the most stringent requirements in road tunnels (PIARC - Road tunnels: vehicle emissions and air demand for ventilation, 2019R02EN). The assessment uses one dimensional modelling software IDA Road Tunnel Ventilation to assess pollutant concentrations in steady state.

Conclusions from the air quality assessment determine that acceptable air quality below the landbridge is maintained under normal, congested and stationary traffic conditions.

Diesel generator flues from Darling Park Tower 1 have been re-routed to ensure that they do not discharge under the landbridge. In addition, the existing ventilation stack for the Darling Park carpark and existing southbound underpass needs to be re-routed to exhaust out from underneath the future landbridge, so that pollutants are not exhausted into the underside of the landbridge.

The full air quality assessment report is provided in Appendix E.

2.6 Prevention of falling objects

A Risk Assessment in accordance with TfNSW *Circular BTD2012/01* – Provision of Safety Screens on Bridges has been undertaken to determine the requirements for screens at the edge of the landbridge above the Western Distributor.

The Risk Assessment Matrix calculates the score to determine if a screen is required. A screen is required if the Risk Rating Score is 30 or more.

Undertaking a risk assessment for the landbridge results in a score of 31.1.

Appendix I of *Circular BTD2012/01* outlines the geometric requirements of the safety screen. The most important ones are listed below:

Geometric Requirements

Safety screens shall have the following geometrical properties:

(a) A minimum height of 3.0 m above the roadway or footway surface or 2.0 m above the top rail or top surface of any adjacent pedestrian or traffic barrier, whichever is the greater.

(b) The safety screen shall extend at least 6 m beyond the edge lane line of the roadway below or, if this is not possible, to within 1 m of the end of the Abutment wing walls or on pedestrian and shared path bridges to the landings at the end of the main bridge spans.
The safety screen shall be at or above the minimum height for a distance of at least 2 m past the outer edge lane line of the roadway below, and may then taper down in height.

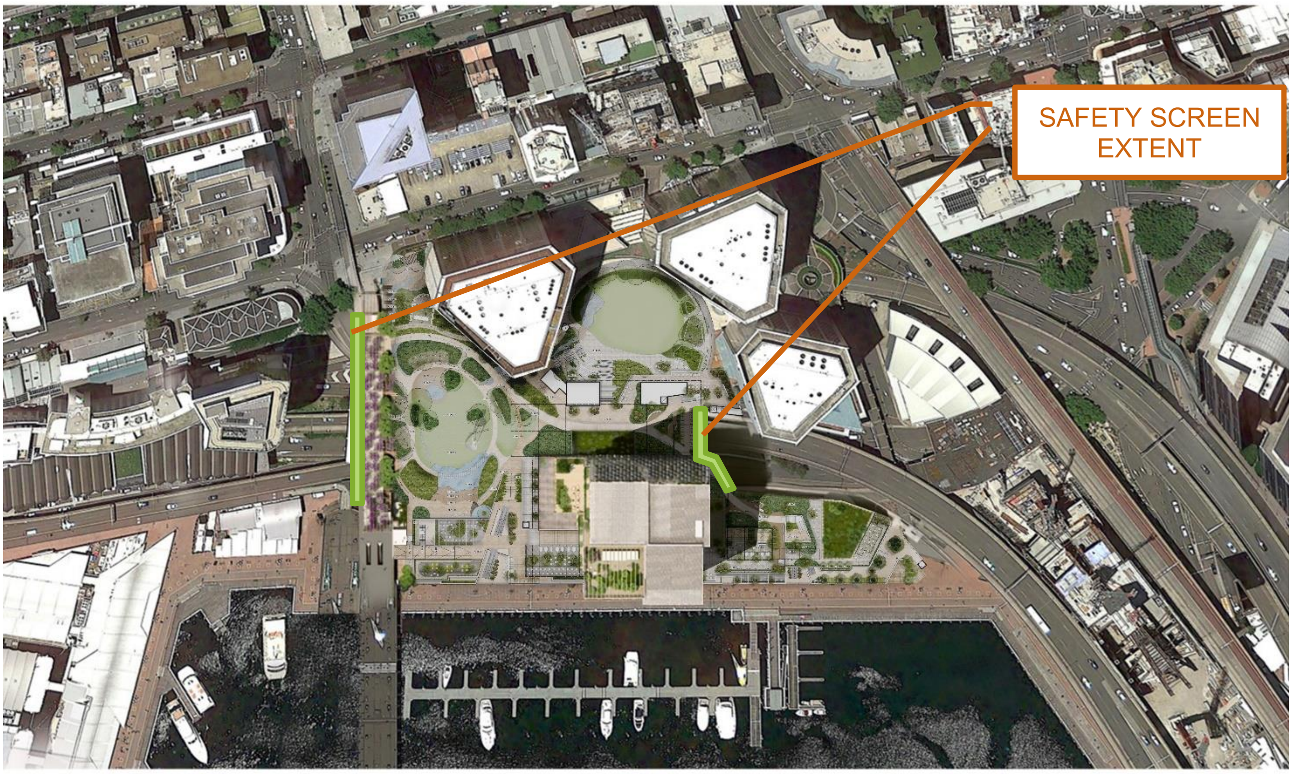

Figure 2 – Proposed Edge Protection to Landbridge

A presentation of the proposal was delivered to TfNSW on 28.05.2021.

Their response received on 16 June 2021 by email was as follows:

Western Distributor edge

The risk assessment is over 30 risk rating so will need to follow the BTD geometric requirements.

Material choice for the infill panels may be flexible, such as safety glass/Perspex as long as the design still qualifies the geometric requirements.

The full falling objects assessment is provided in Appendix F.

A second presentation detailing the edge condition is proposed to be held on 17 September.2021.

3 Structural assessments

A significant feature of the Cockle Bay Park redevelopment is the planned landbridge connecting the city on the East to the Harbour on the West. The landbridge will restore a direct link between Pyrmont Bridge and Market St across the Western Distributor and Harbour Street, providing large public plaza and park spaces.

Constructability of the landbridge structure is a key element for design consideration to ensure an efficient and buildable arrangement is provided. The structural system developed for the landbridge predominantly utilises precast concrete elements to minimise onsite construction time and allow the structure to be built through night possessions of the Western Distributor. The precast structure also has the benefit of good inherent fire resistance and durability requiring minimal maintenance over the design life of the structure.

Due to the structure being constructed over the road corridor, the landbridge structure is to be designed and constructed in accordance with Transport for NSW (TfNSW) requirements. Regular consultation with TfNSW has occurred throughout the EIS process to progress the approval of the landbridge design. The consultation process with TfNSW has been positive and collaborative and is working towards execution of a Works Authorisation Deed (WAD) with TfNSW.

The Landbridge structure abuts the existing Darling Park development which will require integration of vertical structure to support the landbridge. Construction of new structure supported off the existing structure at Crescent Garden will facilitate connection to the Landbridge and provide a single contiguous space.

Figure 3 – Existing Landbridge Site Context

Figure 4 – Proposed Landbridge Footprint

3.1 Design, location and impact of structural supports

Columns and walls within the proposed Cockle Bay Park podium have been located to meet planning requirements of the proposed development. The dense network of existing infrastructure within the road corridor has undergone a detailed assessment by the project team and TfNSW to reconcile support locations with existing infrastructure, planned infrastructure expansion and clearances required, with the column locations on plan representing a resolution of these requirements. Refer drawings attached in Appendix G.

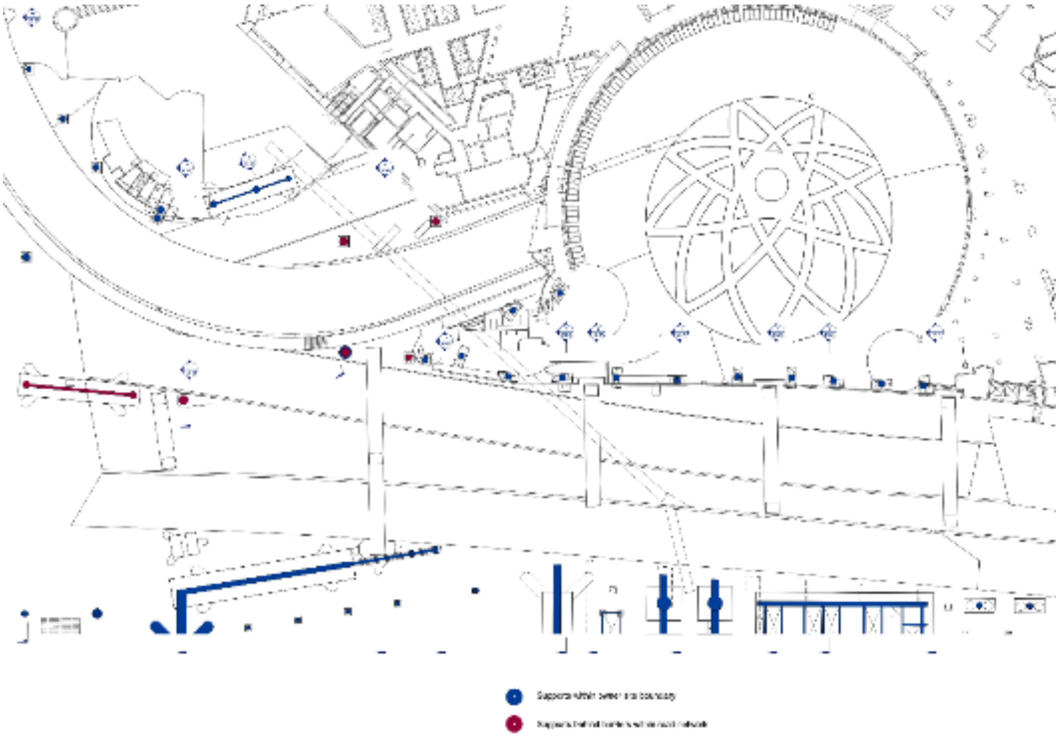

Figure 5 – Proposed Landbridge Supports

These supports are designed as reinforced concrete columns and walls with sufficient capacity to support the proposed landbridge and also resist code impact loading from the adjacent roads.

Due to the nature of the build being over a roadway, precast headstock beams will need to be temporarily supported by way of a corbel. This will be installed at the top level of the column to provide temporary support of the headstock beam prior to it being fully poured tying the two elements together.

Further, construction of the columns was considered with respect to impacts to the road network and a formwork arrangement was proven which utilises shutters braced to supports adjacent the road to minimise impacts on the network.

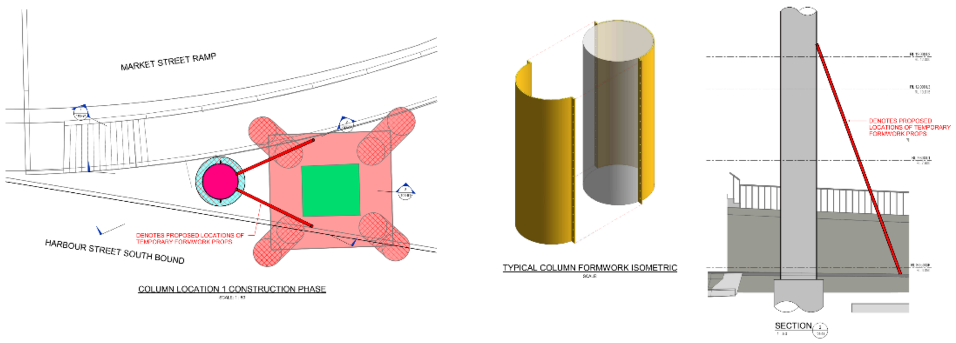

Figure 6 – Typical column withing road network formwork concept

3.2 Impact on the structural integrity and durability of the Western Distributor

3.2.1 Road Clearances

A critical planning constraint incorporated into the design is maintaining minimum vertical clearance between the proposed landbridge structure and the existing Western Distributor roadway. A minimum clearance of 5.4m has been adopted everywhere. An additional 0.4m services zone clearance has been generally adopted. It has been identified that the services clearance zones could be reduced in some areas which will be investigated as the design progresses and if possible utilised to minimise the elevation of the landbridge in these areas.

An additional horizontal clearance between the road edge and any vertical structure has been incorporated into the design at all new column locations. Refer drawings attached in Appendix G.

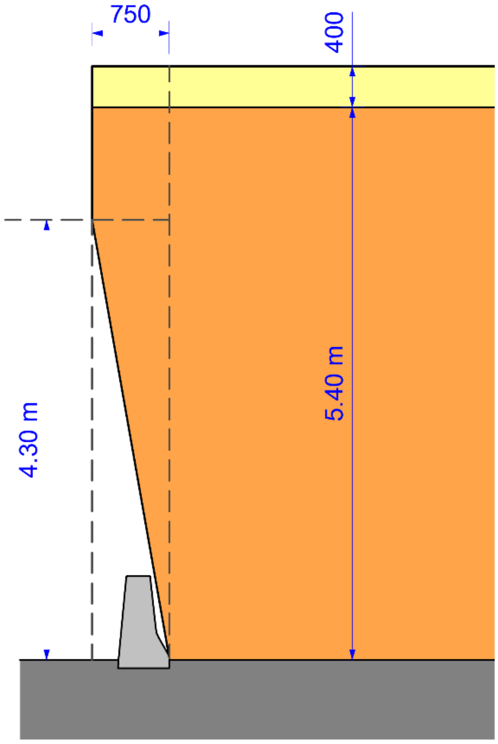

Figure 7 – Road clearance requirements

enstruct has incorporated 2D and 3D point cloud survey of the existing road infrastructure into the project structural BIM model. All elements of the existing road infrastructure have been assessed relative to the planned landbridge structure. The required clearances have been demonstrated at all critical cross sections. Refer drawings attached in Appendix G.

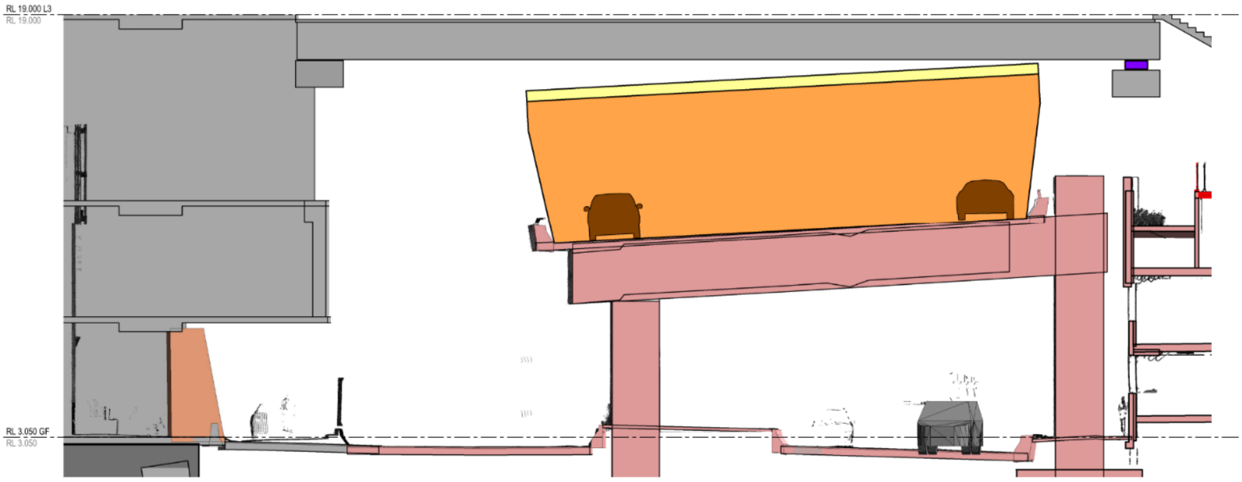

Figure 8 – Typical road clearance section

3.2.2 Horizontal Clearances to the Western Distributor

Adequate clearance has been identified as a key planning consideration to ensure the proposed vertical elements do not compromise TfNSW's ability to maintain the existing road infrastructure. To this end, a detailed co-ordination process was undertaken to identify any locations where clearance was less than 2m, a threshold identified by TfNSW as needing further consideration. At each of the four relevant locations, it was demonstrated that less than 2m clearance to the proposed landbridge would not compromise TfNSW's ability to maintain the existing infrastructure. Refer drawings attached in Appendix G.

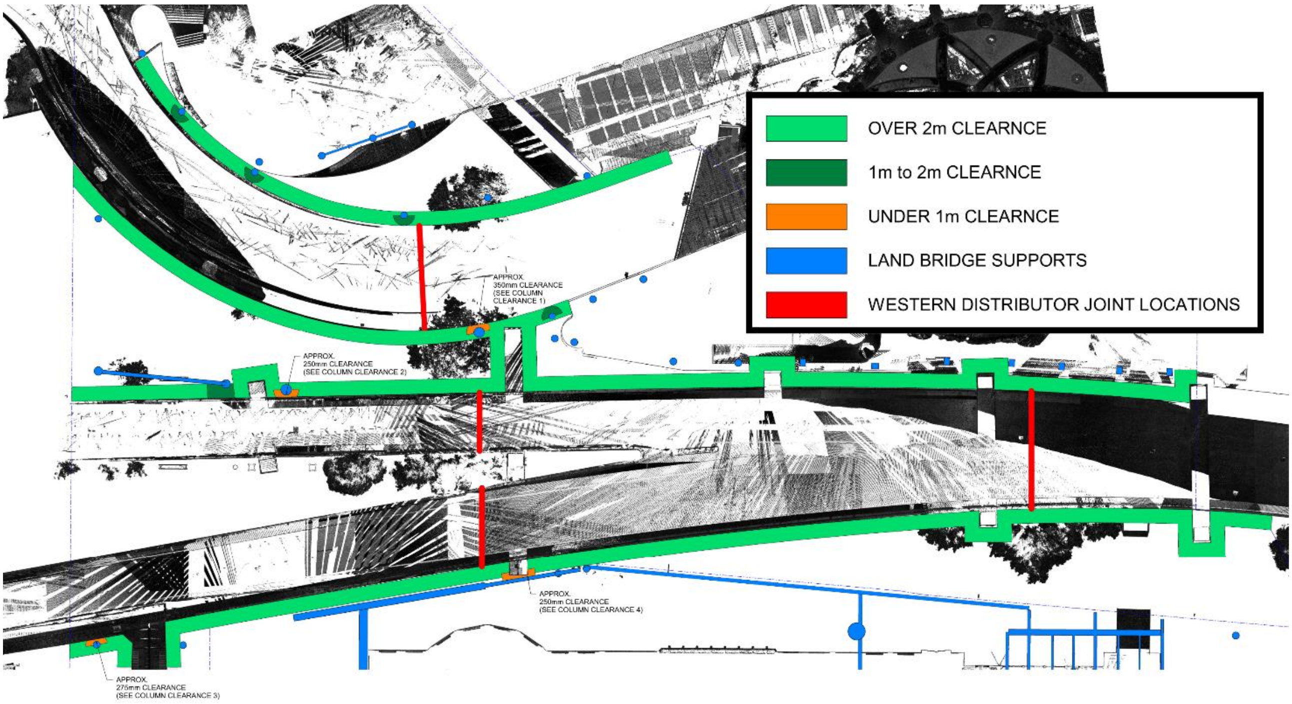

Figure 9 - Clearance Diagram between Western Distributor and New Structure

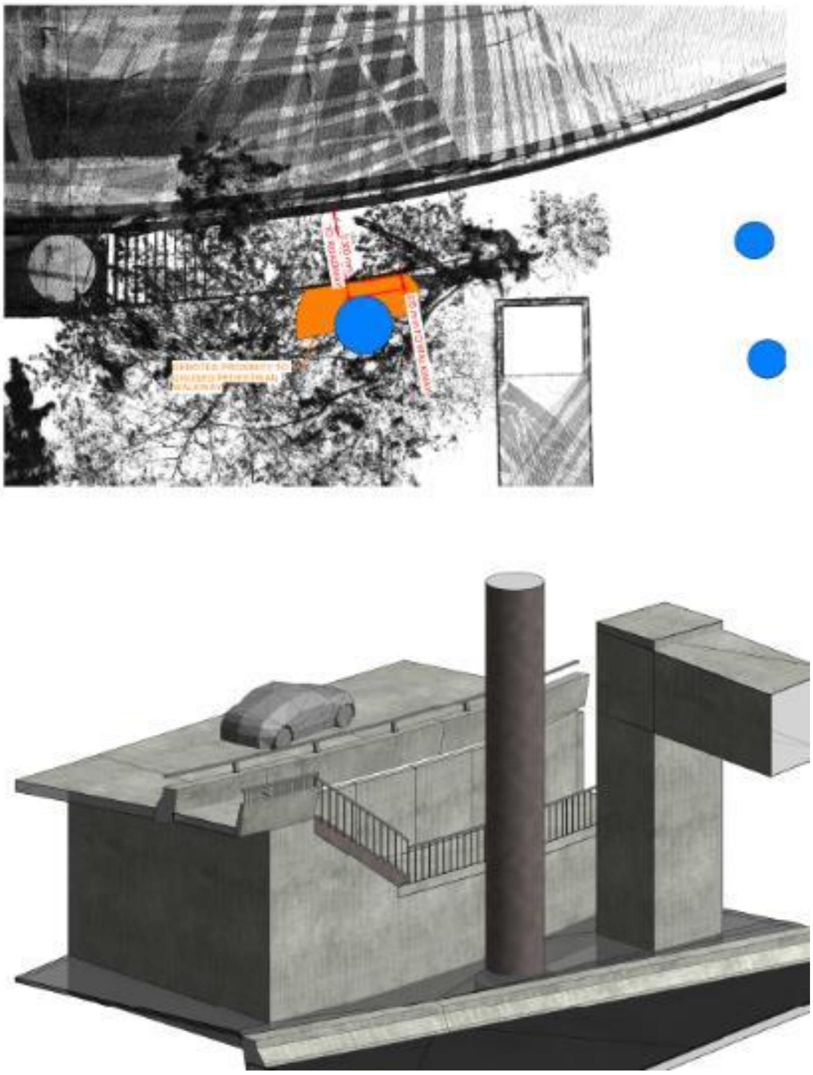

Figure 10 - Typical detailed clearance investigation

3.3 Maintenance of appropriate clearance in accordance with RMS requirements

The proposed new landbridge structure will be constructed clear of the existing Western Distributor, with the previous sections and Appendices demonstrating foundations and supports are clear of the existing structure and able to be maintained as outlined in the following section. All adjacent Western Distributor in-ground structural elements and foundations have been included in the project BIM model based on As-Built information provided by TfNSW. Additional site, in-ground and topographical survey provided by Lawrence Consulting Group has been incorporated to confirm clearance of columns and foundation elements from the Western Distributor. Refer TfNSW Presentation attached in Appendix H.

All new foundations are to be positioned to avoid existing Western Distributor in-ground structural elements/foundations. Further co-ordination and positioning of all new foundation elements in-ground services (unless relocation of service is proposed) is to be undertaken in the BIM model across all project disciplines, with assessment of interaction with existing Western Distributor foundations undertaken by Douglas Partners (project geotechnical engineer). All new foundations to be arranged to maintain current capacity of existing foundations

An assessment of impact of works on TfNSW controlled land has been undertaken by Rygate Surveyors.

Modification of the existing structures through the road corridor is limited to the following:

- Demolition of existing Market St footbridge connecting to Pyrmont Bridge with this connection replaced by the new landbridge. This footprint structure is independent of all other TfNSW assets, and its removal does not impact any other existing structures on the site.
- Demolition of existing monorail station. This monorail station structure is independent of all other TfNSW assets, and its removal does not impact any other existing structures on the site.
- Modification of existing Druitt St footbridge stairs and lift structure in Darling Harbour to facilitate connection with the new Cockle Bay Park podium structure and improve connection to Darling Harbour. Modifications to the Druitt St footbridge have been planned so that all existing structure north of Harbour St is unaffected by the proposed works, therefore the current clearances and arrangement is maintained. This has been achieved by keeping all works to the footbridge connection at Darling Harbour to the western side of the western most support of the existing footbridge so that modification works are kept within the zone of works for the Cockle Bay Park development.
- Demolition of the existing footbridge linking Darling Park and the existing Cockle Bay development. This footbridge is independent of all TfNSW structures and is to be completely removed and replaced with the landbridge to improve connection across the road corridor.
- Modification of the bike lane connection between the eastern end of Pyrmont Bridge and the western edge of the Western Distributor. This connection is currently a “clip-on” structure to the primary Western Distributor structure and the modifications are limited to this “clip-on” structure to improve the connection of the bike path to Pyrmont Bridge with no modifications to the primary Western Distributor structure.

As outlined above no modifications to the primary Western Distributor structures are proposed in the works and all new works will be designed to avoid impact to the existing primary structures.

3.4 Road network safety and the safety of the landbridge in case of earthquake

The analysis and design of all structural elements will be in accordance with AS/NZS 1170.0 (2002) – General Principles, AS 1170.4 (2007) – Earthquake Actions in Australia, AS5100 (2017) – Bridge Design, and AS3600 (2018) – Concrete Structures. Refer Appendix I.

The Landbridge deck has been provided with an east/west running movement joint due to the length of the deck in the north south direction. To accommodate this the lateral structure for the Landbridge is split into northern and southern zones to keep either half of the deck independent of the other.

The lateral systems for both zones are incorporated into the podium and tower planning, with dedicated lateral walls or enhanced core capacity providing the required support.

3.4.1 Northern Zone

The lateral structure for the northern zone of the Landbridge consists of the following elements:

- North/south shear wall along the eastern edge of the Landbridge within the existing Darling Park structure.
- North/south shear wall within the road corridor. This shear wall will be located between the northern and southern lanes of the Western Distributor within the support zones approved in-principle by TfNSW.
- North/south shear wall at the western edge of the Landbridge along the edge of the podium structure.
- East/west shear wall within the podium structure.

The lateral elements for the northern zone have been arranged so that there is only a single lateral element in the east/west direction located close to the centre of mass in the north/south direction so that creep, shrinkage and thermal movements of the deck in both directions are centred on this wall. The multiple north/south lateral elements have been located close to the centre of mass in the east/west direction also.

As the north/south shear walls are uncoupled elements they allow the creep, shrinkage and thermal movements of the deck in the east/west direction to be accommodated by rotation of these walls about their weak axis. The lateral system will be integrated into deck/podium structure with isolation of the deck from the Darling Park structure occurring along the eastern edge of the deck where bearings are provided.

3.4.2 Southern Zone

The lateral structure for the southern zone of the Landbridge consists of the following elements:

- Tower structure lateral core system.
- East/west shear wall within the podium structure to the north of the core.

The lateral elements for the southern zone have been arranged so that there is only a single lateral element in the north/south direction which is the tower core so that creep, shrinkage and thermal movements of the deck in both directions are centred on core. The east/west shear wall has been located close to the east/west centre of stiffness of the tower core ensuring that creep, shrinkage and thermal movements of the deck in the north/south direction can be accommodated by rotation of this shear wall about its weak axis. The lateral system will be integrated into deck/podium structure with isolation of the deck from the Darling Park structure occurring along the eastern edge of the deck where bearings are provided.

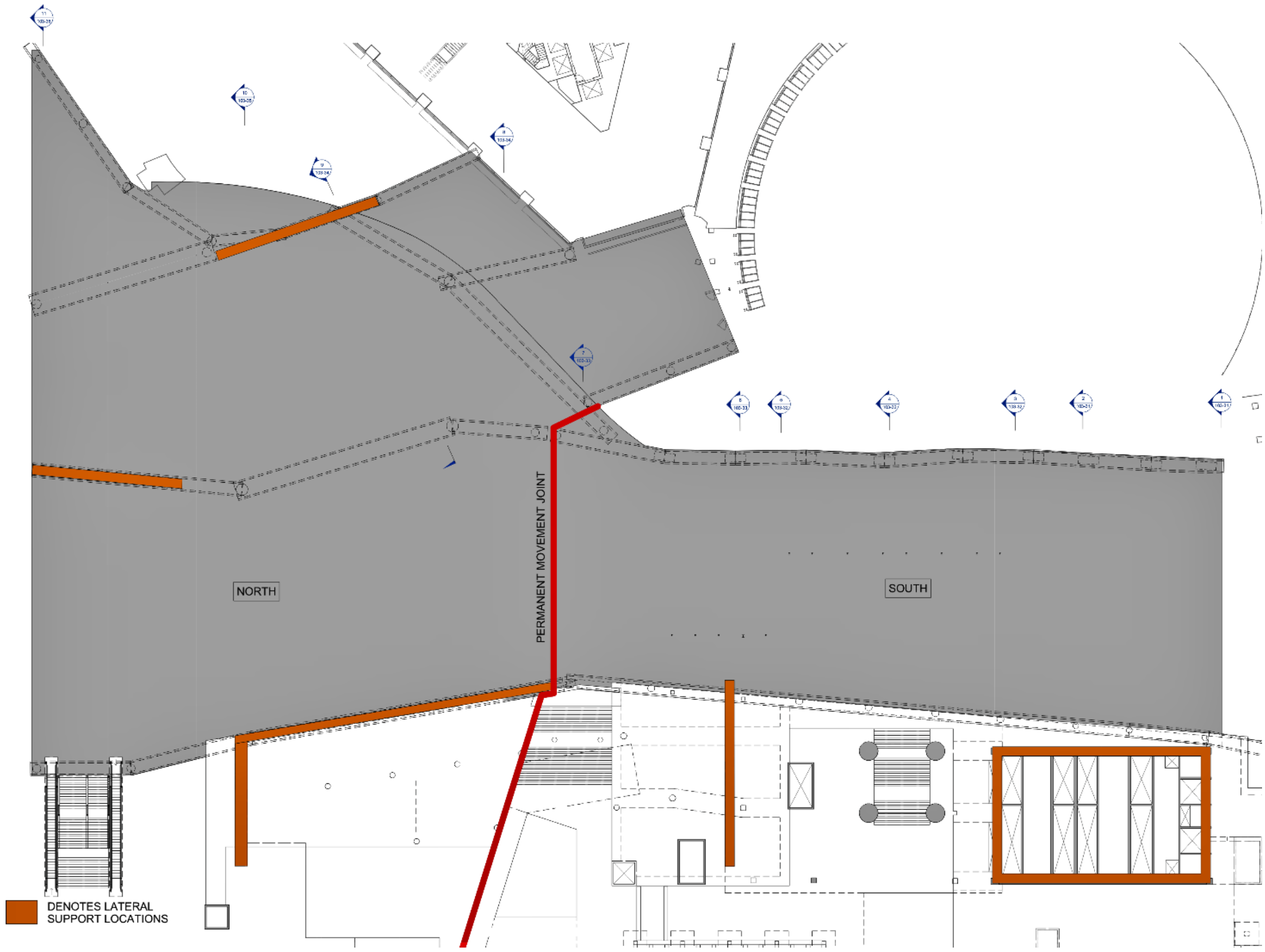

Figure 11 – Landbridge southern zone lateral supports plan

4 Maintenance requirements

PowerPoint presentations were submitted to TfNSW to demonstrate the adequacy and viability of maintenance activities which can be undertaken to adequately respond to:

- the maintenance requirements required to be met for the Western Distributor as defined in Condition 23 of the Conditions of Planning Approval, namely:

  (g) maintenance of the road reserve / corridor width

  (i) access for maintenance and repair

  (k) maintenance of appropriate clearance in accordance with RMS requirements

- TfNSW request to demonstrate the maintenance of Cockle Bay Assets adjacent to the Western Distributor and Landbridge.

The PowerPoint presentations are contained in Appendix J and include:

Cockle Bay Park - Maintenance of CBP Assets - Rev 4.pptx

Cockle Bay Park - Maintenance of CBP Assets Addendum 1 - Rev 1.pptx

4.1 Maintenance of the road reserve

Presentations included in Appendix J address the following elements of the Western Distributor and the Landbridge that lie within the Western Distributor road reserve requiring access for maintenance:

- Maintenance of Landbridge
  - Underside Lights and Sprinklers,
  - Girder Bearings,
  - Structural Concrete Facades)
- Maintenance of Western Distributor
  - Topside surfaces

As confirmed by the presentations, the general maintenance within the Western Distributor road reserve can be undertaken using standard construction methods.

4.2 Access for maintenance and repair

Presentations included in Appendix J address the following elements of the Western Distributor and the Landbridge that lie within the Western Distributor road reserve requiring access for maintenance:

- Access for maintenance of Western Distributor Surfaces near the Landbridge
- Access for maintenance of Landbridge Columns / Blade Walls near the Western Distributor
- Access for repair (strengthening) of Western Distributor Column / Headstock after completion of Landbridge
- Access for repair (demolition) of the Western Distributor after completion of Landbridge
- Access for repair (construction) of the Western Distributor after completion of Landbridge

As confirmed by the presentations, access for maintenance and repair can be undertaken using standard construction methods.

4.3 Responsibility for elements of the development that interfaces with RMS infrastructure and long-term maintenance.

The owner of Cockle Bay Park and the building towers will have responsibility for Landbridge maintenance.

As demonstrated by the presentations in Appendix J, TfNSW will be able to retain responsibility for long-term maintenance of their infrastructure, including those elements which interface with the Cockle Bay Park development.

5 Methodology for construction

Further details on the methodology for construction can be found in Appendix K - Construction Management Plan, revision 1 dated 1 September 2021.

5.1 Emergency response management during construction, site emergencies and incidents

Preparing for emergency situations greatly reduces the risk of injury, illness and fatalities and may limit the damage done to infrastructure and surrounding areas. Well-developed and rehearsed emergency preparations assist staff and internal emergency response personnel to respond quickly and effectively to an emergency.

The Contractor is to provide a management plan for emergency and crisis incidents for CBP Project. The plan will provide guidance, details responsibilities and lines of communication for effective emergency management.

5.1.1 Objectives

The Management Plan is to ensure that all Project Team members are prepared to rapidly respond to and effectively manage all emergency situations in order that:

- the safety and wellbeing of all people on the site, users of the Western Distributor both motorists and pedestrians and the general public is protected,
- damages, losses and the duration of disruption to the project and the Western Distributor are minimised,
- recovery tasks are coordinated to ensure that the project and the Western Distributor is restored to normal operation as soon as possible,
- the extent of the emergency is limited, and;
- an appropriate public relations strategy is implemented where necessary to ensure the public image of the company as well as the interests and responsibilities of the RMS as the legal operator of the Western Distributor is maintained.

The first priority in responding to any emergency situation is the consideration of the safety of the public. The necessary measures must be implemented to ensure the public are not placed at risk. These may include:

- evacuating the public from certain areas
- barricading areas that may pose a risk
- providing assistance where required

Where members of the public become involved in any emergency situation the project manager should make personal contact with them and assess the need to contact company directors.

5.1.2 Emergencies and Evacuation Protocol

Emergency Evacuation Protocols for all Personnel

In the event of an emergency requiring site evacuation, the following emergency evacuation protocols must be followed:

1. On sounding of the evacuation alarm, all work must cease immediately, switch off plant and machinery where possible, and leave tools behind.
2. Workers will be directed to leave the site via the site access gates.
3. The Chief Warden (or his delegate) will be positioned at the above gates and will direct workers to the Emergency Muster Point.
4. No person shall take the hoists or lifts and hoist/lift operators shall lock off their hoist/lift at the ground floor if possible or at the nearest floor (where hoists/lifts are present on the project).
5. Hoists will only be used under the direct instruction of the Contractor management and the emergency services personnel (where hoists/lifts are present on the project).
6. If you notice that other personnel have not heard the evacuation signal, make them aware that the evacuation is in progress.
7. When you are off site, do not re-enter the Site until the all clear has been given by the Chief Warden (or his delegate).
8. Do not go to the lunch sheds or change sheds to collect personal items when evacuating the Site. It is imperative that all personnel be accounted for at the evacuation assembly areas immediately.
9. The Contractor Emergency Management Team will liaise with the Emergency Services if deemed necessary. Evacuation of any adjacent building will only be at the discretion of the Emergency Services.
10. At the assembly point, personnel will assemble in their own company groups and remain there while their company supervisor checks off each person.
11. The results of the head count must be reported to the Chief Warden (or his delegate).
12. Ensure that all employees, contractors and visitors have been accounted for.
13. Only the Chief Warden (or his delegate) will give the 'ALL CLEAR' before allowing personnel to return to the site.

Types of Emergencies requiring Evacuation

The types of emergency that will be covered in the Management Plan will include:

- General evacuation
- Medical emergency
- Bomb threats
- Fire threats
- Natural disasters and or storms
- Civil disorder/site invasion
- Plant vehicle collision
- Public safety
- Major environment pollution incidents
- Structural instability/collapse

6 Major works authorisation deeds

A major Works Authorisation Deed (WAD) has been prepared in consultation with Transport for NSW. TfNSW has prepared an initial draft for the Co-owners' review, attached in Appendix L, and will reference the schedule for road closures.

Appendices

Appendix A – Fire Safety Assessment Report

Appendix B – Lighting Assessment Report

Appendix C – Dangerous Goods Vehicles Safety Risk Assessment Report

Appendix D – Reflectivity Assessment Report

Appendix E – Air Quality Assessment Report

Appendix F – Falling Objects Report

Appendix G – Landbridge Structural Drawings

Appendix H – Structural Foundation Presentation to TfNSW

Appendix I – Earthquake Assessment Report

Appendix J – Maintenance Requirements Presentation to TfNSW

Appendix K – Construction Methodology Presentation to TfNSW

Appendix L – Major Works Authorisation Deeds

Appendix A

Fire Safety Assessment Report

aurecon

Cockle Bay Park Landbridge over the Western Distributor

Fire Safety Study

DPT and DPPT Operator Pty Ltd

28 September 2021

Revision: A

Reference: 253427

Bringing ideas to life

Document control record

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Cockle Bay Park Landbridge over the Western Distributor

Date 28 September 2021
Reference 253427
Revision A

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Contents

Figures

1 Introduction

This report has been prepared to accompany a detailed State Significant Development (SSD) Development Application (DA) (Stage 2) for a commercial mixed use development, Cockle Bay Park, which is submitted to the Minister for Planning and Public Spaces pursuant to Part 4 of the Environmental Planning and Assessment Act 1979 (EP&A Act). The development is being conducted in stages comprising the following planning applications:

- Stage 1 – Concept Proposal setting the overall 'vision' for the redevelopment of the site including the building envelope and land uses, as well as development consent for the carrying out of early works including demolition of the existing buildings and structures. This stage was determined on 13 May 2019, and is proposed to be modified to align with the Stage 2 SSD DA.
- Stage 2 – detailed design, construction, and operation of Cockle Bay Park pursuant to the Concept Proposal.

As part of this redevelopment a new land bridge structure over the Western Distributor has been proposed. This land bridge will create a 'tabletop' cover over the elevated northbound Western Distributor and southbound Market St towards Anzac Bridge, and the on grade northbound and southbound Western Distributor and northbound Wheat Rd.

This report assesses the risk of a fire involving a heavy goods vehicle and separately a fire involving a petrol tanker dangerous goods vehicle on the Western Distributor. A separate report has been prepared to address the transportation of all types of Dangerous Goods Vehicles that could use the Western Distributor.

This report describes in detail:

1. Preliminary Computational Fluid Dynamics (CFD) modelling to describe how conditions in terms of temperature and visibility change beneath the land bridge; and
2. The proposed design criteria for the next design stage.

The length of the land bridge is approximately 150 m and the cross sections, which are indicative only, are shown in the figures below.

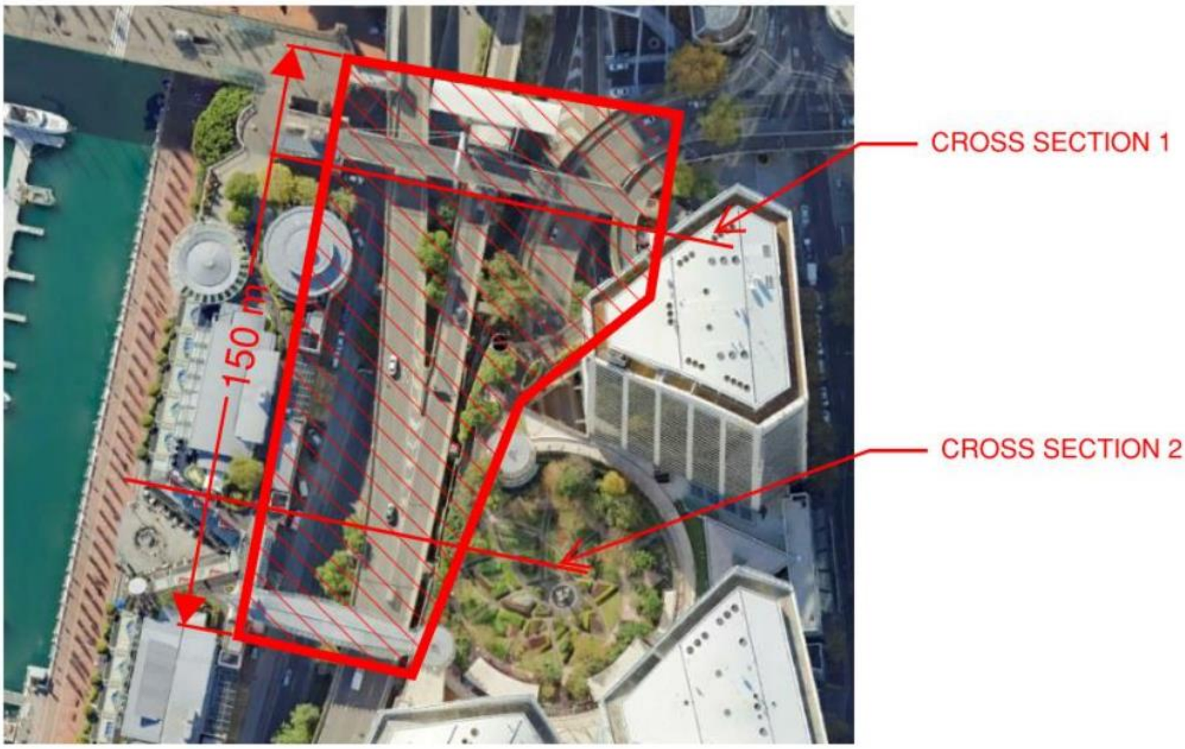


Figure 1: Extent of proposed land bridge - plan

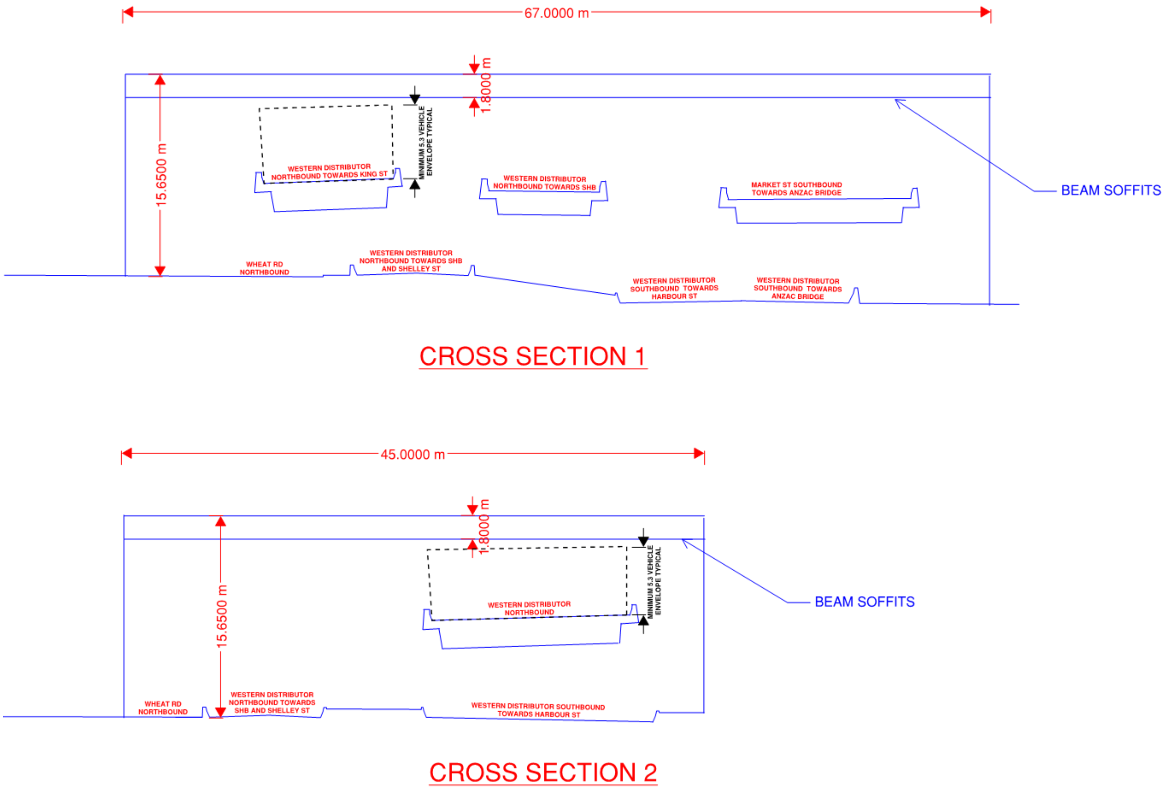


Figure 2: Indicative cross sections of roadways beneath the proposed land bridge (dimensions are approximate only)

The envelope of the enclosure created by the proposed land bridge is significantly larger than the kinematic envelopes of the roads it encapsulates. The following sub-sections contains a preliminary assessment of a fire occurring beneath the landbridge and it shows how heat and smoke from this fire spreads through the enclosure.

2 Design fire

Heat release rates from NFPA 502 2020 for a variety of vehicle fires is shown below.

Δ Table A.11.4.1 Fire Data for Typical Vehicles

	Experimental HRR		Representative HRR		Experimental HRR with FFFS	
Vehicles	Peak HRR (MW)	Time to Peak HRR (min)	Peak HRR (MW)	Time to Peak HRR (min)	Peak HRR (MW)	Time to Peak HRR (min)
Passenger car	5–10	0–54[a]	8	10	—	—
Multiple passenger car	10–20	10–55[b]	15	20	10–15[g]	35[g]
Bus	25–34[c]	7–14	30	15	20[g,h]	—
Heavy goods truck	20–200[d]	7–48[e]	150	15	15–90[g]	10–30[g]
Flammable/ combustible liquid tanker	200–300	–	300	–	10–200[f]	

Figure 3: Heat release rate for vehicle fires from NFPA 502 2020

For a fire generated by a typical heavy goods vehicle, test results presented in NFPA 502 indicate a peak heat release rate between 20 MW and 200 MW. For a fire involving a flammable/combustible liquid tanker, the peak heat release rate is between 200 and 300 MW. As the heat release rate for the petrol tanker fire is larger than the heavy goods truck fire, the assessment in this report for fires on the Western Distributor will be based on a combustible liquid tanker. The design fire for a petrol tanker dangerous goods vehicle is shown in Figure 4 below.

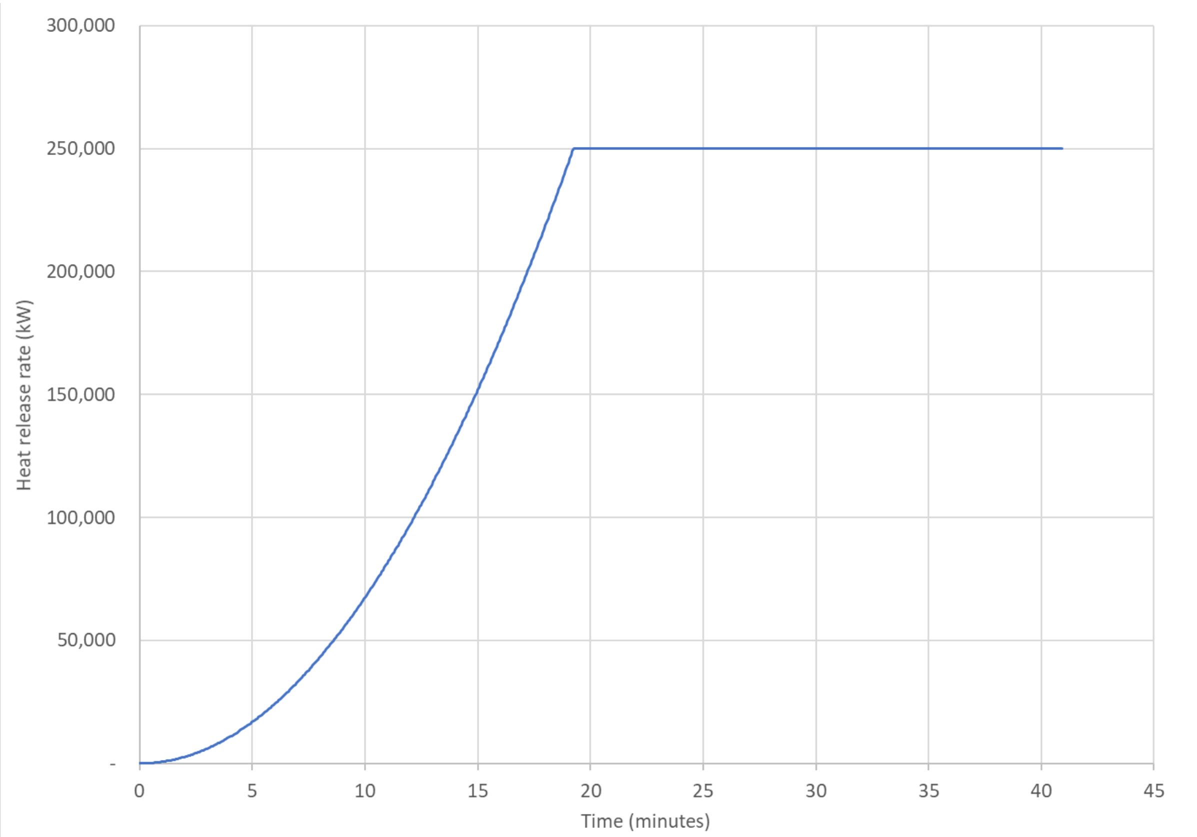


Figure 4: Heat release rate for a combustible liquid tanker

The fire is located at the centre of the enclosure as this is considered critical for smoke spread and infilling; a fire towards the end of the enclosure would result in smoke and heat escaping the covered area sooner. Although the egress time will be greater for fires closer to the portals, the increased risk to persons evacuating due to a longer evacuation time is offset by more heat and smoke being discharged by the portal.

This analysis has been undertaken with no reliance on the use of fire suppression systems or mechanical ventilation.

3 Fire scenarios

Two scenarios have been considered for the purposes of this study and these are described below.

Scenario 1: A combustible liquid tanker fire at mid-length of the enclosure on the elevated northbound Western Distributor.

Scenario 2: A heavy goods vehicle fire at mid-length of the enclosure on Harbour St.

These scenarios are shown below in Figure 5 and Figure 6.

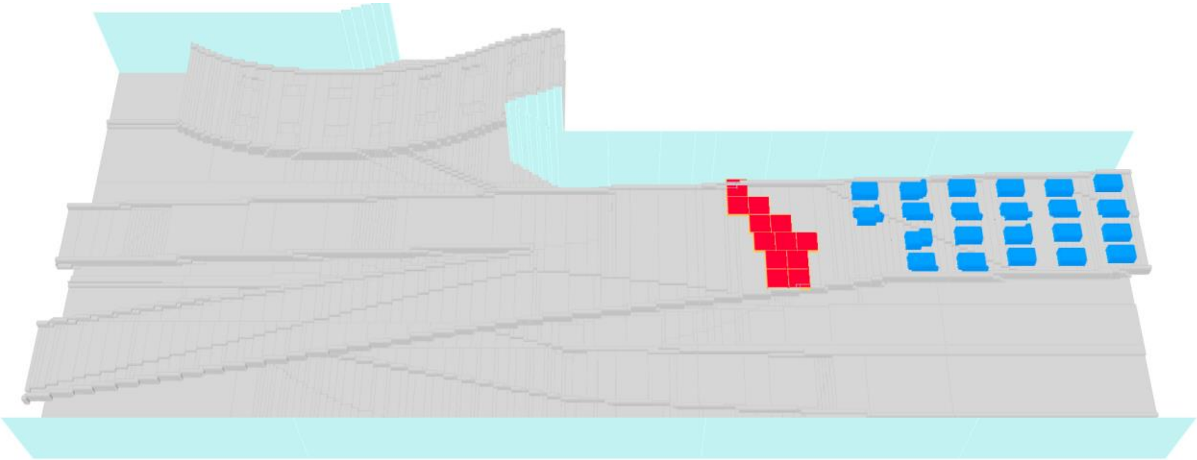


Figure 5: Scenario 1: Combustible liquid tanker fire on the elevated Western Distributor

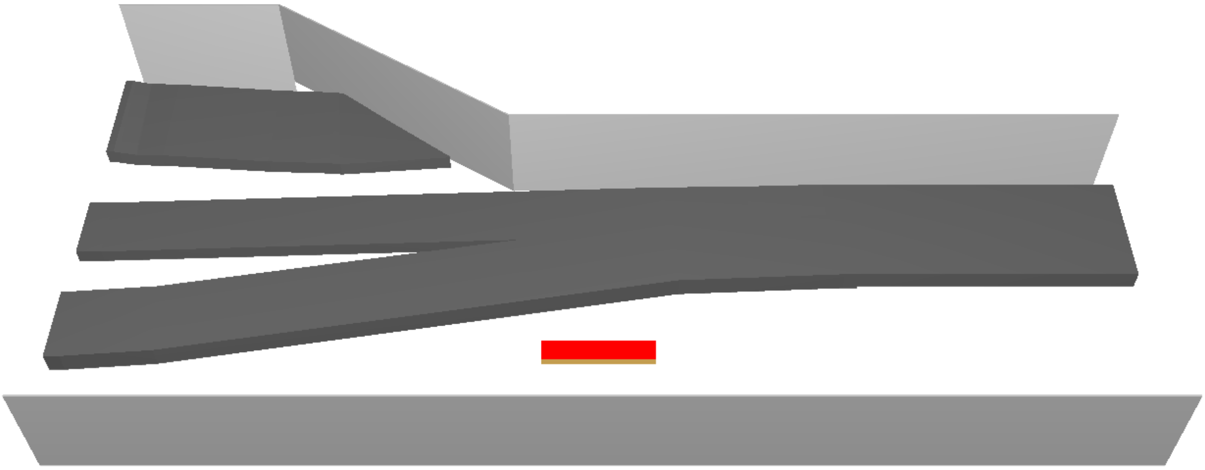


Figure 6: Scenario 2: Heavy goods vehicle fire on Harbour St

Tenability conditions are measured 2 m above the surface where people need to evacuate i.e. 2 m above the road level. The acceptance criteria for tenability is taken from NFPA 502 as follows:

- Visibility: > 10 m
- Temperature: < 60 C

4 Computational Fluid Dynamics (CFD) Modelling

In order to understand how heat and smoke from a fire spreads beneath the landbridge, a series of CFD simulations have been conducted. The modelling was undertaken with the Fire Dynamics Simulator (FDS) CFD package.

An assessment of the time required to evacuate from the area beneath the landbridge is also given in this report in sub-section 5.

5 Occupant Egress

The egress and human movement simulator, Pathfinder, has been used to estimate the occupant movement and evacuation times. The following parameters have been considered:

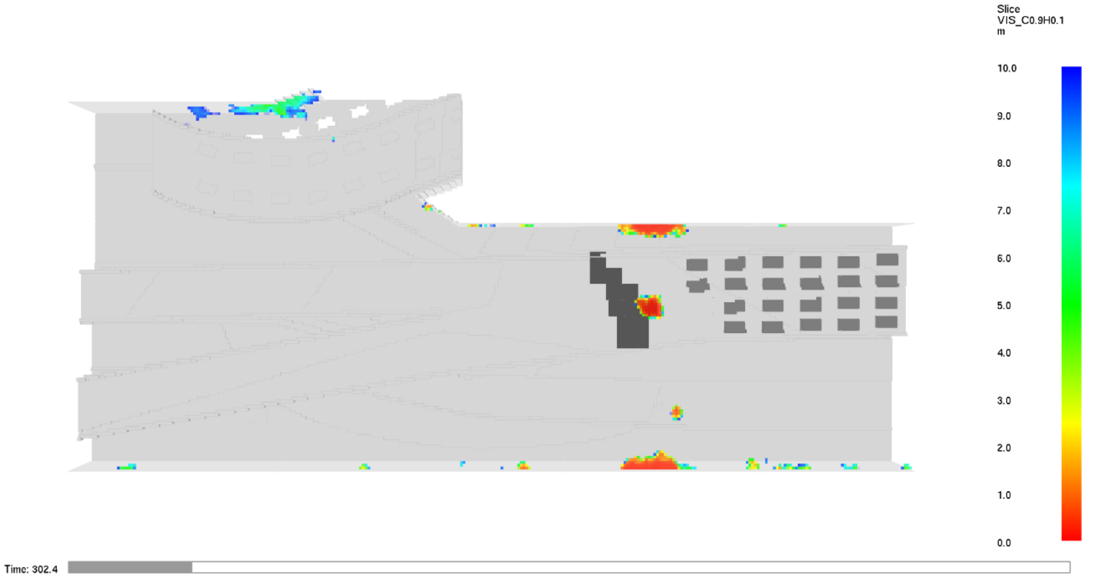
- An average of 1.5 occupants per vehicle;
- Cars are estimated to be approximately 4.9-5.2m in length and queuing at 6.7m centres;
- Each lane has been assessed to have 22 vehicles. It has been conservatively assumed that there are four full lanes of traffic along the entire length of the land bridge even though there are only three lanes at the entry;
- One passenger bus containing 50 passengers has also been included without reducing the number of cars;
- Thus a total of 182 occupants;
- The fire is assumed to be located at the northern end of the land bridge and to be conservatively blocking exit via both of the Western Distributor streams towards the Sydney Harbour Bridge and towards King St;
- Population distribution and travel speed;
  - Adults (90%): 1.2m/s
  - Child (5%): 0.5m/s
  - Disabled (5%): 0.5m/s
- Egress is via the road ways only; and
- Combined cue time and pre-movement time is taken as 1-4 minutes uniformly distributed over the occupants.

Our analysis indicates that the required egress time for upstream users to safely evacuate in the above scenario is 9 minutes.

In the case where the fire is located in the centre of the elevated roadway beneath the land bridge (as assessed as being the most critical case for the fire simulations), and exits were available at either end, the egress time has been determined as 6.5 minutes. Users downstream would continue to drive and exit the underpass as normal and are not expected to be affected by the fire.

6 Fire on the Northbound Western Distributor

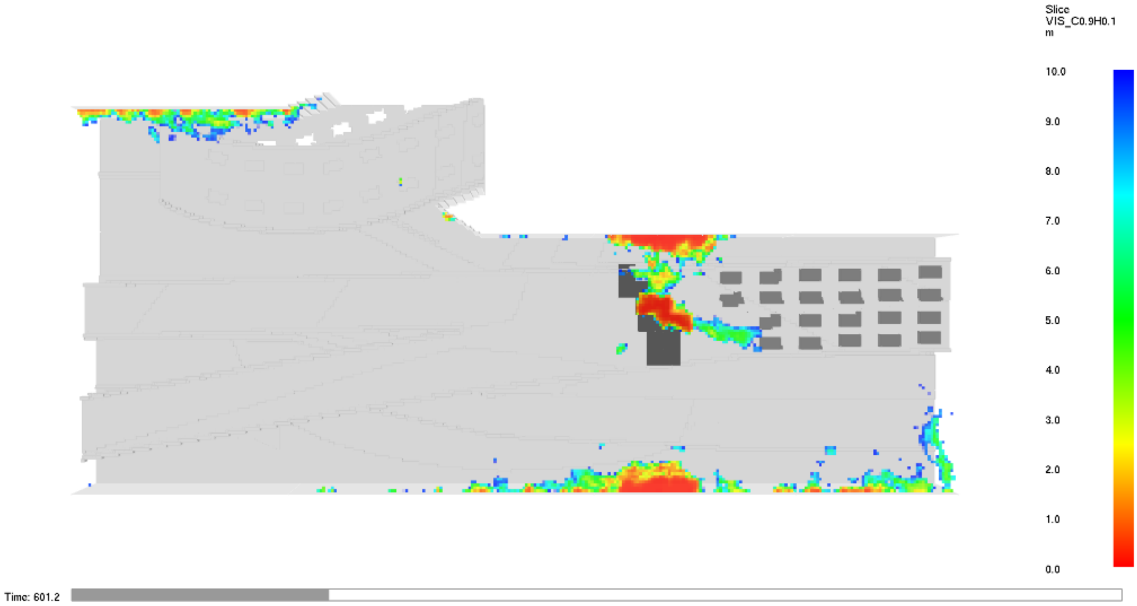
6.1 Visibility – after 5 minutes

	Scenario 1 – Liquid tanker fire on the elevated Western Distributor
Plan – 2m above road	 Note: no contour implies visibility greater than 10m

6.2 Visibility – after 10 minutes

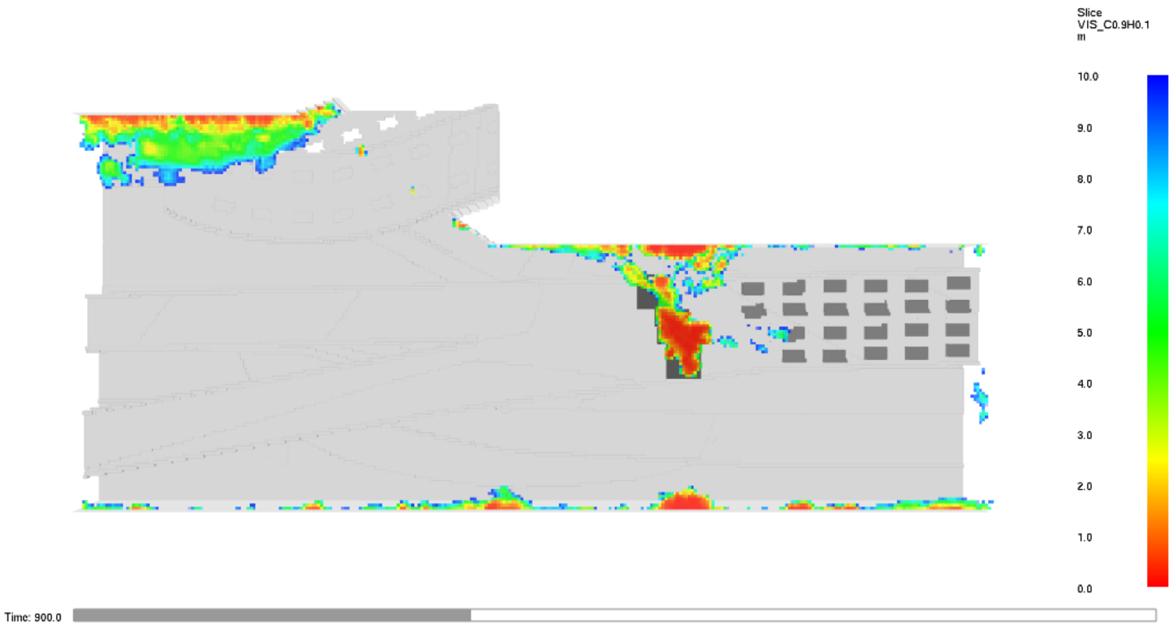
Scenario 1 – Liquid tanker fire on the elevated Western Distributor

Plan – 2m above road

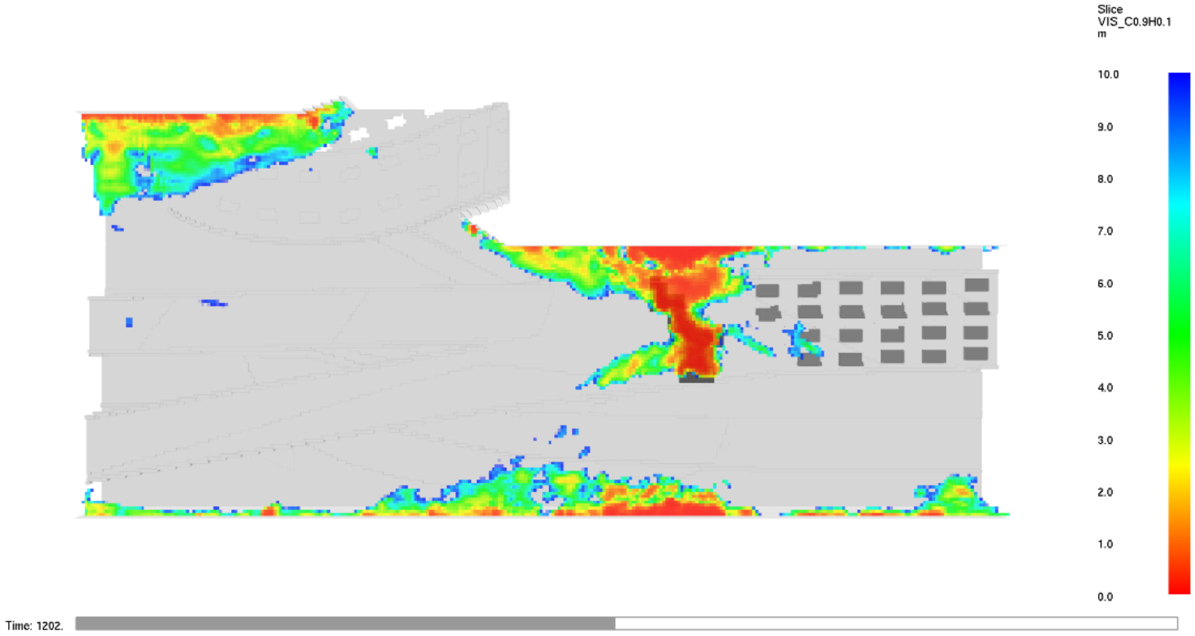


Note: no contour implies visibility greater than 10m

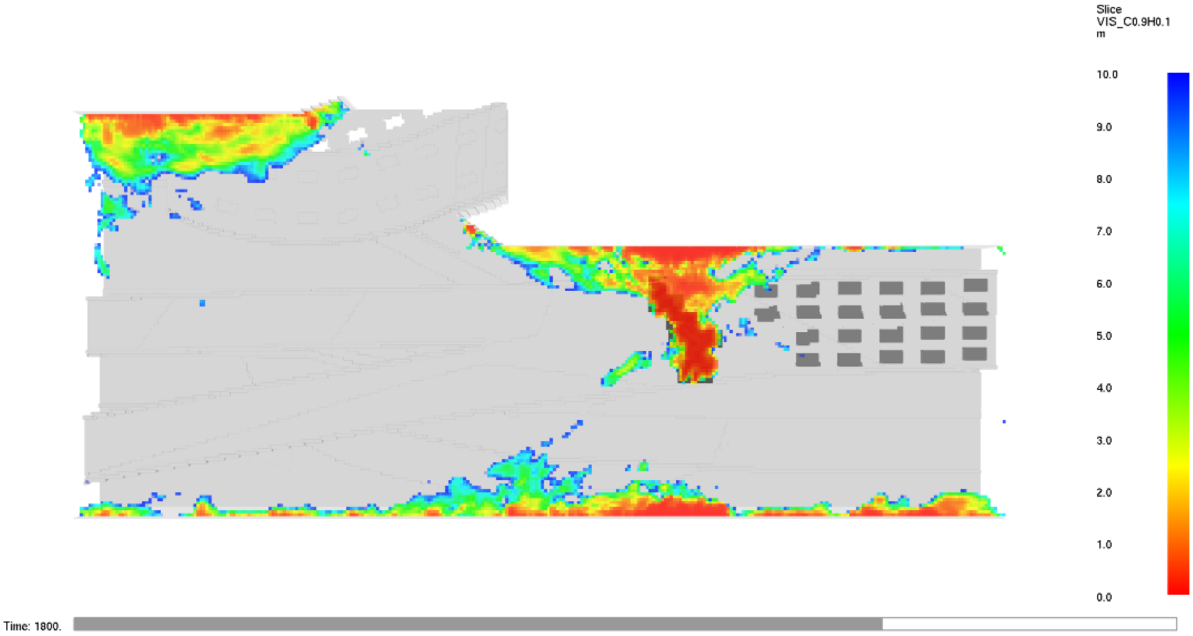
6.3 Visibility – after 15 minutes

	Scenario 1 – Liquid tanker fire on the elevated Western Distributor
Plan – 2m above road	 Note: no contour implies visibility greater than 10m

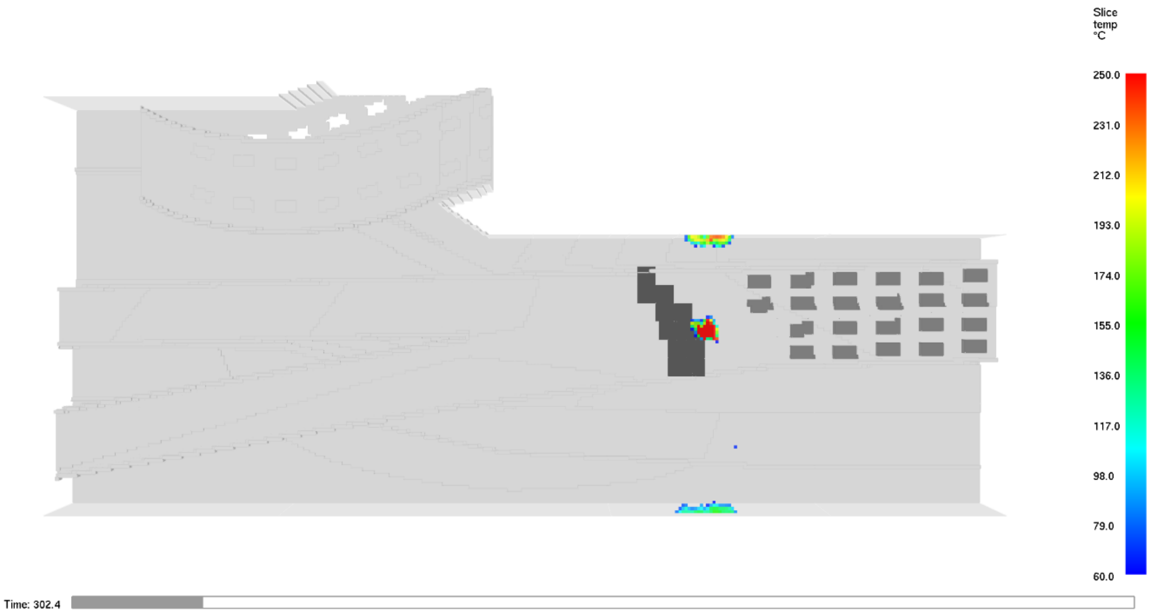
6.4 Visibility – after 20 minutes

	Scenario 1 – Liquid tanker fire on the elevated Western Distributor
Plan – 2m above road	 Note: no contour implies visibility greater than 10m

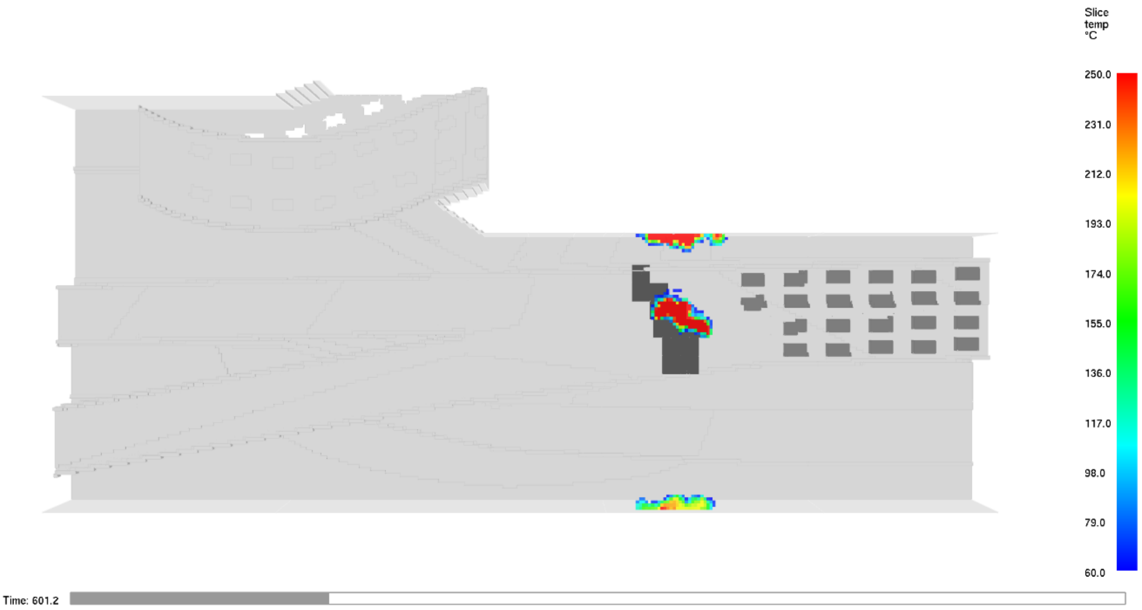
6.5 Visibility – after 30 minutes

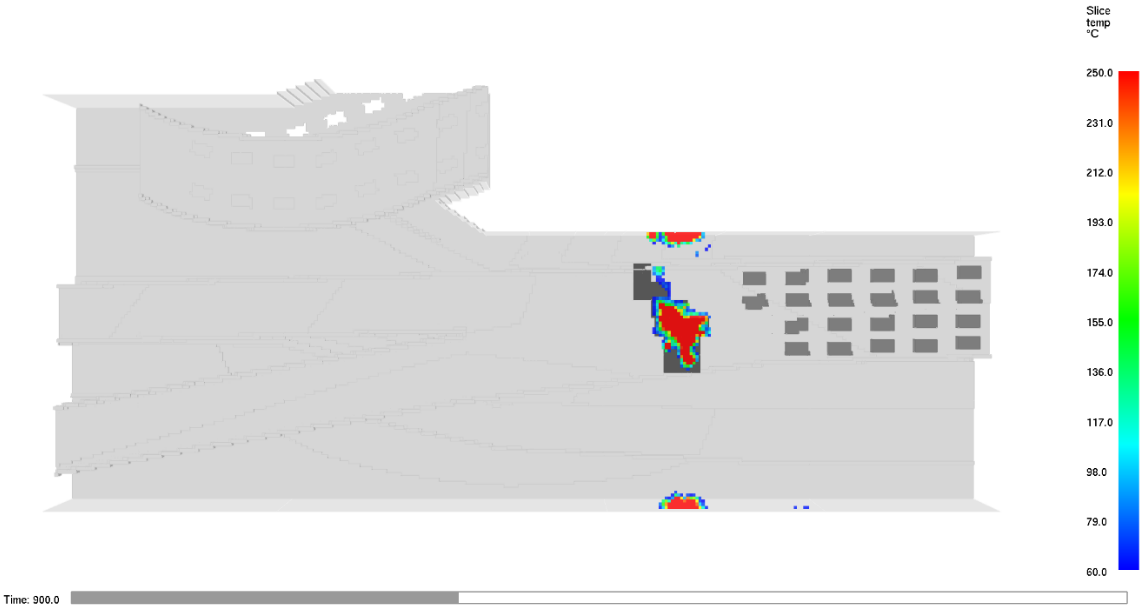
	Scenario 1 – Liquid tanker fire on the elevated Western Distributor
Plan – 2m above road	 Note: no contour implies visibility greater than 10m

6.6 Temperature – after 5 minutes

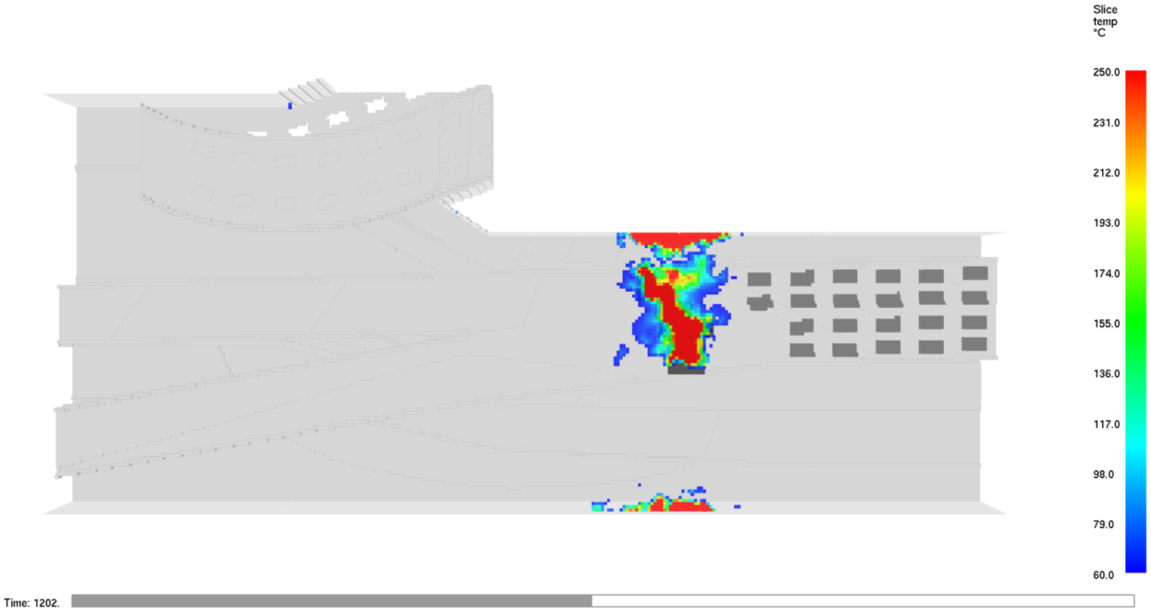
	Scenario 1 – Liquid tanker fire on the elevated Western Distributor
Plan - 2m above road	 Note: no contour implies temperature less than 60°C

6.7 Temperature – after 10 minutes

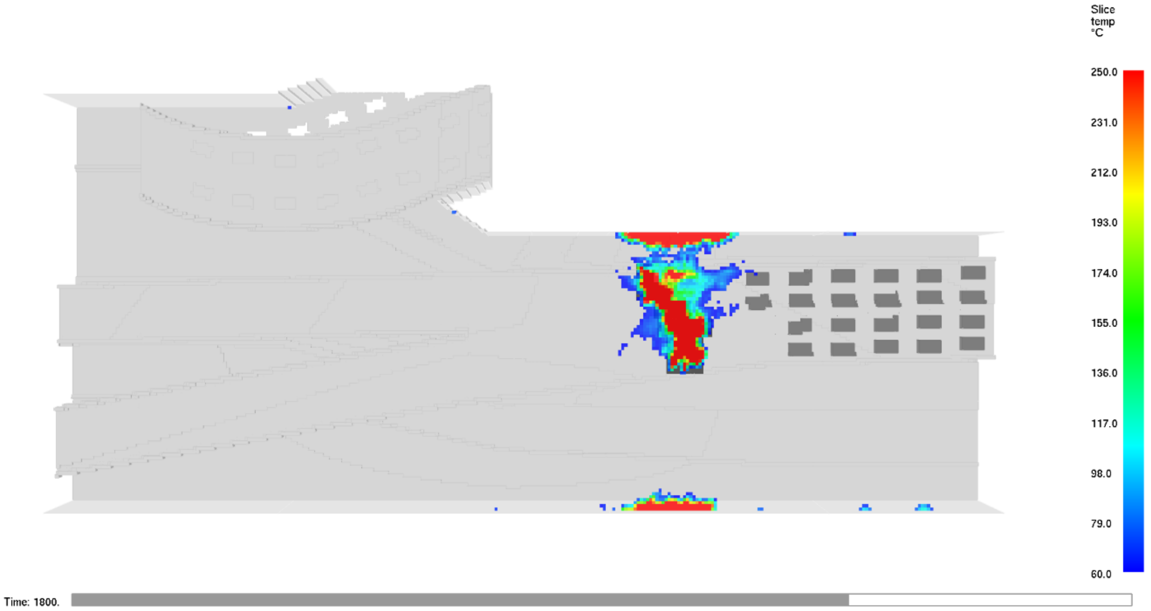
	Scenario 1 – Liquid tanker fire on the elevated Western Distributor
Plan – 2m above road	 Note: no contour implies temperature less than 60°C

## 6.8 Temperature – after 15 minutes	
	Scenario 1 – Liquid tanker fire on the elevated Western Distributor
Plan – 2m above road	 Note: no contour implies temperature less than 60°C

6.9 Temperature – after 20 minutes

	Scenario 1 – Liquid tanker fire on the elevated Western Distributor
Plan – 2m above road	 Note: no contour implies temperature less than 60°C

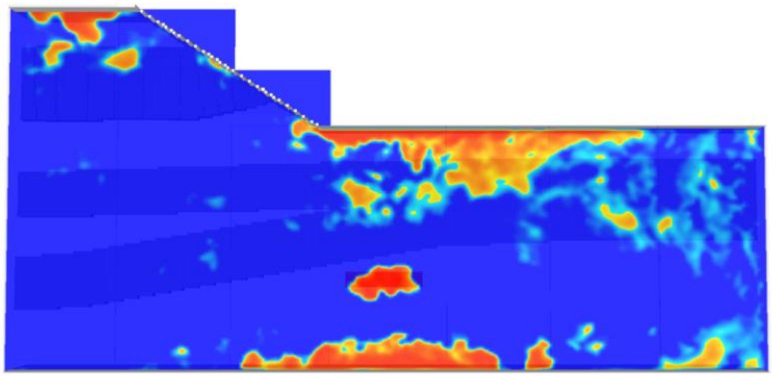
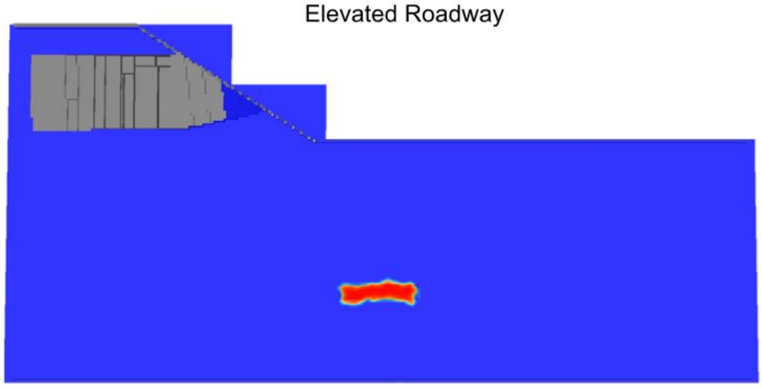
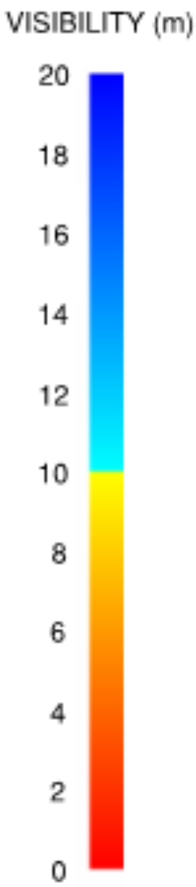
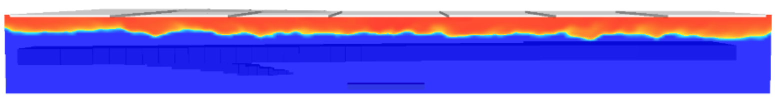
6.10 Temperature – after 30 minutes

	Scenario 1 – Liquid tanker fire on the elevated Western Distributor
Plan – 2m above road	 Note: no contour implies temperature less than 60°C

7 Fire on the Northbound Harbour St

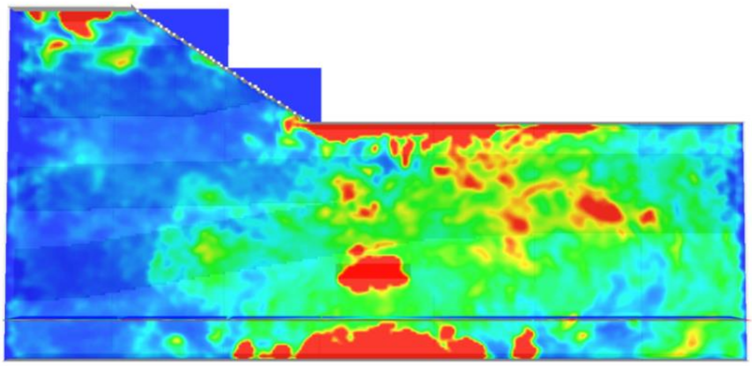
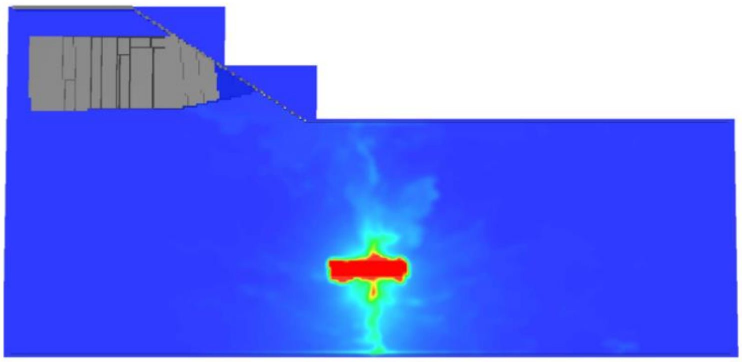
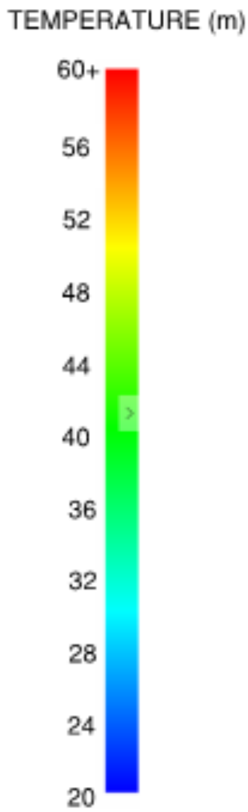
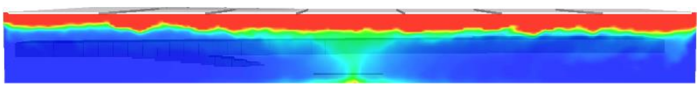
7.1 Visibility – after 20 minutes

(Simulations indicated stable conditions in the underpass after this time)

	Scenario 2 – HGV fire on the northbound Harbour St	
Plan – 2m above road	 Elevated Roadway  Harbour St	
Long Section		

7.2 Temperature – after 20 minutes

(Simulations indicated stable conditions in the underpass after this time)

	Scenario 2 – HGV fire on the northbound Harbour St	
Plan – 2m above road	 Elevated Roadway  Harbour St	
Long Section		

8 Summary of findings

The CFD assessment found the following:

Scenario 1:

- In the event of a fire involving a combustible liquid tanker starting on the northbound lanes of the Western Distributor, heat and visibility is acceptable for persons behind the fire for a period of at least 30 minutes. This is longer than the estimate time to escape from the landbridge.
- Temperatures in excess of 60^0C are confined to the area around the fire source.
- Modelling outputs are shown in Section 7.

Scenario 2:

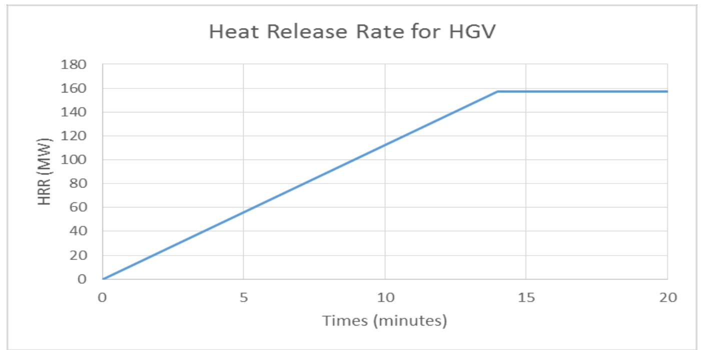
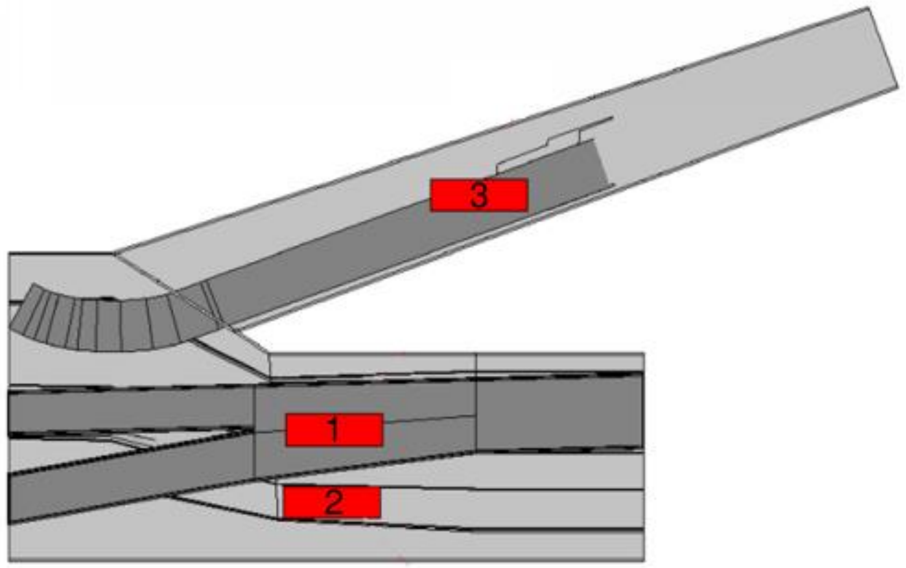
- In the event of a fire starting on Harbour Street, conditions on the Western Distributor are tenable for at least 20 minutes. Conditions on Harbour Street are expected to remain tenable for longer than 20 minutes due to the large height of the enclosure allowing the smoke and heat to rise well above the roadway.
- Due to the risk of localised patches of reduced visibility occurring on the Western Distributor, it is recommended to consider the use of traffic management systems to reduce the risk of accidents occurring on the Western Distributor from poor visibility due to a vehicle fire beneath the Western Distributor.
- Modelling outputs are shown in Section 8

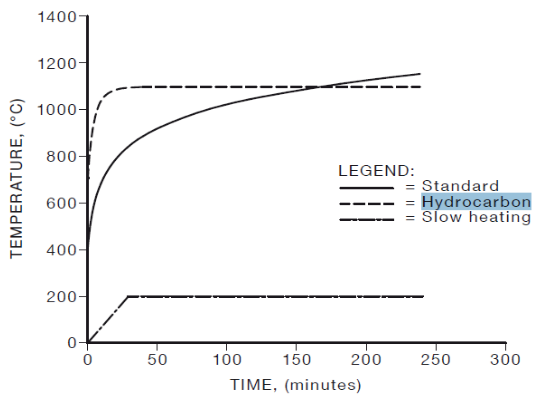
Refer to sections 7 and 8 below for the comparative outputs of the scenarios described above.

9 Proposed Landbridge Design Criteria

Based on these fire assessments, landbridge design criteria has been developed and coordinated with TfNSW. The design development in the next stage of design is to be assessed against these criteria, which is detailed in the following pages.

Design Item	Design Parameters	Acceptance Criteria	Reference

1. Fire Load for Tenability	Heavy Goods Vehicle (HGV)
	• Peak heat release rate (HRR) 157MW
	• Peak value reached after 14 minutes at which point it remains constant
	• 82% wood pallets, 18% polyurethane plastic
	
	• Soot yield 0.1g/g
	• Heat transfer: radiation 35%, convection 65%
	• Ambient temperature 20°C
	• Three fire locations to be assessed separately:
	  ○ 1. Mid-length of the enclosure on the elevated Western Distributor viaduct
	  ○ 2. Mid-length of the enclosure on the northbound Harbour St
	  ○ 3. Mid length of the existing Darling Park underpass
	
		Computational Fluid Dynamics (CFD) assessment and egress modelling to demonstrate tenable conditions such that the Available Safe Egress Time (AEST) is greater than the Required Safe Egress Time (RSET) based on the below criteria:
		• Visibility greater than 10m (2m above the evacuation surface)
		• Temperature less than 60°C (2m above the evacuation surface)
		• Fractional effective dose of toxic gases, FED_{co} less than 0.3
			• Based on findings from the large scale fire test in Runehamar Tunnel in 2003 by Technical Research Institute of Sweden (SP)
			• Buchanan, April 2001

Design Item	Design Parameters	Acceptance Criteria	Reference
2. Egress Conditions	• Cars approximately 4.9 – 5.2 m in length queuing at 6.7 m centres in all lanes • Average 1.5 people per car • One passenger bus with 50 passengers • Population distribution and travel speeds: 90% adults 1.2m/s, 5% children 0.5m/s, 5% disabled 0.5m/s • Combined cue time and pre-movement time is taken to be 1-4 minutes uniformly distributed over the occupants • Egress path via the existing roadways with safe places to be nominated in conjunction with the assessment • The conditions in non-incident areas such as within the existing Darling Park underpass during a fire incident on the elevated roadway within the new enclosure and vice versa are to be assessed • The ability of the road user to identify their location in the event of a fire incident is to be addressed in the assessment	Computational Fluid Dynamics (CFD) assessment and egress modelling to demonstrate tenable conditions such that the Available Safe Egress Time (AEST) is greater than the Required Safe Egress Time (RSET) based on the below criteria: • Visibility greater than 10m (2m above the evacuation surface) • Temperature less than 60°C (2m above the evacuation surface) • Fractional effective dose of toxic gases, FED_{co} less than 0.3	NFPA 502
3. Emergency Services Response	The access strategy and incident response for emergency services, and the return to service requirements after a fire event are to be workshopped with RMS and the relevant emergency services once they become involved in the design development	To be workshopped with RMS and emergency services	
4. Hydrocarbon Fire Load Event	Fire Resistance Level (FRL) 120/120/120 to the modified hydrocarbon curve 	Demonstrate that the land bridge structure can avoid collapse and explosive concrete spalling	AS 1530.4: 2014
5. Fire Detection		Under NFPA 502, fire detection is not a mandatory requirement for an enclosure less than 240m long with the exception of a means to stop approaching traffic from entering the underpass. The extent of fire detection is to be agreed between Fire and Rescue NSW (FRNSW), RMS and the Developer during the FER process.	NFPA 502: Table A.7.2
6. Fire Suppression	Provision for FRNSW firefighting connections and means of containment and collection of water required for FRNSW firefighting.	Under NFPA 502, a fixed suppression system is not a mandatory requirement for an enclosure less than 240m long. Austroads Dangerous Goods in Tunnels indicates a deluge system to be provided. Requirement for a deluge system to be based on the outcomes of the Dangerous Goods Risk assessment and with demonstration of adequate facility for FRNSW firefighting of the above fire loads including provision of adequate water supply, hydrants etc..	NFPA 502: Table A.7.2

Design Item	Design Parameters	Acceptance Criteria	Reference
7. Smoke Ventilation	Flow of smoke within the enclosure.	CFD assessment to demonstrate that reliance on natural ventilation will allow tenable conditions to the criteria described in item 1.	Refer to item 1
8. Smoke Flow and Air Temperature Outside the Enclosure	Parameters as described in item 1 except that the fire event occurs at the ends of the enclosure.	CFD assessment to show the flow of smoke as it exits the portals and demonstrate that the air temperature and smoke content at adjacent infrastructure (including the 161 Sussex St underpass) is below limits appropriate to the façade materials and functionality of space during a fire event.	
9. Separation of Land Bridge and 161 Sussex St Underpass	Lighting assessment to encompass the driver journey that includes the adjacent 161 Sussex St underpass in addition to the length of road beneath the proposed land bridge and their approaches. This is in order to demonstrate that the adjacent developments may remain separated and that the parameters and acceptance criteria outlined in item 7 are adequate to assess the interaction in a fire event.	Demonstrate that the lighting conditions over the journey provide acceptable light adaptation between internal and external areas without the need for additional measures between the 161 Sussex St underpass and the land bridge	• AS 1158.5 • RMS specification R158

10 Conclusion

Two fire scenarios have been modelled and assessed using CFD for the purposes of this fire assessment. The two scenarios are:

Scenario 1: A combustible liquid tanker fire (Dangerous Goods Vehicle) at mid-length of the landbridge enclosure on the elevated northbound Western Distributor.

Scenario 2: A Heavy Goods Vehicle fire at mid-length of the enclosure on Harbour St below the elevated Western Distributor.

This fire assessment indicates that:

- **Scenario 1:** Heat and visibility is acceptable for persons behind the fire for a period of at least 30 minutes. This is longer than the estimated time to escape from a fire event on the Western Distributor
- **Scenario 2:** Conditions within the egress pathways on the roadways beneath the landbridge are acceptable.

Due to the risk of localised patches of reduced visibility occurring on the Western Distributor, it is recommended to consider the use of traffic management systems (e.g. existing variable message signs on the Western Distributor) to reduce the risk of accidents occurring on the Western Distributor from poor visibility due to a vehicle fire beneath the Western Distributor.

In undertaking simulations of the two fire scenarios, no means of external provision was used to improve the tenability condition (e.g. fire suppression).

This report assesses the risk of a fire involving a heavy goods vehicle and a separately a fire involving a petrol tanker dangerous goods vehicle on the Western Distributor. A separate report has been prepared to address the transportation of all types of Dangerous Goods Vehicles that could use the Western Distributor.

Requirement for a FFFS under the landbridge is to be assessed on the outcomes of the Dangerous Goods Risk assessment and with demonstration of adequate facility for FRNSW firefighting of the above fire loads including provision of adequate water supply, hydrants etc.

Appendix B

Lighting Assessment Report

Cockle Bay Park

Landbridge Lighting Study

DPT and DPPT Operator Pty Ltd

Reference: 253427

Revision: A

2021-10-08

Bringing ideas to life

Document control record

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Approval			
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Title	Senior Lighting designer	Title	Roads Capability Leader

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1 Introduction

DPT Operator Pty Ltd and DPPT Operator Pty Ltd (the Proponent) is seeking to secure concept approval for the Cockle Bay Park development. As part of this development a new landbridge structure over the Western Distributor has been proposed. This landbridge would create a partial enclosure to the elevated northbound Western Distributor and southbound Market St towards Anzac Bridge, the on grade northbound and southbound Harbour St, Western Distributor and northbound Wheat Rd.

This report provides an indication of the preliminary assessment of the lighting design requirements below the landbridge for each carriageway section.

2 Overview

The purpose of this study is to determine the luminescence values required for each of the carriageways affected by the landbridge development in accordance with *AS 1158.5:2014 – Lighting for roads and public spaces – Part 5: Tunnels and underpasses.* Appropriate lighting design for underpasses is essential in overcoming the 'black hole' often seen by motorists on the approach to an underpass portal. These potential effects may result in high light adaptation of a motorist's vision and impact their ability to see objects as they traverse through the underpass.

This report details the L20 luminescence values calculated for each affected carriageway, which has been used in turn to estimate the luminescence values in each of the underpass zones: threshold, transition, interior and exit zones. This study provides preliminary information to inform the detailed underpass lighting design as well as describing the information required to provide a holistic design assessment throughout subsequent design development stages. This study demonstrates that lighting compliance can be achieved in the detailed design phase.

3 Background

3.1 Documentation

As part of the contract design requirements, Aurecon has been provided with the following documentation, upon which it has based its design:

- Cockle Bay Redevelopment Landbridge General Arrangement provided by Enstruct group Pty Ltd dated 28.05.20
- Landbridge Control Sections - Heights provided by Enstrust Group Pty Ltd dated 26.05.20
- Coordinated Revit model dated 10.05.21

We have reviewed the SSDA Stage 2 submission documents and confirm that the above design basis documentation used for this lighting assessment are consistent and will not materially alter the lighting assessment outcomes of this report.

4 Design Investigations

4.1 Identification of affected Roads

As part of the design investigation Aurecon has identified the carriageways that will be affected by the new landbridge. The affected carriageways are the Western Distributor Northbound, Western Distributor Southbound, Harbour Street Northbound, Market Street Southbound, Sussex Street Southbound and Harbour Street Southbound. The extents of the affected areas are shown in the figures below.

All elevated and on-grade carriageways fall under the same design considerations requiring new underpass lighting treatment to support the changed visual conditions as a result of the overhead Landbridge. This includes full supporting threshold lighting, with varying requirements for threshold, interior and exit lighting as illustrated in section 4.4 for each carriageway.

The existing streetlighting systems servicing these carriageways are deemed to not be suitable for the new underpass characteristics, and new underpass lighting systems will be required for each carriageway.

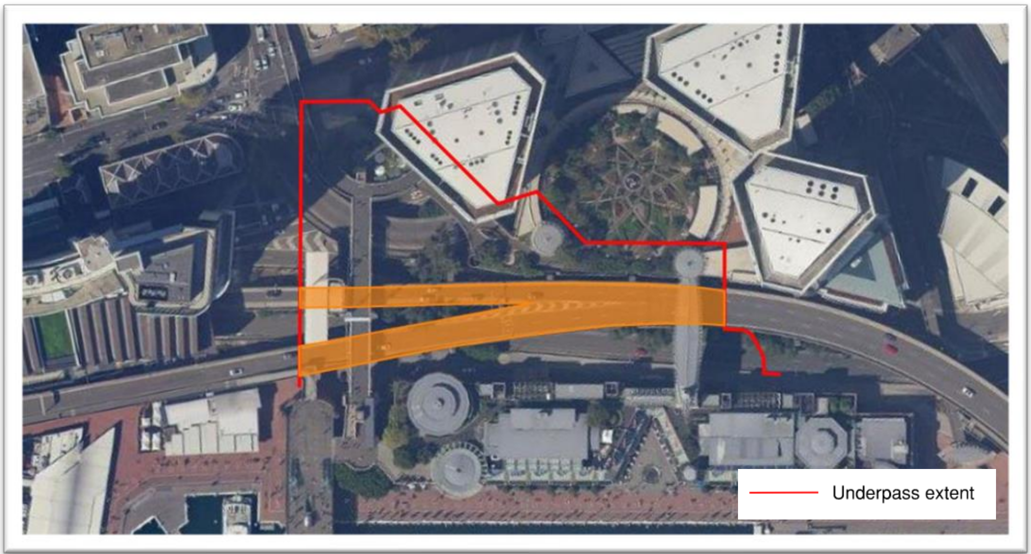


Figure 1: Western Distributor Northbound

Figure 2: Harbour Street Northbound

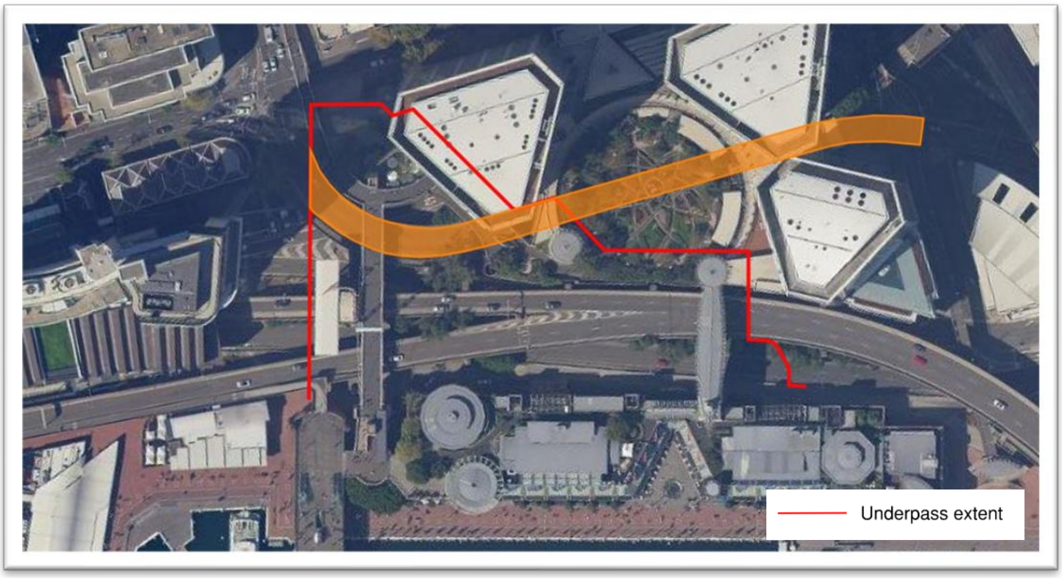


Figure 3: Market Street Southbound

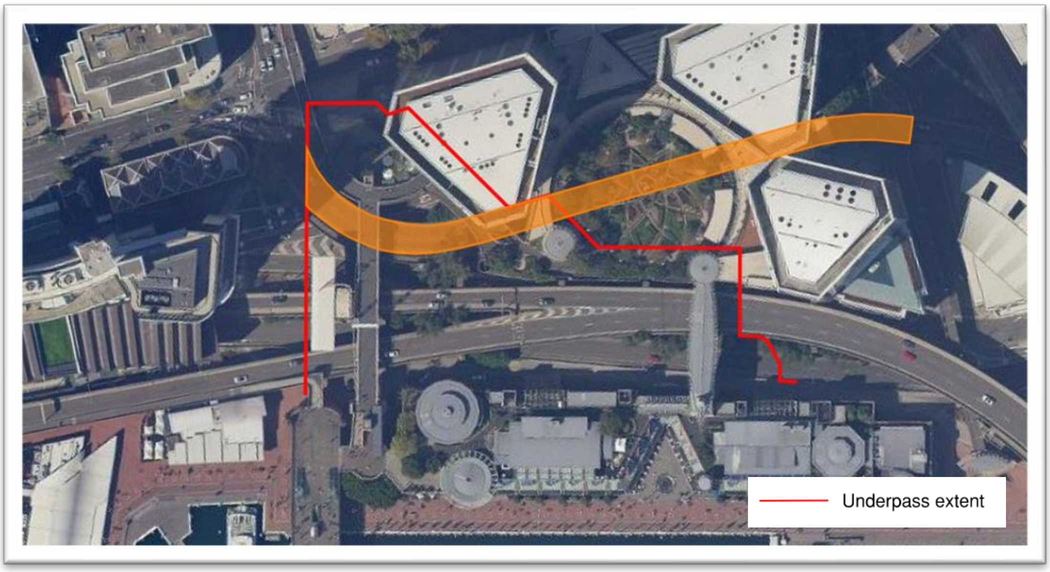


Figure 4: Sussex Street turn to Market Street Southbound

Figure 5: Western Distributor Southbound

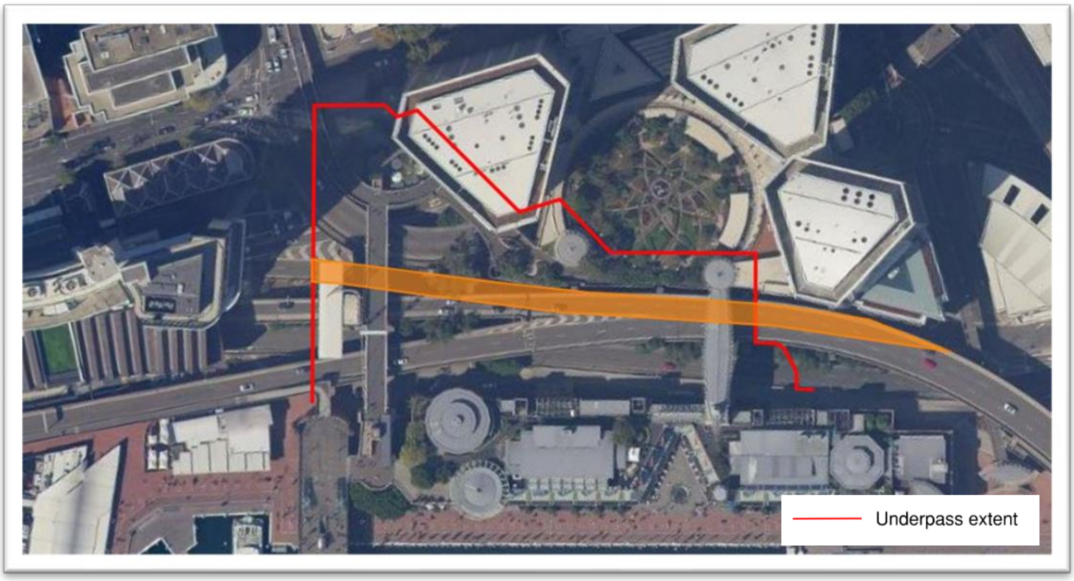


Figure 6: Harbour Street Southbound

Figure 7: Wheat Rd

4.2 Wheat Rd

The existing Wheat Rd service Rd will largely be consumed by the new building footprint and the carriageway will be modified to act as a private service road, porte cochere and carpark.
The lighting to service these elements will be private lighting forming part of the building services scope of works.
A small portion of the existing Wheat Rd carriageway will be retained beyond the building boundary to allow connection from this service road back on to the Harbour Street northbound carriageway. The extent of this small portion of Wheat Rd which will remain an asset of TfNSW is shown in Figure 7.
It is recommended that this small connection carriageway element beyond designed to a lighting sub-category of PR2 using TfNSW approved luminaire types.

4.3 Road Speeds and Sight Stopping Distances

The road speeds for each carriageway have been determined from existing carriageway posted speed limits using Google Streetview. The underpass length for each carriageway section has been determined from the current 'Issued for Information' structural drawing set.

The values for the Sight Stopping Distances (SSD) have been based on the recommended SSD's stipulated in *AS1158.5:2014 – Lighting for roads and public spaces – Tunnels and underpasses Table 2.2.*

Table 1 Carriageway Road Design Speeds

Carriageway	Road Speed (km/h)	Road Alignment Length Beneath the Landbridge (m)	Sight Stopping Distance SSD (m)
Western Distributor Northbound	70	161	91
Harbour Street Northbound	50	176	54
Market Street Southbound	60	243	71
Sussex Street Southbound	60	243	71
Western Distributor Southbound	70	214	91
Harbour Street Southbound	70	224	91

Note: the precise SSD allowing for the road gradiants on approach to the entrance portal are provided within the assessment data tables within Appendix 1 of this document.

4.4 Zone Parameters

The information to establish the Zone parameters has been based on the recommendations made in *AS1158.5:2014 – Lighting for roads and public spaces – Tunnels and underpasses* and shall be discussed in the following sections.

4.4.1 Threshold Zone

AS1158.5:2014 – Lighting for roads and public spaces – Tunnels and underpasses Section 3.3.2 stipulates a total 'Threshold Zone' length equal to no less than the SSD.

This is comprised of a Threshold Zone 1 which is equal to half the SSD and maintains a luminance for the full length as determined from the L20 luminance investigation, and a Threshold Zone 2 which is equal to half the SSD and has a linear luminance reduction over the length from the Threshold Zone 1 luminance to half of the Threshold 1 luminance.

4.4.2 Transition Zone

The length of the transition zone for this study has been determined by the required luminance depreciation over time (distance) as stipulated in *AS1158.5:2014 – Lighting for roads and public spaces – Tunnels and underpasses Figure 3.2.*

The transition zone is determined by the road design speed and the length required at that speed to achieve a linear luminance depreciation to a value to twice that of the Interior Zone. Due to the short length of some of the underpass profiles however, the underpasses do not always allow for a completion of that luminance reduction and are interrupted by the Exit Portal.

4.4.3 Interior Zone

The Interior Zone, where the length of the underpass permits one, allows for a maintained luminance value for the entire extent which is determined based on the road design speed as stipulated in *AS1158.5:2014 – Lighting for roads and public spaces – Tunnels and underpasses Table 3.2.* In this instance that luminance value will be 7.5cd/m^2 as all carriageways have a designed road speed of 70km/hr or less.

4.4.4 Exit Zone

The Exit Zone, where the luminance reduction profile and length of underpass permit one, will increase the luminance level to five (5) times that of the Interior Zone lineally prior to the Exit Portal.

Where no Exit Zone is provided Section 3.3.5 then carries on to suggest that prior to the exit portal the luminance value should increase lineally to a value of five times that in the interior zone. This will assist in providing satisfactory light levels in the rear-vision of the vehicle as a result of rapidly increasing light adaptation due to the high light levels in the forward view of the driver on approach to the exit portal.

4.5 Zone determination parameters

4.5.1 L20 Luminance Values

All zone luminance values for each carriageway section are derived from their respective calculated ‘L20’ value. The L20 value is the luminance value of the field of view of the motorist on approach to the portal, where the field of view is a 20° steradian representation of the motorist’s focal position at a distance equal to the Sight Stopping Distance SSD from the tunnel portal.

As detailed in *AS1158.5:2014 – Lighting for roads and public spaces – Tunnels and underpasses*, the calculated L20 value takes into account the luminance values of all the objects within that 20° window including road surface, sky, tunnel portal and surrounding infrastructure and foliage.
Figure 11 shows an example of an L20 field of view and a break-down of the primary element types within that field of view. The luminance characteristics and percentage of area of each element are used to provide an aggregated average luminance to that driver which in turn informs the Threshold Zone luminance level and all subsequent underpass Zone luminance values and lengths.

The L20 view at the SSD from the portal is divided into the areas that comprise its main elements as described in *AS1158.5:2014 – Lighting for roads and public spaces – Tunnels and underpasses* Table H1 and H2; Sky, Road Surface R3, Concrete, Building and vegetation.

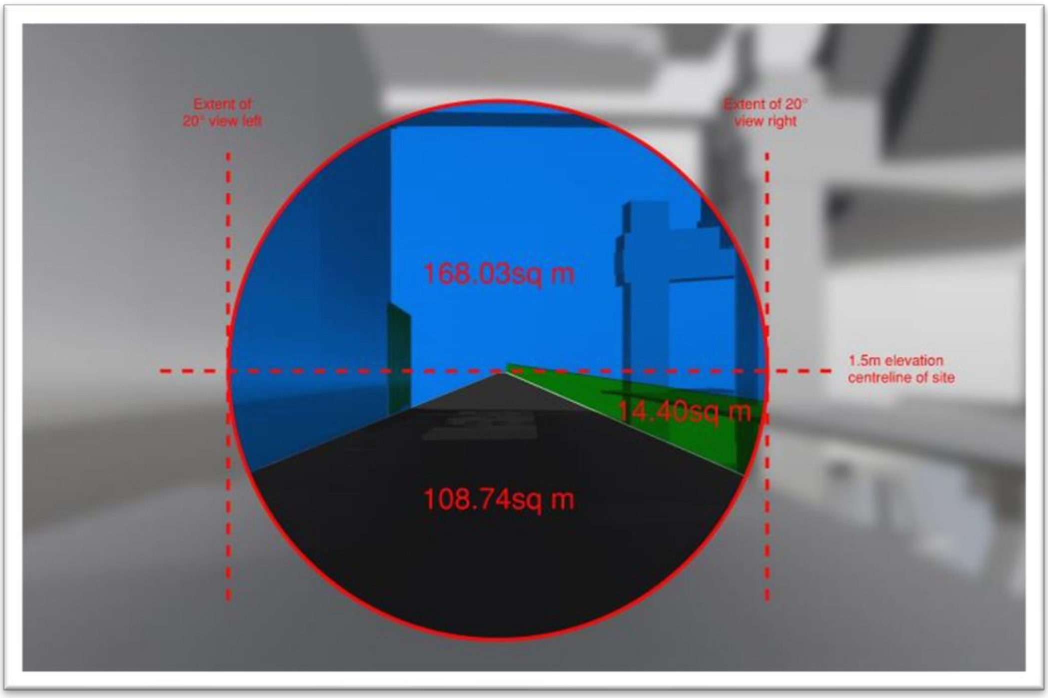


Figure 7: L20 Assessment Example

All determined L20 values for each carriageway are presented within the assessment data table provided in Appendix 1 of this document.

4.5.2 Solar Analysis

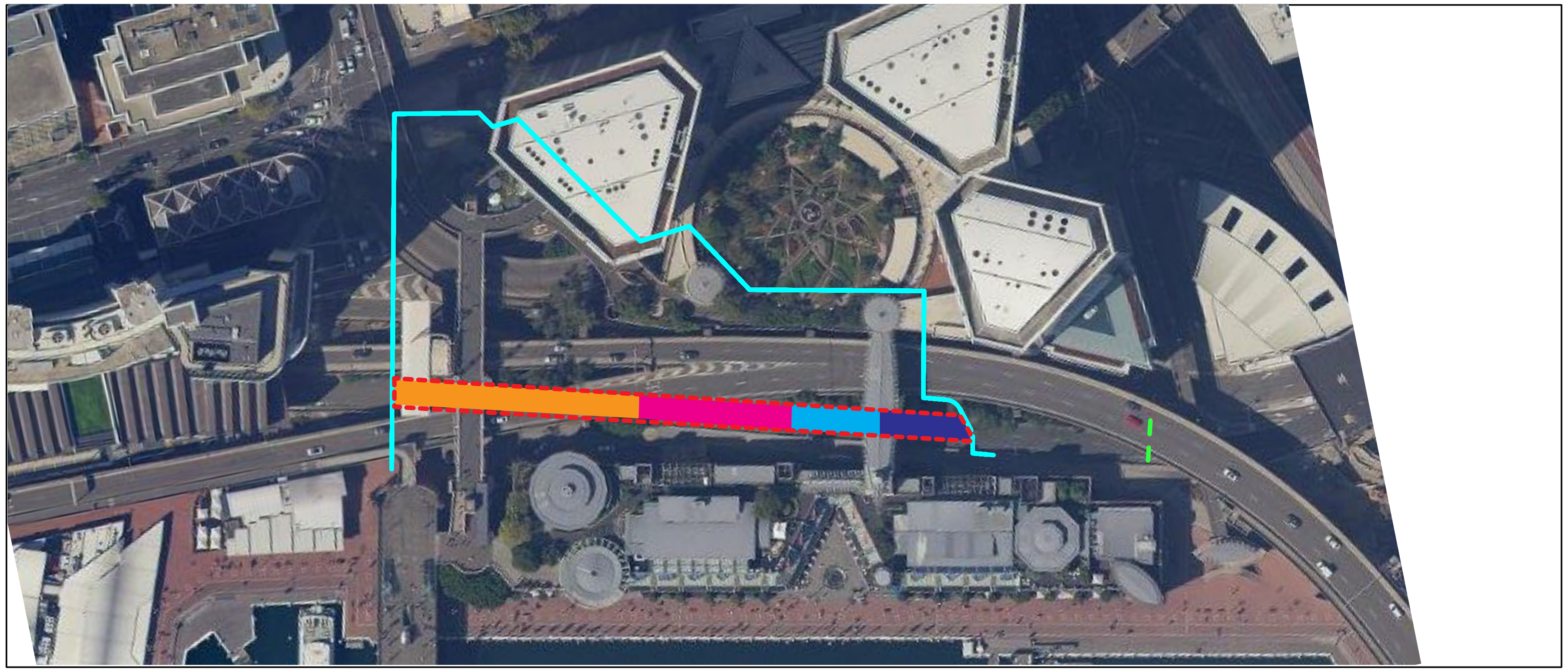
Daylighting ingress into the underpass should be considered in the lighting design for carriageways. Daylight contribution may alleviate some of the electric lighting system requirements. However, consideration also needs to be given to whether daylighting compensation is required to maintain high lighting uniformity in the transverse direction of the carriageways.

The daylighting analysis shall be undertaken as part of the lighting design development in the next design stage.

Appendix 1

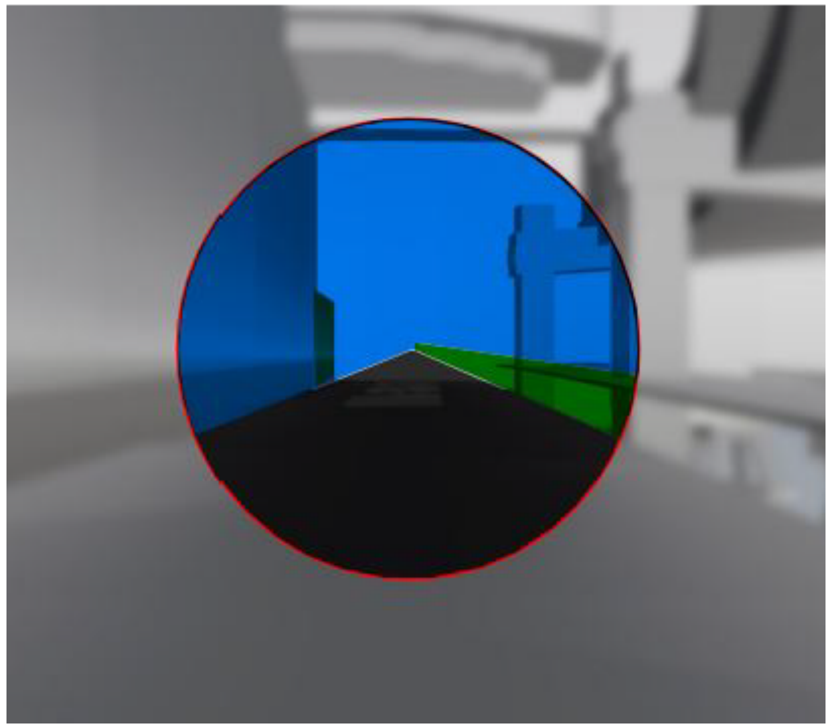
Underpass Luminance Zone Determination

Harbour Street Northbound



Legend

- Underpass extents
- SSD Position (for L20 Determination)
- Carriageway(s) Alignment
- Threshold Zone 1 - 27.5m
- Threshold Zone 2 - 27.5m
- Transistion Zone - 46m
- Exit Zone - 55m



L20 Value

- Buildings - North
- Vegetation - North
- Road Surface (R3) - North

The L20 value is determined by the average of the sum of each primary elements' luminance value (cd/m2) within the 20° steradian field of view of a drivers viewing position at a setback from the underpass threshold equal to the Sight Stopping Distance (SSD).

The determined luminance value for the Threshold Zone 1 and all subsequent Threshold and Transition Zones is determined from this luminance appraisal.

Transition Luminance (Ltr) =

$$Lth(1.9+t)^{-1.4}$$

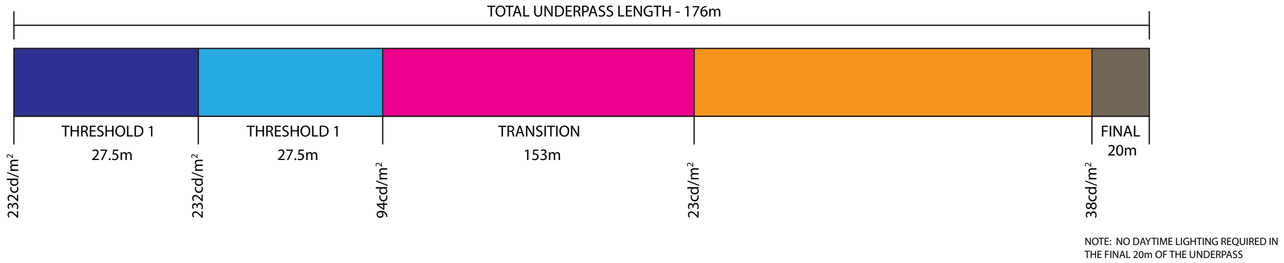
Where:
t= time travelled in seconds
Lth = 100% (of the Threshold Luminance)

Harbour Street Northbound					
Speed (km/hr)	m/s	SSD (m)	Gradient (m)	Add (m)	Final SSD (m)
50	13.89	54	0.361	0	55

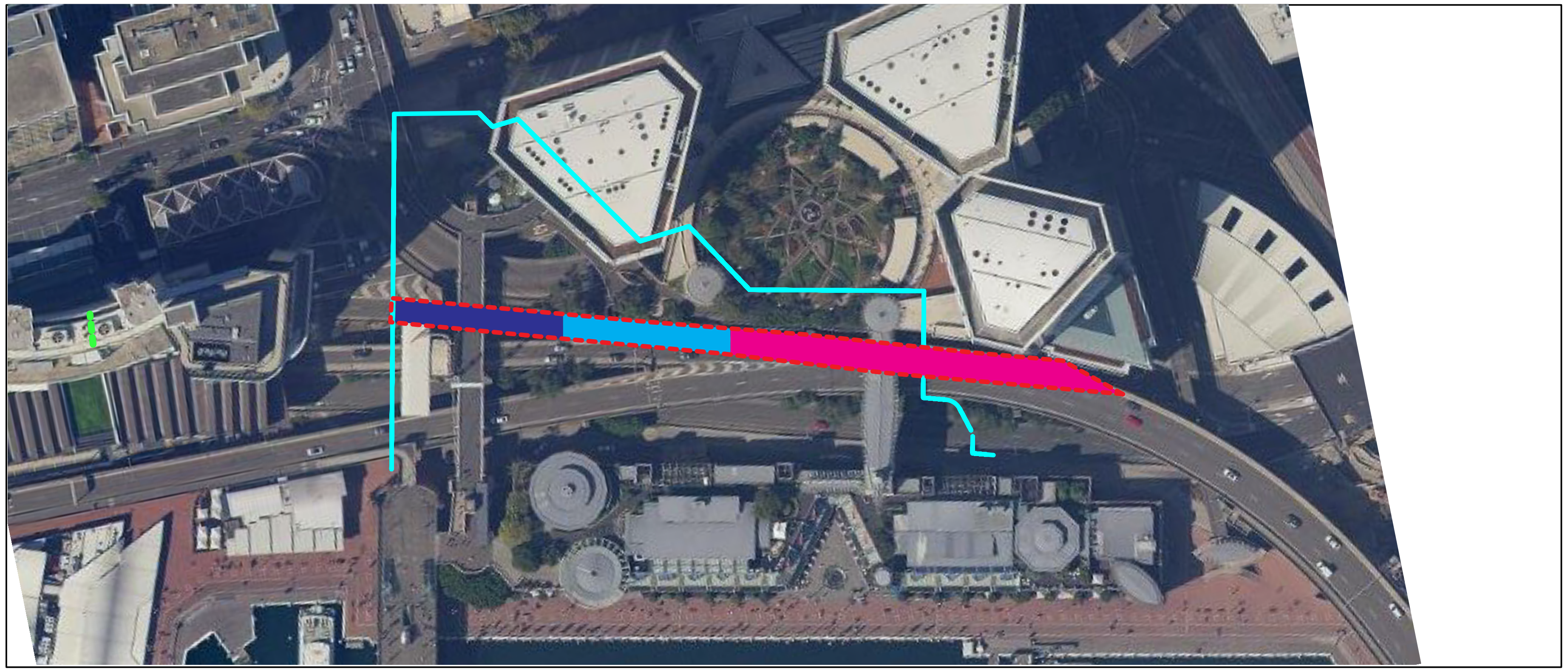
L20 Parameters		
Radius (m)	Area (m2)	k @ 50km/hr
9.7	295.45	0.05

L20 Elements					
	Area (m2)	Luminance (cd/m2)	A*L	∑ AL/A (L20)	k*L20 (Lth)
Road surface R3 North	108.74	6000	652440		
Building North	172.31	4000	689240		
Vegetation North	14.4	2000	28800		
	295.45		1370480	4638.619056	231.9309528

Interior Luminance				
Threshold 1	Threshold 2	Transition	Interior	Exit
27.5m	27.5m	46.0m	N/A	55m
232cd/m2	232cd/m2	94cd/m2		23cd/m2
to	to	to		to
232cd/m2	94cd/m2	23cd/m2		37.5cd/m2

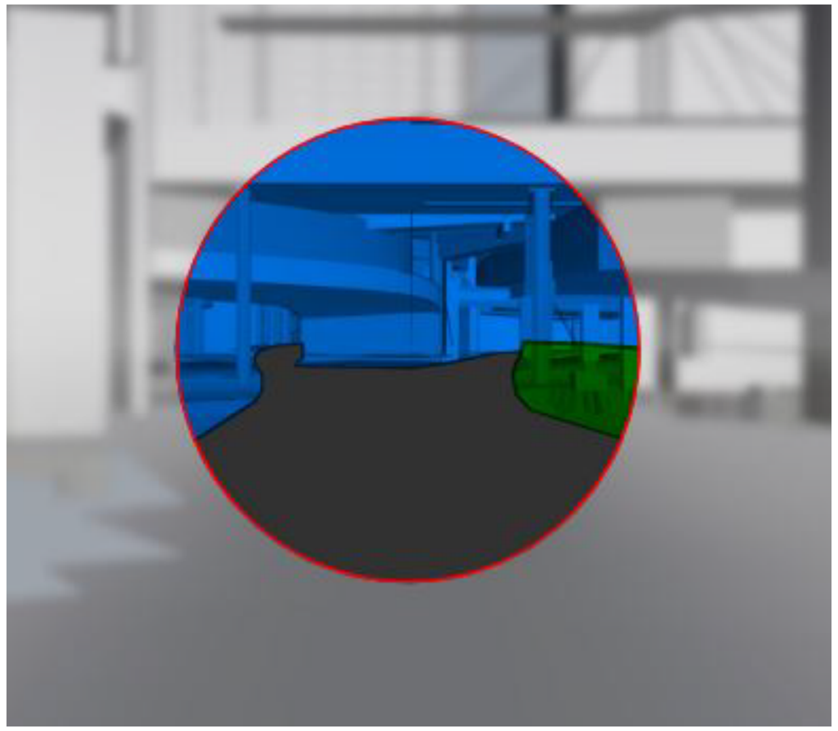


Harbour Street Southbound



Legend

- Underpass extents
- SSD Position (for L20 Determination)
- Carriageway(s) Alignment
- Threshold Zone 1 - 45m
- Threshold Zone 2 - 45m
- Transistion Zone - 114m



L20 Value

- Buildings - South
- Vegetation - South
- Road Surface (R3) - South

The L20 value is determined by the average of the sum of each primary elements' luminance value (cd/m2) within the 20° steradian field of view of a drivers viewing position at a setback from the underpass threshold equal to the Sight Stopping Distance (SSD).

The determined luminance value for the Threshold Zone 1 and all subsequent Threshold and Transition Zones is determined from this luminance appraisal.

Transition Luminance (Ltr) =

$Lth(1.9+t)^{-1.4}$

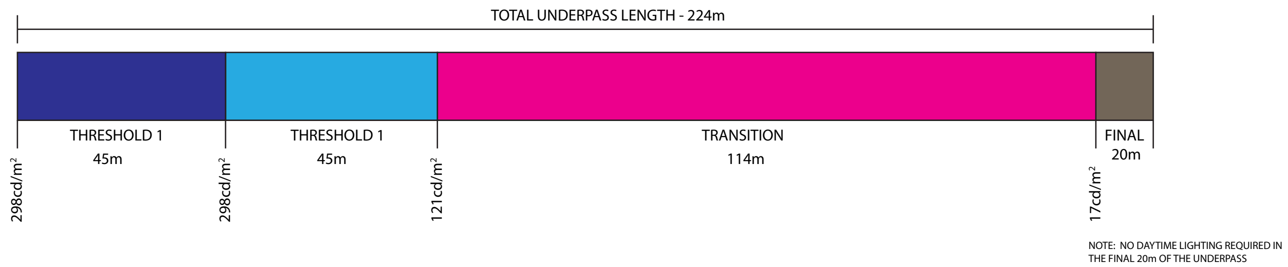
Where:
t= time travelled in seconds
Lth = 100% (of the Threshold Luminance)

Harbour Street Southbound					
Speed (km/hr)	m/s	SSD (m)	Gradient (m)	Add (m)	Final SSD (m)
70	19.44	91	0	0	90

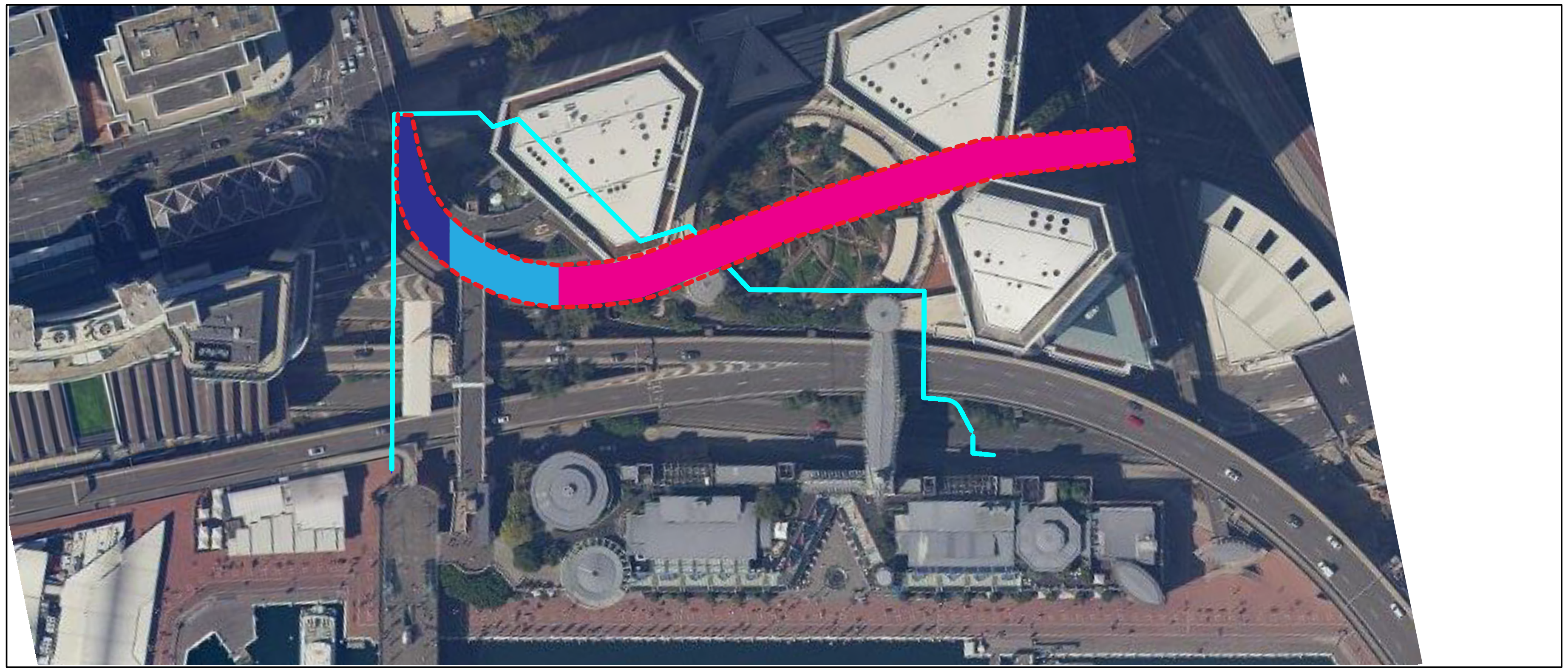
L20 Parameters		
Radius (m)	Area (m2)	k @ 70km/hr
15.84	787.85	0.0525

L20 Elements					
	Area (m2)	Luminance (cd/m2)	A*L	∑ AL/A (L20)	k*L20 (Lth)
Road surface R3 South	315.15	3000	945450		
Building South	429.46	8000	3435680		
Vegetation South	43.24	2000	86480		
			4467610	5670.635273	297.7083518

Interior Luminance				
Threshold 1	Threshold 2	Transition	Interior	Exit
45m	45m	114m	N/A	N/A
298cd/m2	298cd/m2	121cd/m2		
to	to	to		
298cd/m2	121cd/m2	17cd/m2		

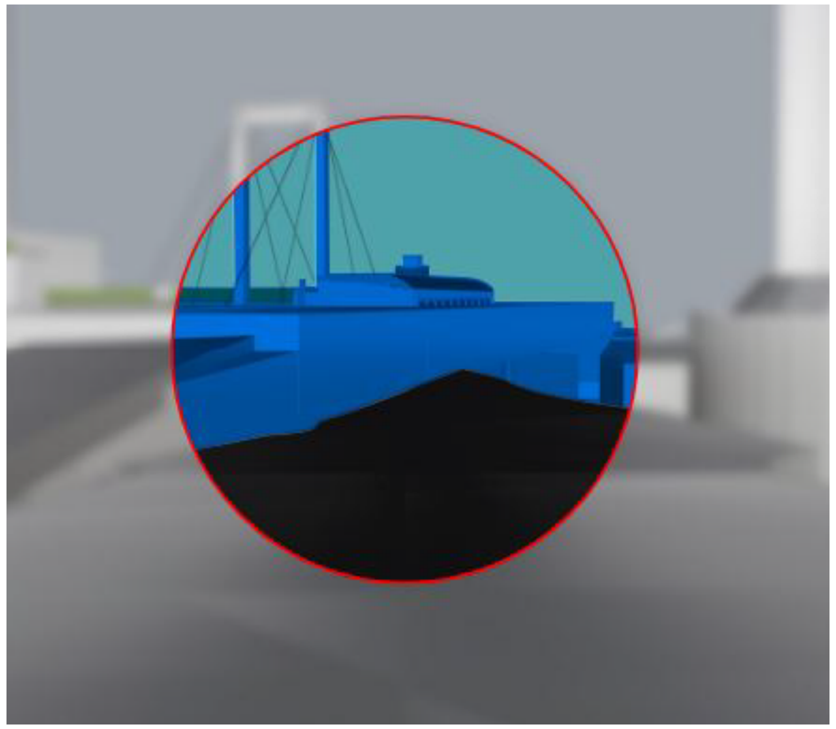


Market Street Southbound



Legend

- Underpass extents
- SSD Position (for L20 Determination)
- Carriageway(s) Alignment
- Threshold Zone 1 - 37.5m
- Threshold Zone 2 - 37.5m
- Transistion Zone - 148m



L20 Value

- Buildings - West
- Vegetation - West
- Road Surface (R3) - West

The L20 value is determined by the average of the sum of each primary elements' luminance value (cd/m2) within the 20° steradian field of view of a drivers viewing position at a setback from the underpass threshold equal to the Sight Stopping Distance (SSD).

The determined luminance value for the Threshold Zone 1 and all subsequent Threshold and Transition Zones is determined from this luminance appraisal.

Transition Luminance (Ltr) =

$Lth(1.9+t)^{-1.4}$

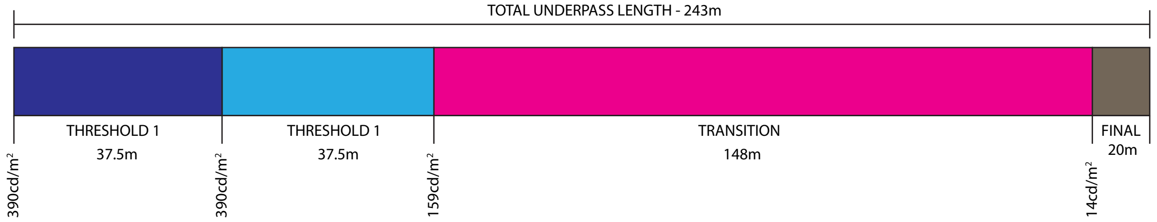
Where:
t= time travelled in seconds
Lth = 100% (of the Threshold Luminance)

Market Street Southbound					
Speed (km/hr)	m/s	SSD (m)	Gradient (m)	Add (m)	Final SSD (m)
60	16.66	71	-2.615	3	75

L20 Parameters		
Radius (m)	Area (m2)	k @ 60km/hr
13.2	547.11	0.05

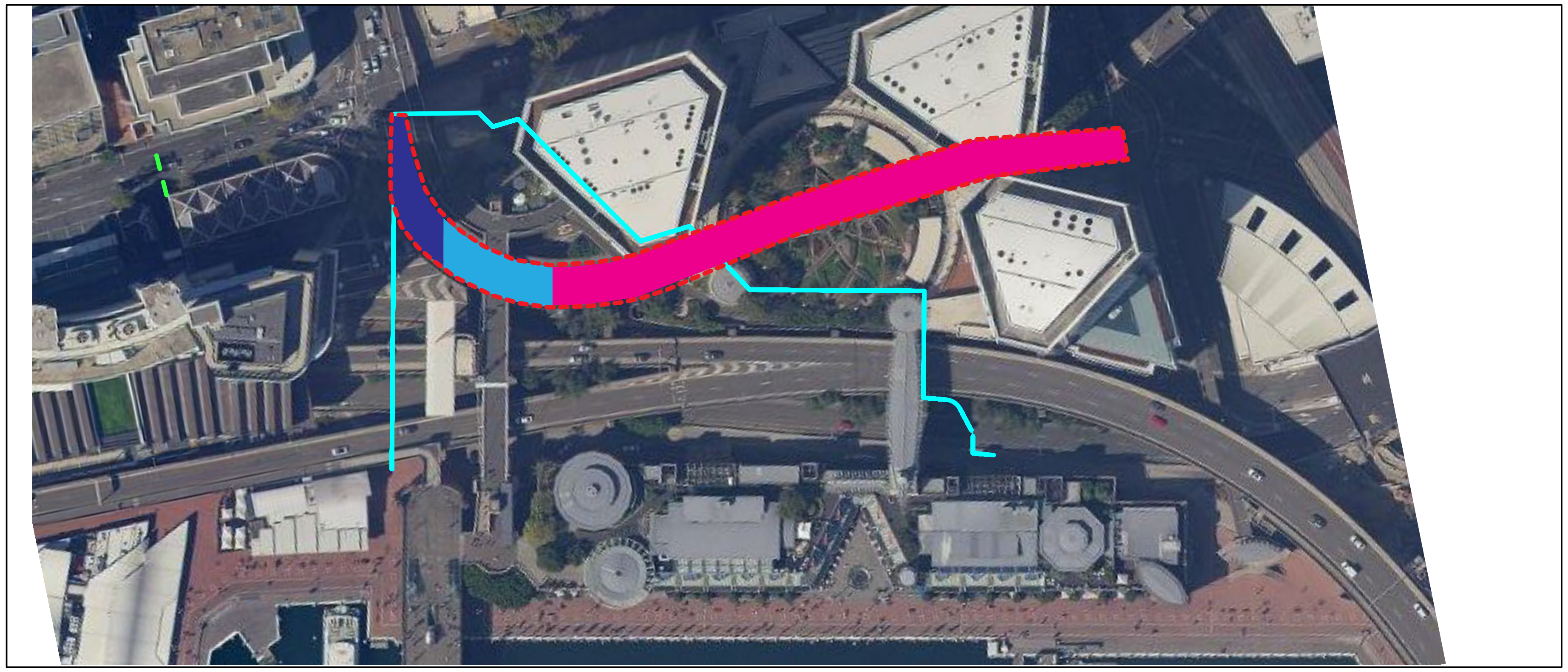
L20 Elements					
	Area (m2)	Luminance (cd/m2)	A*L	∑ AL/A (L20)	k*L20 (Lth)
Road surface R3 West	188.49	4000	753960		
Building West	188.55	6000	1131300		
Sky West	170.07	14000	2380980		
			4266240	7797.773757	389.8886878

Interior Luminance				
Threshold 1	Threshold 2	Transition	Interior	Exit
37.5m	37.5m	148m	N/A	N/A
390cd/m2	390cd/m2	159cd/m2		
to	to	to		
390cd/m2	159cd/m2	14cd/m2		



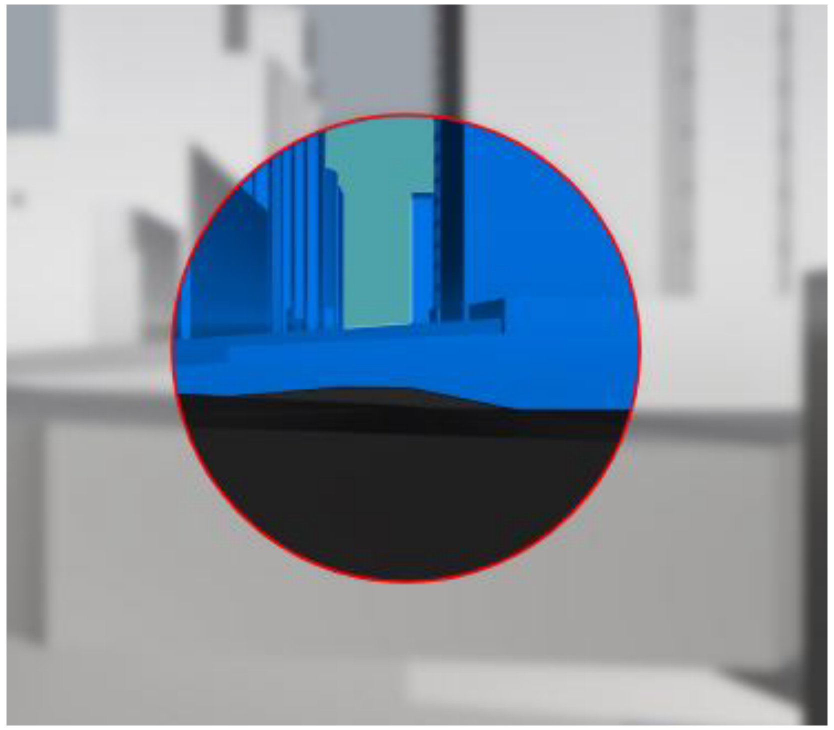
NOTE: NO DAYTIME LIGHTING REQUIRED IN THE FINAL 20m OF THE UNDERPASS

Sussex Street Southbound



Legend

- Underpass extents
- SSD Position (for L20 Determination)
- Carriageway(s) Alignment
- Threshold Zone 1 - 35m
- Threshold Zone 2 - 35m
- Transistion Zone - 153m



L20 Value

- Buildings - South
- Vegetation - South
- Road Surface (R3) - South

The L20 value is determined by the average of the sum of each primary elements' luminance value (cd/m2) within the 20° steradian field of view of a drivers viewing position at a setback from the underpass threshold equal to the Sight Stopping Distance (SSD).

The determined luminance value for the Threshold Zone 1 and all subsequent Threshold and Transition Zones is determined from this luminance appraisal.

Transition Luminance (Ltr) =

$$Lth(1.9+t)^{-1.4}$$

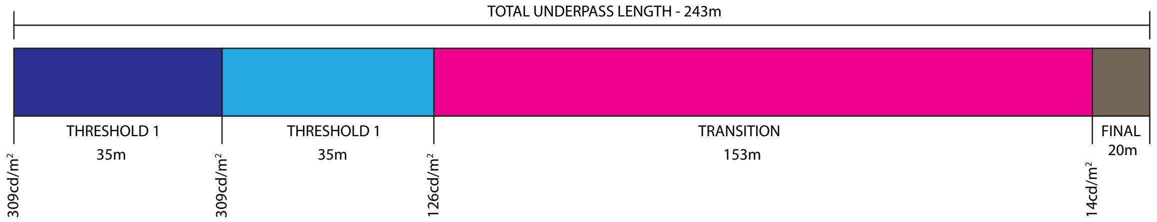
Where:
t= time travelled in seconds
Lth = 100% (of the Threshold Luminance)

Sussex Street Southbound					
Speed (km/hr)	m/s	SSD (m)	Gradient (m)	Add (m)	Final SSD (m)
60	16.66	71	-0.08	0	70

L20 Parameters		
Radius (m)	Area (m2)	k @ 60km/hr
12.32	476.59	0.05

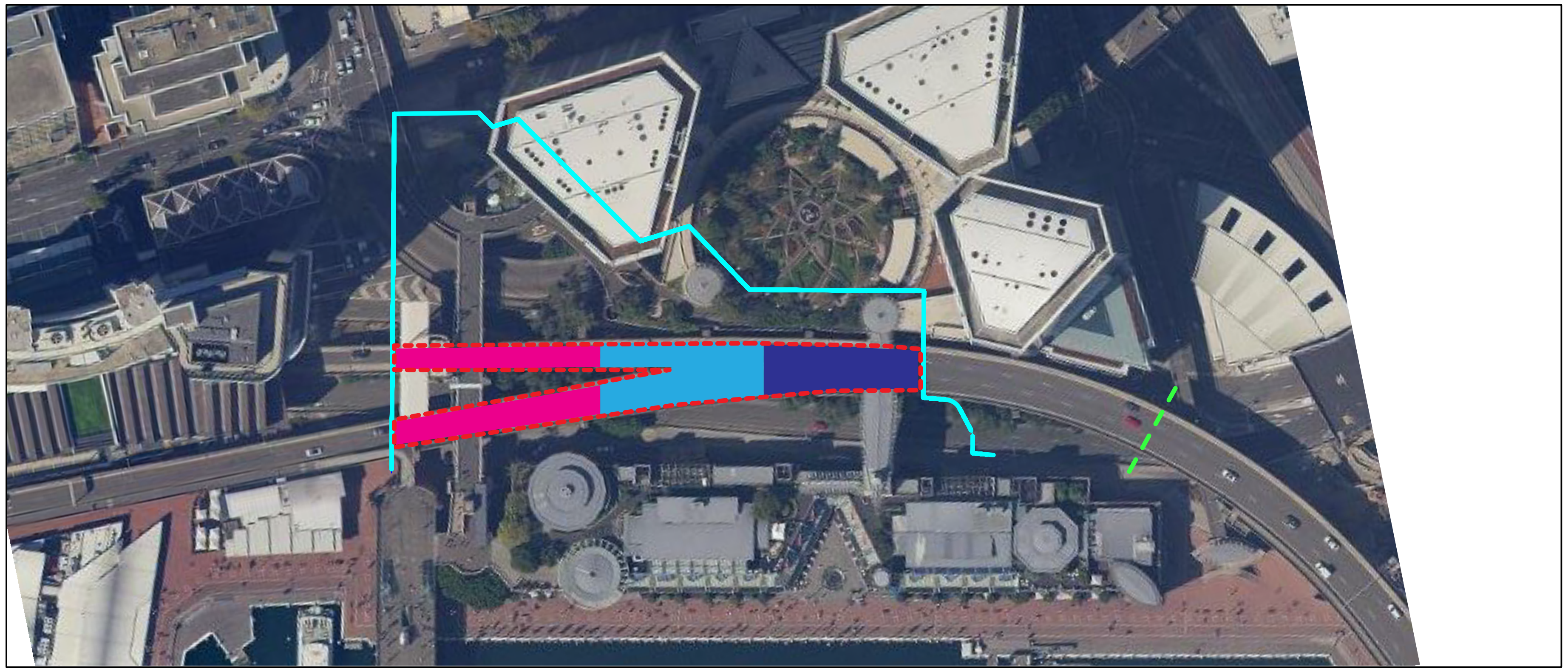
L20 Elements					
	Area (m2)	Luminance (cd/m2)	A*L	∑ AL/A (L20)	k*L20 (Lth)
Road surface R3 South	173.92	3000	521760		
Building South	256.06	8000	2048480		
Sky South	46.61	8000	372880		
			2943120	6175.370864	308.7685432

Interior Luminance				
Threshold 1	Threshold 2	Transition	Interior	Exit
35m	35m	153m	N/A	N/A
309cd/m2	309cd/m2	126cd/m2		
to	to	to		
309cd/m2	126cd/m2	14cd/m2		



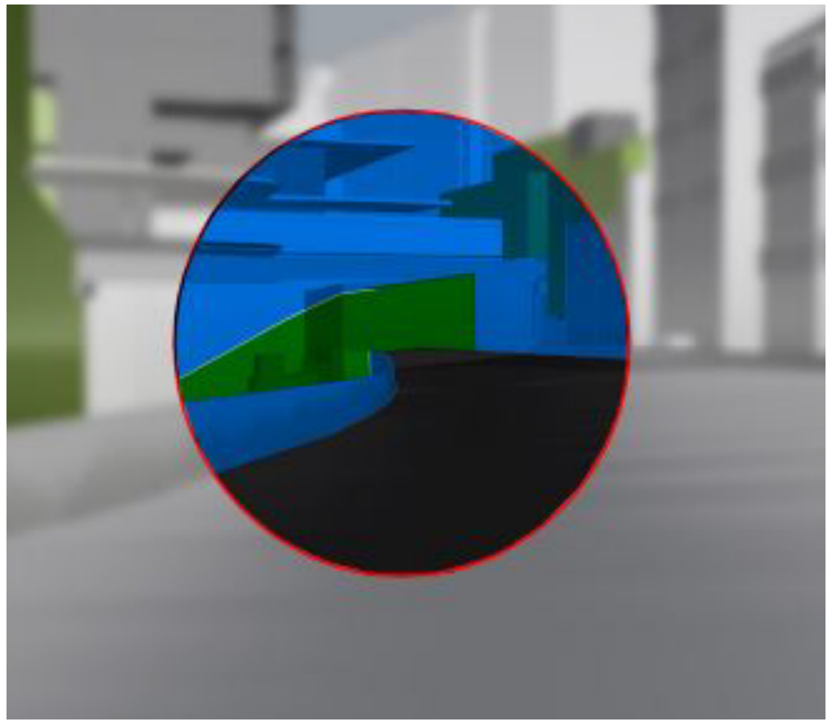
NOTE: NO DAYTIME LIGHTING REQUIRED IN THE FINAL 20m OF THE UNDERPASS

Western Distributor Northbound



Legend

- Underpass extents
- SSD Position (for L20 Determination)
- Carriageway(s) Alignment
- Threshold Zone 1 - 45m
- Threshold Zone 2 - 45m
- Transistion Zone - 51m



L20 Value

- Buildings - North
- Vegetation - North
- Road Surface (R3) - North

The L20 value is determined by the average of the sum of each primary elements' luminance value (cd/m2) within the 20° steradian field of view of a drivers viewing position at a setback from the underpass threshold equal to the Sight Stopping Distance (SSD).

The determined luminance value for the Threshold Zone 1 and all subsequent Threshold and Transition Zones is determined from this luminance appraisal.

Transition Luminance (Ltr) =

$$Lth(1.9+t)^{-1.4}$$

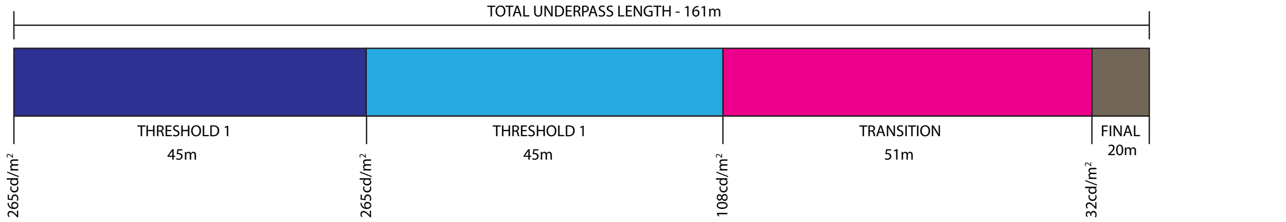
Where:
t= time travelled in seconds
Lth = 100% (of the Threshold Luminance)

Western Distributor Northbound					
Speed (km/hr)	m/s	SSD (m)	Gradient (m)	Add (m)	Final SSD (m)
70	19.44	91	0.361	0	90

L20 Parameters		
Radius (m)	Area (m2)	k @ 70km/hr
15.84	787.84	0.058

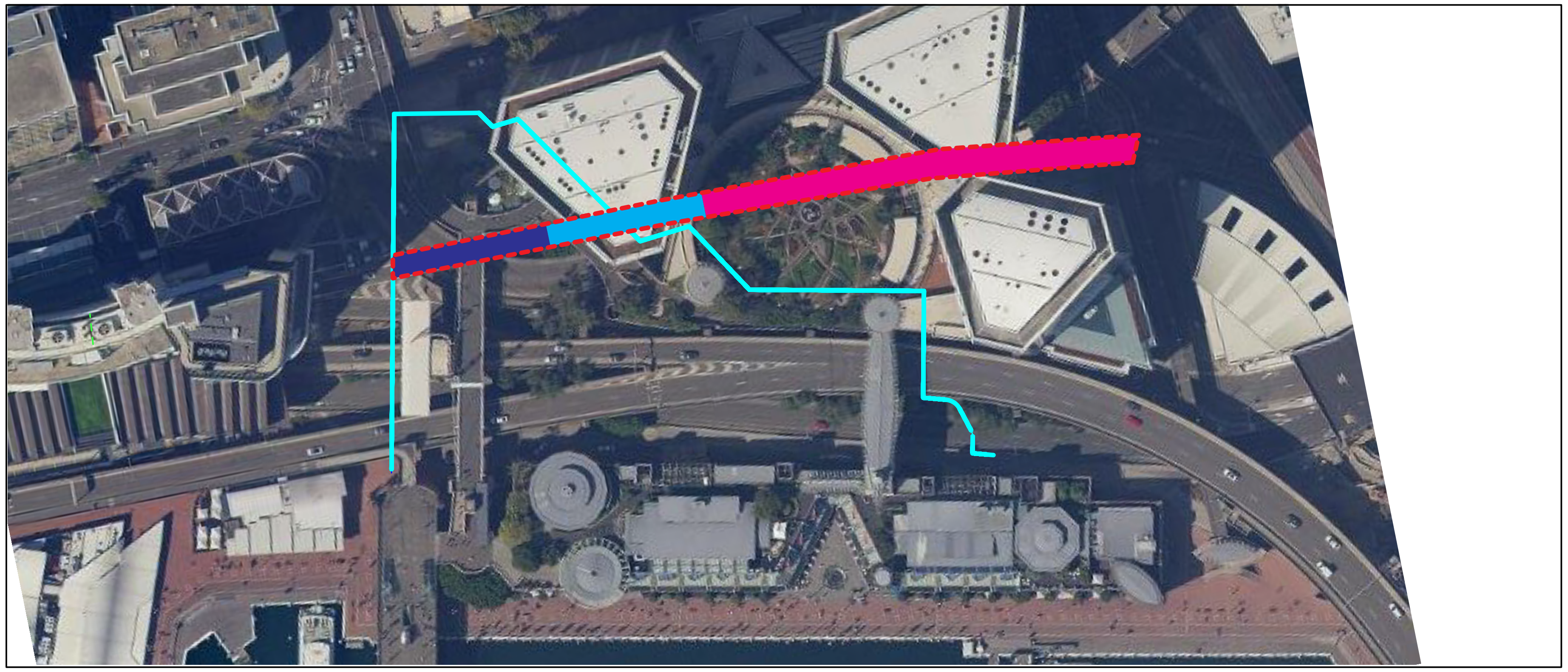
L20 Elements					
	Area (m2)	Luminance (cd/m2)	A*L	∑ AL/A (L20)	k*L20 (Lth)
Road surface R3 North	291.62	6000	1749720		
Building North	421.87	4000	1687480		
Vegetation North	84.35	2000	168700		
			3605900	4576.944557	265.4627843

Interior Luminance				
Threshold 1	Threshold 2	Transition	Interior	Exit
45m	45m	51m	N/A	N/A
265cd/m2	265cd/m2	108cd/m2		
to	to	to		
265cd/m2	108cd/m2	32cd/m2		



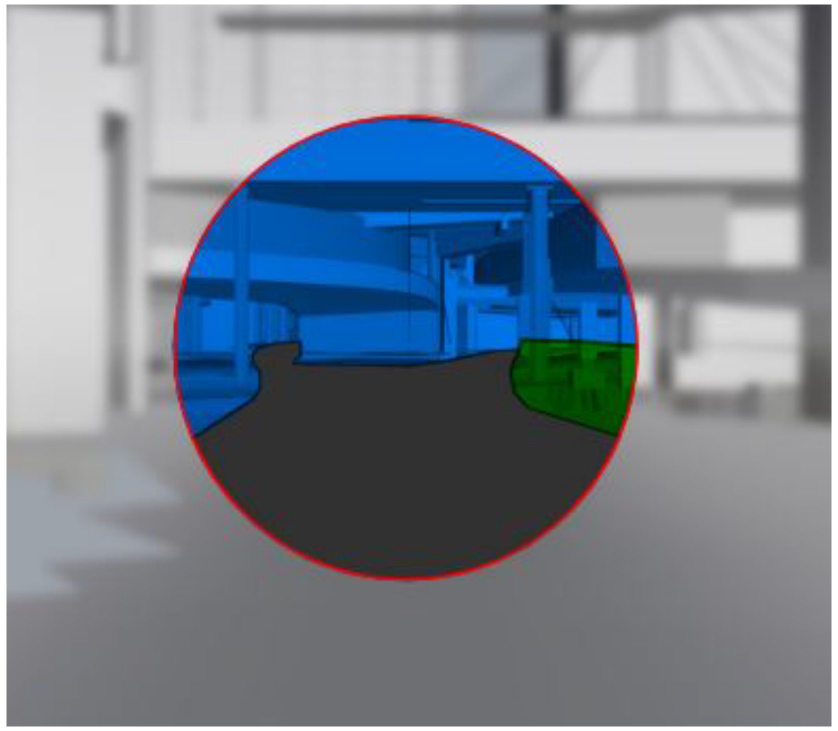
NOTE: NO DAYTIME LIGHTING REQUIRED IN THE FINAL 20m OF THE UNDERPASS

Western Distributor Southbound



Legend

- Underpass extents
- SSD Position (for L20 Determination)
- Carriageway(s) Alignment
- Threshold Zone 1 - 45m
- Threshold Zone 2 - 45m
- Transistion Zone - 104m



L20 Value

- Buildings - South
- Vegetation - South
- Road Surface (R3) - South

The L20 value is determined by the average of the sum of each primary elements' luminance value (cd/m2) within the 20° steradian field of view of a drivers viewing position at a setback from the underpass threshold equal to the Sight Stopping Distance (SSD).

The determined luminance value for the Threshold Zone 1 and all subsequent Threshold and Transition Zones is determined from this luminance appraisal.

Transition Luminance (Ltr) =

$$Lth(1.9+t)^{-1.4}$$

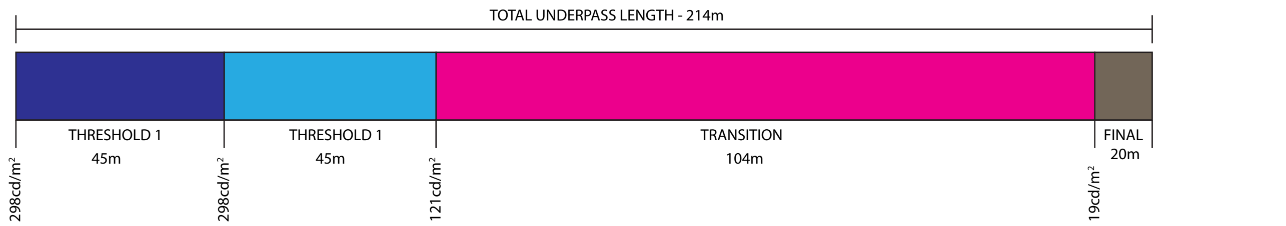
Where:
t= time travelled in seconds
Lth = 100% (of the Threshold Luminance)

Western Distributor Southbound					
Speed (km/hr)	m/s	SSD (m)	Gradient (m)	Add (m)	Final SSD (m)
70	19.44	91	0	0	90

L20 Parameters		
Radius (m)	Area (m2)	k @ 70km/hr
15.84	787.85	0.0525

L20 Elements					
	Area (m2)	Luminance (cd/m2)	A*L	∑ AL/A (L20)	k*L20 (Lth)
Road surface R3 South	315.15	3000	945450		
Building South	429.46	8000	3435680		
Vegetation South	43.24	2000	86480		
			4467610	5670.635273	297.7083518

Interior Luminance				
Threshold 1	Threshold 2	Transition	Interior	Exit
45m	45m	104m	N/A	N/A
298cd/m2	298cd/m2	121cd/m2		
to	to	to		
298cd/m2	121cd/m2	19cd/m2		



NOTE: NO DAYTIME LIGHTING REQUIRED IN THE FINAL 20m OF THE UNDERPASS

Appendix C

Dangerous Goods Vehicles Safety Risk Assessment Report

Cockle Bay Park

Dangerous Goods Vehicles Safety Assessment Summary Report

DPT and DPPT Operator Pty Ltd

Reference: 253427

Revision: E

2021-09-16

aurecon

Bringing ideas to life

Document control record

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Approval			
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Contents

1 Introduction

1.1 Background

DPT Operator Pty Ltd and DPPT Operator Pty Ltd (the Proponent) has obtained Stage 1 SSDA Planning Consent and is making application for a Stage 2 SSDA approval for the proposal details for the redevelopment of the Cockle Bay Wharf Building and surrounding areas to create a new open space and a commercial, retail and tourist precinct in the heart of the CBD, referred to as Cockle Bay Park (CBP).

The development of this landmark tower incorporating public spaces is a city-defining development. The landbridge will create open public spaces, replacing two small pedestrian bridges, and create open access over the Western Distributor which currently forms a barrier between the City, Cockle Bay and the rest of Darling Harbour.

The development comprises of the following:

- Landbridge over the Western Distributor to create an area of publicly accessible open space;
- Retail outlets, including new food and beverage destinations;
- Commercial office tower adjacent to the Western Distributor.

Figure 1 – Conceptual architectural render of proposed office tower and Cockle Bay

As part of this redevelopment, a new landbridge structure over the Western Distributor is proposed. The landbridge will facilitate improved pedestrian accessibility from the Sydney CBD to Darling Harbour, removing the existing 'barrier' of the Western Distributor. It will also create significant new public open space and parkland.

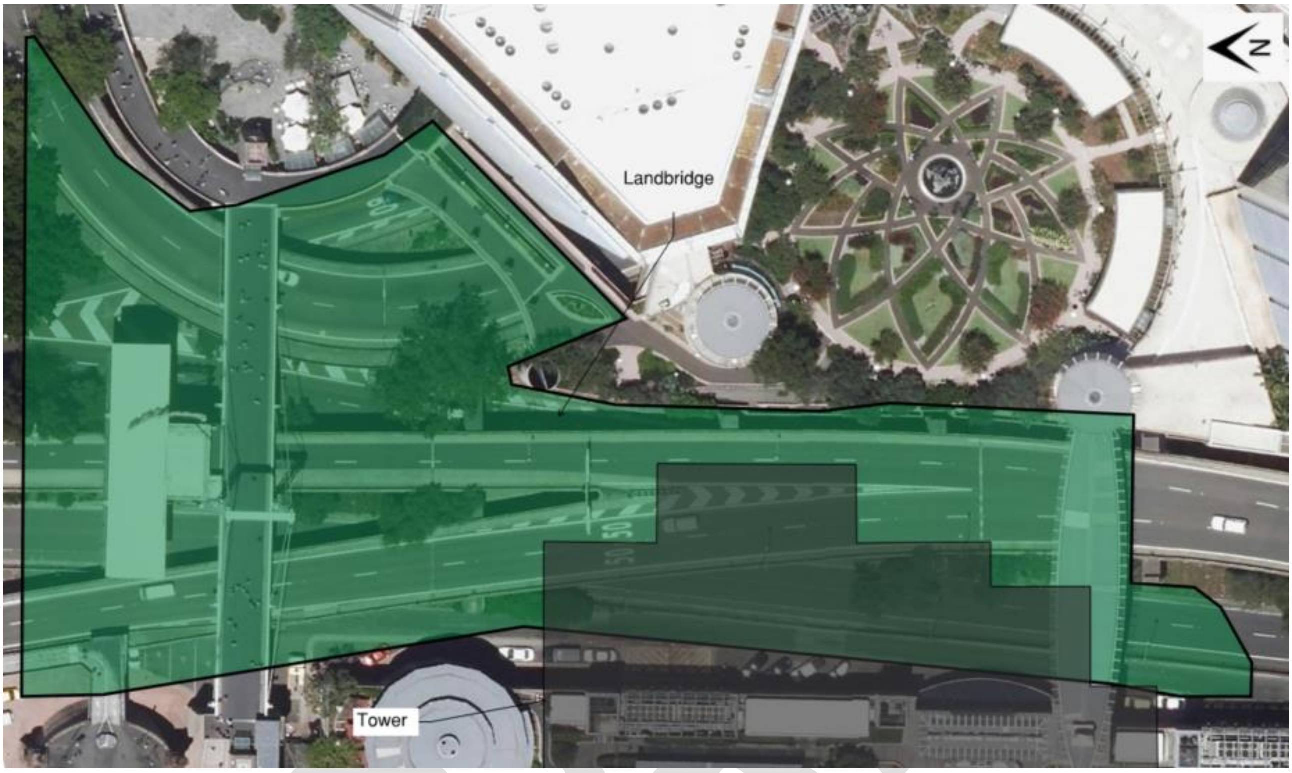

Figure 2 – Proposed landbridge and tower area

The landbridge will create a 'tabletop' cover over the elevated northbound Western Distributor and southbound Market St towards Anzac Bridge, and the on-grade northbound and southbound Western Distributor and northbound Wheat Rd (The Project Location).

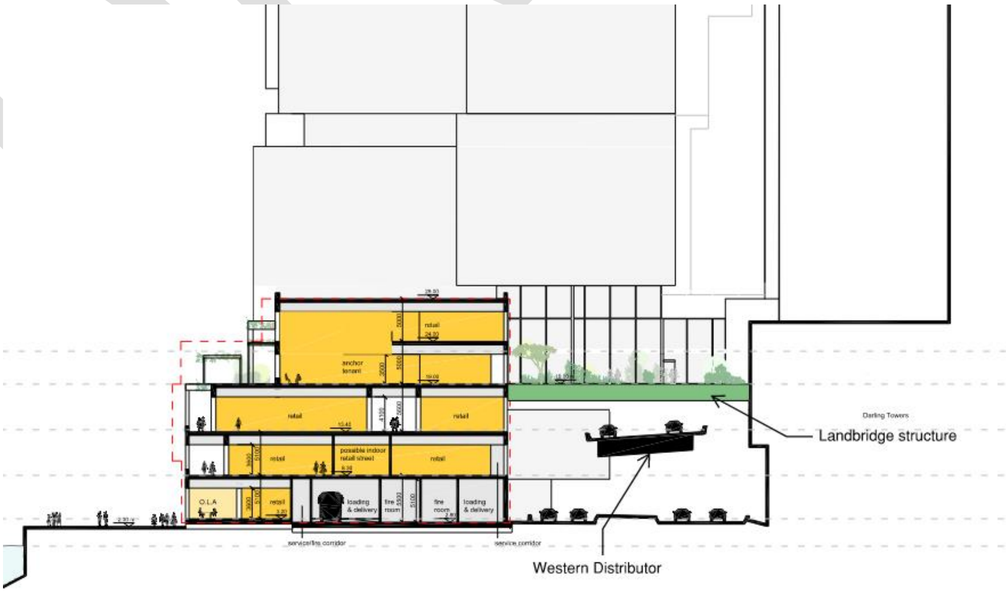

Figure 3 – Typical cross-section through tower and landbridge

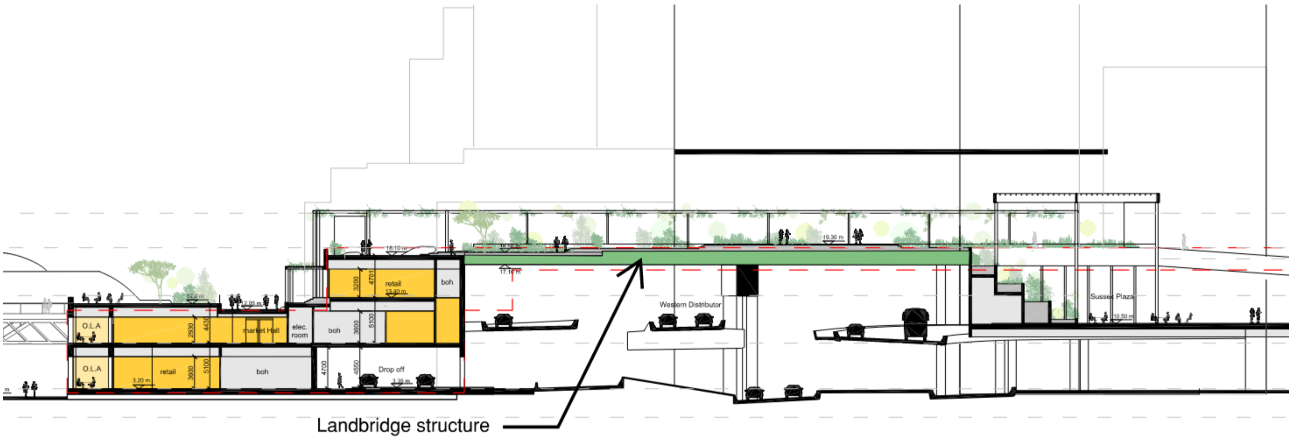

Figure 4 – Typical cross-section through landbridge

The Proponent has been consulting with TfNSW over the last few years on the CBP development, in particular on the impacts to the Western Distributor. Stage 1 Development Consent was granted for the project in May 2019 and an 'Agreement in Principle' for the landbridge development was received from TfNSW in September 2020.

1.2 Purpose

This report documents the approach and outcomes for determining the safety risk identification and assessment pathway for Dangerous Goods Vehicles (DGVs) using the TfNSW road assets impacted by the proposed landbridge over the Western Distributor.

The safety identification and risk assessment pathway to be used for the DGV assessment will be based on ASA Standard T MU MD 20001 ST *System Safety Standard for New or Altered Assets* in order to ensure, so far as is reasonably practicable (SFAIRP) that:

- The safety risks of DGVs, using TfNSW road assets, impacted by the proposed landbridge development are evaluated following the procedure:
  - Step 1: Hazard identification and current (baseline) risk assessment (Section 4)
  - Step 2: Risk assessment workshop (Section 6)
  - Step 3: Risk evaluation (Section 7)
  - Step 4: SFARP demonstration (Section 8) - sufficient evidence is provided to demonstrate a safety argument that the proposed landbridge development achieves the following:
    - designed to best ensure DGV safety is reduced to SFAIRP during its operation
    - eliminate[1] or reduce all foreseeable DGV safety risks to SFAIRP, in relation to the area under the proposed landbridge development.

The basis of this pathway was discussed and agreed with representatives of TfNSW who clarified that the SFAIRP approach is recommended and proposed to be used for the DGV assessment. This is as per the

[1] It is recognised that DGV events can currently occur on the Western Distributor and elimination of DGV events under the landbridge are not within the control of the CBP Team.

TfNSW requirements[2] *"for operations to demonstrate that risks are managed to SFAIRP and that no individual risks are intolerable",* where intolerable risk is defined as 1 in 10,000 fatalities per year for a member of the public.

The purpose of this safety study approach is to ensure that appropriate and sufficient assurance activities and evidence is provided for proposed mitigations, with regards to the operation of DGVs under the proposed landbridge development, to satisfy the duties that TfNSW and designers have under the legislation. This report is not a quantitative risk assessment.

1.3 Risk Assessment Process

The intent of these processes and requirements is to provide an approach that ensures safety risk management is integrated into the design and engineering activities, including evidence-based safety assurance arguments structured around the effective management of safety risks.

The safety risk management process on this project was conducted in line with *AS/NZS ISO 31000 Risk Management – Principles and guidelines*, which is represented by the figure below. Additional activities and rigor will be conducted to ensure an appropriate safety engineering and assurance approach, which is outlined in the following sections.

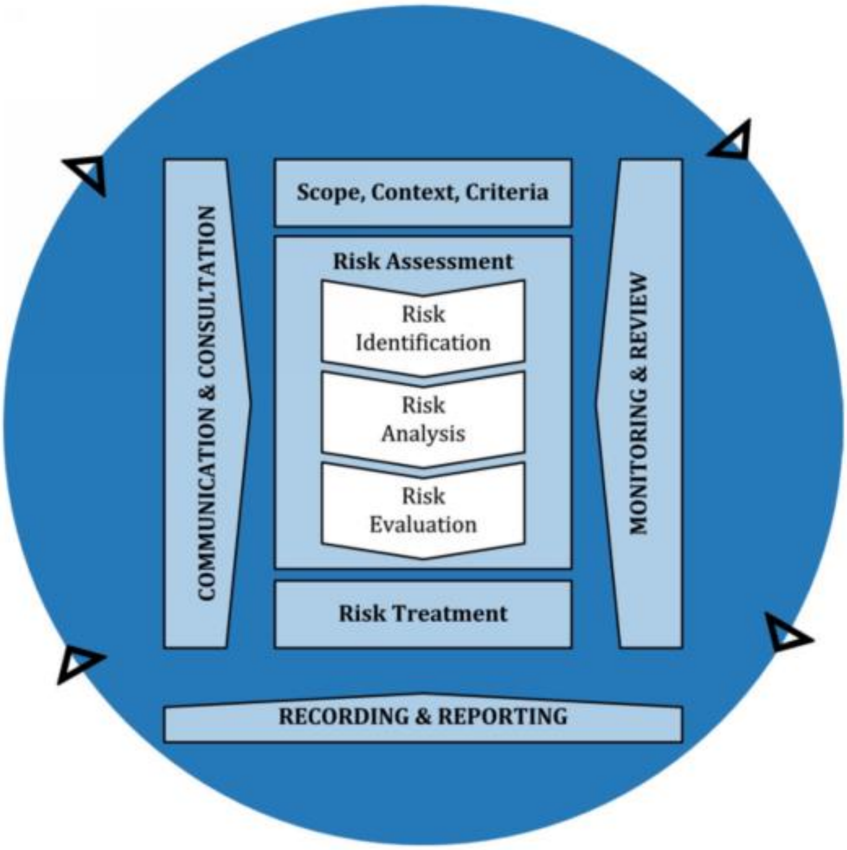

Figure 5 - Risk management process from AS/NZS ISO 31000

[2] TfNSW standard T MU MD 200003 GU "Quantified Safety Risk Assessment"

Risk assessing DGV events is considered a "very complex task"[3] as described by SafeT. The European Union appointed a task force (SafeT) to evaluate how to harmonise the risk assessment processes associated with DGV events.

SafeT concluded that there are various types of risk assessments and that each type has its own benefits based on the data available and objective of the assessment.

To assist with comparing this safety study to the various risk assessment methods used internationally, the following table details the proposed study risk assessment method

Table 1 – Safety Study Assessment Method

Type of risk assessment method	**Qualitative / Quantitative, Scenario analysis**
Purpose / Objective	▪ Demonstrate that risks are managed to SFAIRP and that the individual future residual risks are tolerable ▪ Assess the effectiveness of safety measures by scenario analysis of all foreseeable DGV safety risks, in relation to the area under the proposed landbridge
Type of accidents	Types of accidents include ▪ Fire, Explosion, Toxic Release ▪ Leak of environmentally sensitive or aggressive materials ▪ Other DG e.g. radioactive, infectious substances Accidents exclude ▪ Non DGV events ▪ DGV traffic disturbance/ collision without damage
Methodology	
Demonstrate risk is below TfNSW intolerability limits (Step 0)	▪ Determine the current level of risk (baseline risk), as per existing bridge (no CBP development/land bridge). ▪ Determine the impacts of the CBP Development, including the landbridge
Hazard Identification (Step 1)	▪ List all types of Dangerous Goods (DG) and typical examples found in and around Sydney ▪ Screen out any regulated DG i.e. DG restricted from transport though Sydney CBD and along the western distributor at the Project Location ▪ Describe the consequence of each individual DGV event based on various material and package sizes. This is the impact of the event with no CBP development/landbridge (current risk consequence)
Risk Assess: Frequency calculation (Step 2a)	Accident frequencies and accident development probabilities are for the greater part left out of scenario analysis as all scenarios need to be considered for SFAIRP assessment. Detailed frequency calculations can be used if further quantification is required through a cost benefit analysis.

[3] TNO. (2004). *SafeT Work Package 5, Task 5.1*. Retrieved from https://ec.europa.eu/transport/road_safety/sites/roadsafety/files/pdf/projects_sources/safet_d5_1.pdf

Risk Assess: Consequence assessment (Step 2b)	Qualitative: consequences are evaluated in terms of - Category 1 – Life safety - Category 2 – Impact to assets, including adjacent infrastructure and surrounding networks - Category 3 - Impact to the environment Quantitative: Quantification of consequence effects can be used if further quantification is required through a cost benefit analysis or to demonstrate design criteria e.g. FRL or smoke CFD
Risk Assess: Calculate the Qualitative Risk Level (Step 2c)	Consider the current controls The scenario analysis will determine the current level of risk through a combination of narrative form, tables and risk matrix evaluation. It is noted that a qualitative risk assessment is proposed. Quantification of risk can be used if required through a cost benefit analysis
Risk Evaluation (Step 3)	Carry forward a limited number of scenarios subject to a more thorough analysis of where the current risk will be impacted in future by the CBP development. Safety risk evaluation will be undertaken to support decisions, the suitability of controls and where additional action may be required. This can lead to decisions such as: - Do nothing - Consider risk treatment options - Undertake further risk analysis - Maintain existing controls - Reconsider objectives Note: where DGV events are not impacted by the CBP development, evaluate if the risk is managed to SFAIRP.
Risk Treatment (Step 4)	- Detail the current design/project controls - Consider further risk treatment options and undertake further risk analysis as required. - SFAIRP assessment will be performed to determine whether all reasonably practical measures have been taken to reduce and manage the safety risks, and that no residual future individual risks are intolerable - Determine whether the costs or business impacts of additional measures to control the risk (over and above those risk controls already in place) would be grossly disproportionate to the risk reduction benefit that they would achieve.

1.4 Definition of key terms

Table 2 – Key Terms

Item	Definition
ALARP	As Low As Reasonably Practicable
Baseline risk	Current level of risk as per existing bridge (no CBP development/land bridge).
CBP	Cockle Bay Park
Consequence	Outcome of an event affecting objectives
Coincidental event	Events involving the coincident release of more than one hazardous material where the materials are not likely to be on the same load.
DGVs	Dangerous Good Vehicles
Hazard	A source or a situation with a potential for harm in terms of human injury or ill health, damage to the environment, damage to property or a combination of these

Item	Definition
Inherent risk	The risk found in the environment and in human activities that is part of existence. Uncontrolled risk
Likelihood	Chance of something happening
Qualitative approach	Identification of key scenarios and qualitative estimate of risk in comparison with qualitative criteria
Residual Risk	Remaining after risk treatment
Quantitative approach	Identification and quantification of all scenarios
Risk	Effect of uncertainty on objectives
Risk assessment	The overall process of risk analysis and risk evaluation
Risk treatment	Process to modify risks
Safety	A state in which the risk of harm (to persons) or damage is limited to an acceptable level
Semi-quantitative approach	Identification of key scenarios and quantification of consequences and likelihoods of all events identified with significant effects
SFAIRP	So Far As Is Reasonably Practicable
SME	Subject Matter Expert
TfNSW	Transport for New South Wales

2 Background Information

2.1 Route Selection and Available Data

Route selection is being discussed to give an overview of the current DGV routes in and around Sydney. This provides the background information to help assess whether it is 'reasonably practicable' for certain bulk quantities of DG to be transported at the Project Location. Transport of dangerous goods in and around Sydney is intensified along the main haulage routes between Port Botany, the intermodal stations at Enfield Intermodal Logistics Centre, Moorebank Intermodal Terminal and Cooks River Intermodal Terminal and then from these stations into greater NSW. As shown below, the routes between Port Botany and these stations are not near or via the Project Location.

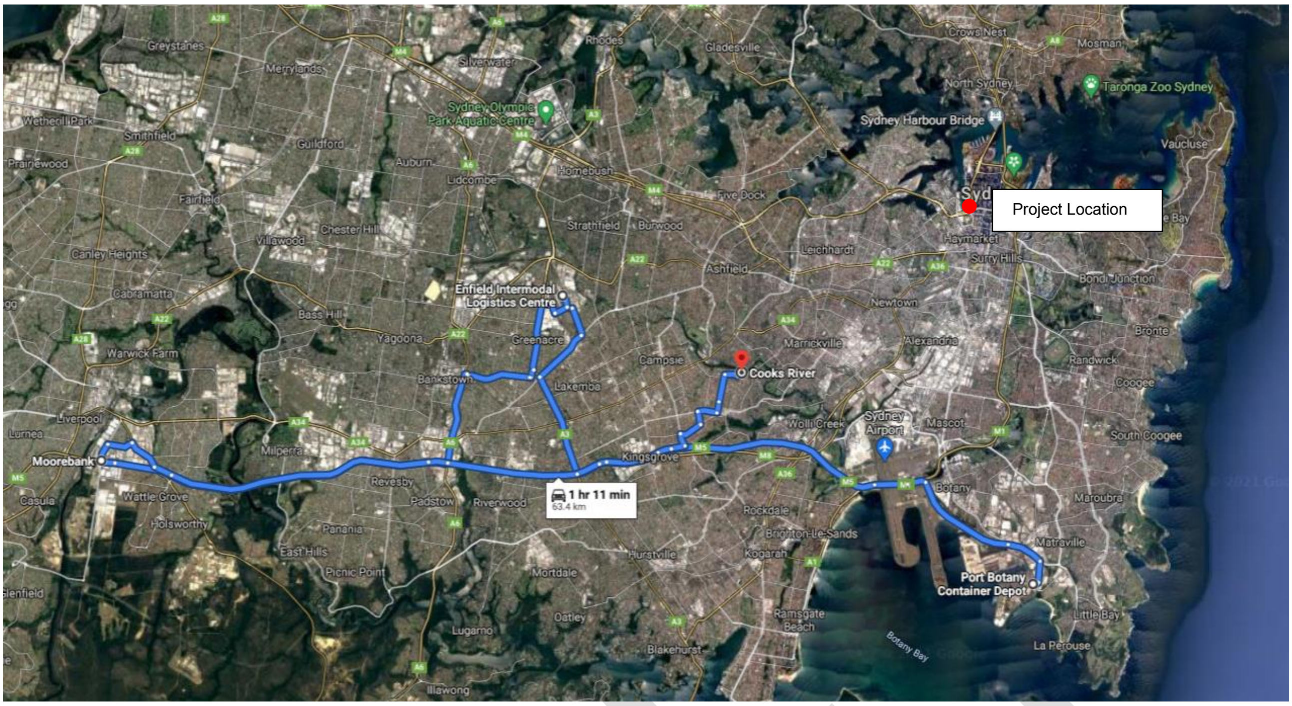

Figure 6 – Project location in relation to Intermodal Terminals and Port Botany

From the intermodal stations at Enfield Intermodal Logistics Centre, Moorebank Intermodal Terminal and Cooks River Intermodal Terminal, DGV make their way into the wider NSW along the TfNSW heavy vehicle haulage routes (Figure 7)[4].

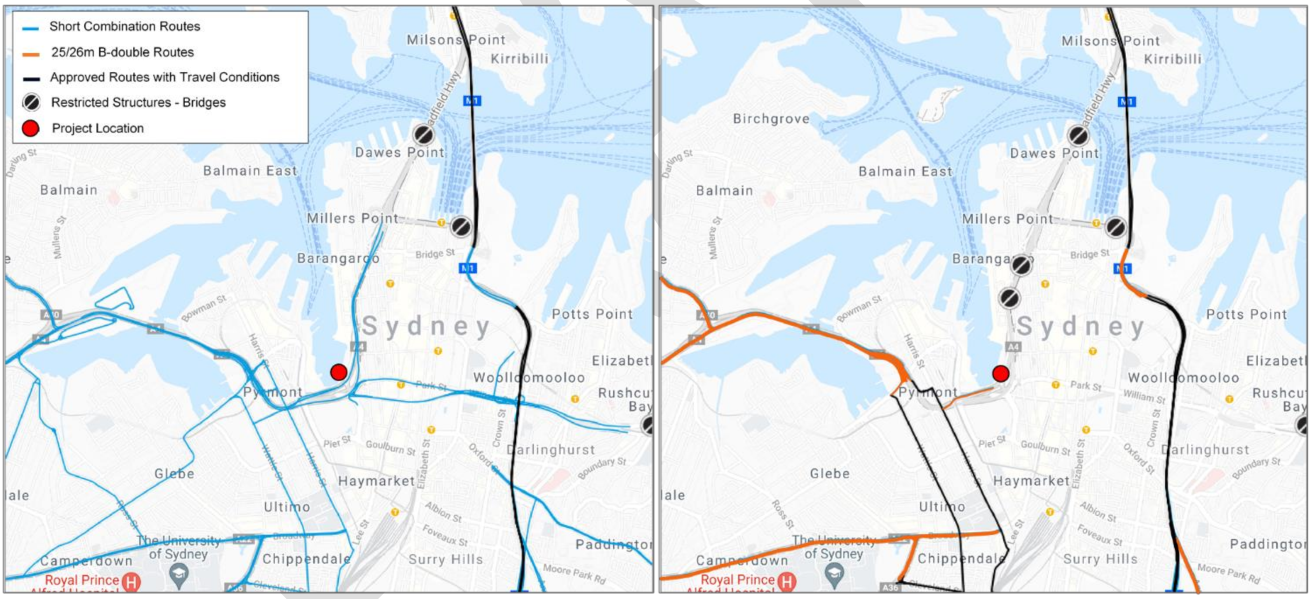

Figure 7 – Project location in relation to heavy vehicle haulage routes

It is noted that the landbridge location is over an approved higher mass limit (HML) vehicle route, for which short combinations (up to 19m long) are allowed as shown in Figure 7. Higher mass limit B-double vehicles

[4] Transport for NSW. (2020). *NSW Combined Higher Mass Limits and Restricted Access Vehicles Map.* Retrieved from https://www.rms.nsw.gov.au/business-industry/heavy-vehicles/maps/restricted-access-vehicles-map/map/index.html

(25 / 26m long) are not allowed to travel along this section of the highway. This means that the potential goods to be transported are not necessarily related to DG freight, but for local consumption, e.g. not bulk liquid fuel (petroleum products) movements from the major fuel distribution terminals at Port Botany, Viva Energy Silverwater, and the Exxon-Mobil and Caltex Terminals at Silverwater but rather local deliveries within and around the CBD.

TfNSW engaged with Transport Certification Australia (TCA) in complete a study in 2019, to determine the current DG road network in NSW generally, with a prioritised emphasis on the Sydney Greater Metropolitan Area. The study has been limited to date to 152 vehicles that mainly transport petroleum products.

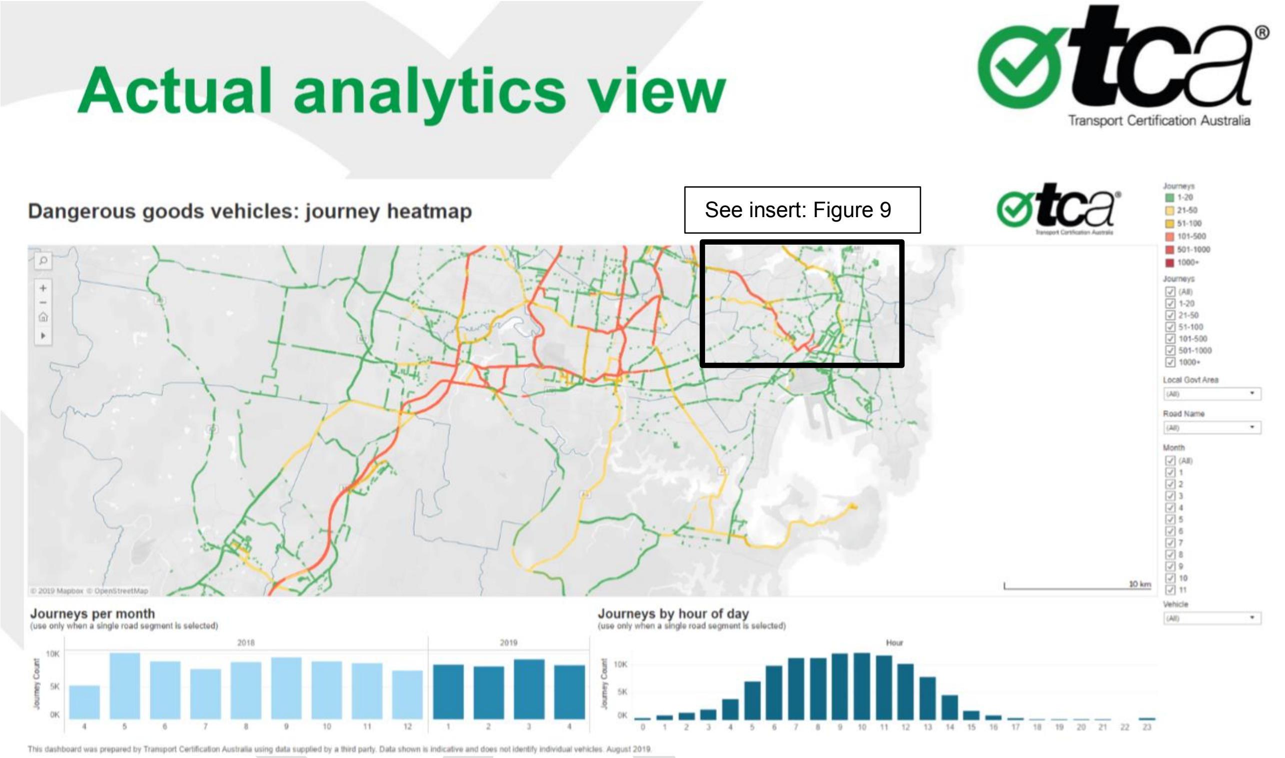

Figure 8 –TCA DG vehicle journey heat map average per month

Although the study does not provide a definitive value of the number and type of DGV, the study can be used to gain a better understanding of DGV at the Project Location. Data, near the project location, from a TCA[5] presentation and email correspondence is provided below.

[5] Hill, G & Gordon, J. (n.d.). *Using the Road Infrastructure Management application for DG vehicle movements*. Retrieved from https://cdn2.hubspot.net/hubfs/3003125/NSW%20Dangerous%20Goods%20Study%20-%20TCA%20Slide%20Pack.pdf

Figure 9 – TCA DG vehicle journey heat map average per month near Project Location

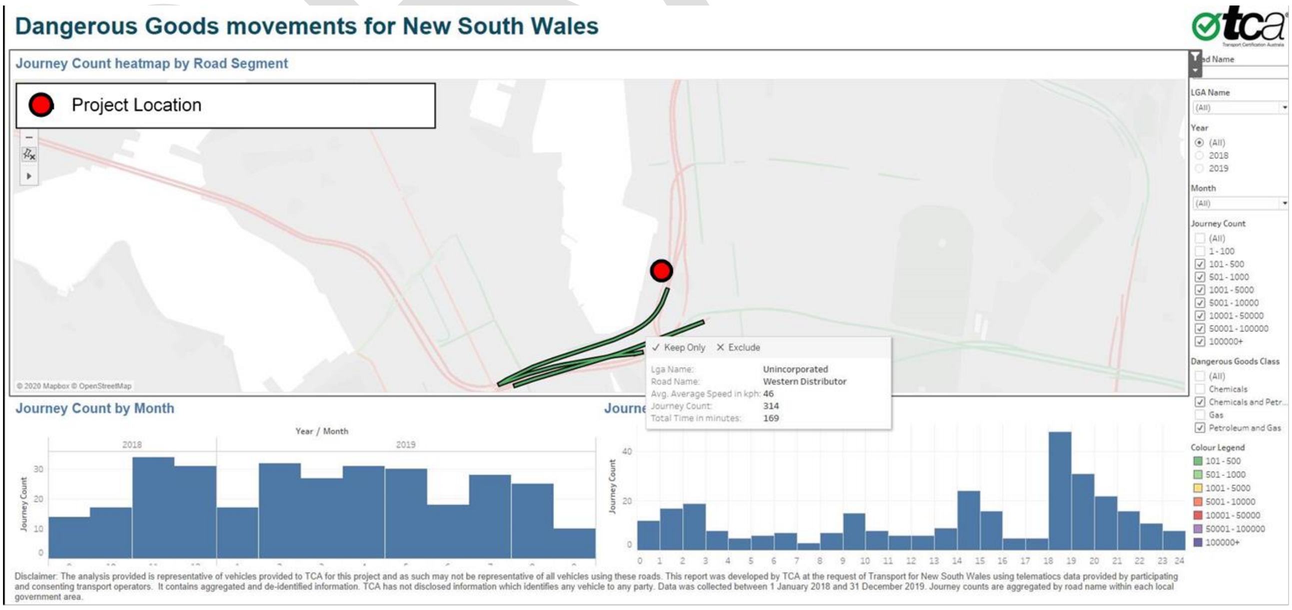

Figure 10 – DGV Journey Count at Project Location

Based on the TCA study above, the routes associated with the project location show that 314 DGV journeys occurred over 24 months (of either full or empty DGVs). This is estimated (based on the TCA data) that the journey count of DGV carrying petroleum products is in the order of 56 mins (or 1E-4 fraction of a year) at the project location. By comparison TCA data shows that the Southwestern Motorway (M5 West) carried over 100,000 DGV journeys and the Western Distributor (A4) route for heavy vehicle haulage (i.e. west of of Darling Drive) carried 16,000 DGV during the same study period.

The following conclusion are made based on the data:

- No higher mass limit B-double vehicles (25 / 26m long) travel at the Project Location. This aligns with the assessment that the current risk (baseline risk) is managed to SFAIRP by ensuring only short combination (up to 19m long) HML vehicles travel through the Sydney CBD
- The Western Distributor at the project location has relatively low movements of DGV (0 to 20 DGV per month) in relation to the Western Distributor west of Darling Drive (21 to 500 DGV per month).
- There no data available to define the type and number of DGVs at the project location.

3 Definition of the System: Assumptions, Constraints and Dependencies

The following assumptions, constraints and dependencies (ACD) will be incorporated into the assessment:

- It is recognised that DGV events can occur under the current circumstances. There is a current level of risk (baseline risk) associated with DGV hazards. It is assumed that this baseline risk level is acceptable and managed to SFAIRP through current practices such as transport regulations and ADG Code practices. An assessment of mitigation measures to prevent or mitigate the baseline risk associated with DGV hazards is not within the scope of this assessment.
- This assessment is specifically in relation to the potential change in risk in relation to DGV hazards due to the CBP development, including the landbridge.
- Elimination of DGV events under the landbridge development is not within the control of the CBP Team.
- Long term alternative routes or restrictions on DGVs are not within the control of the CBP Team.
- The landbridge design for this DGV safety risk assessment is that the structure is not defined as a Tunnel in accordance with AS 4825-2011.
- Exclusion of events involving the coincident release of more than one DG where they are not on the same load.
- Exclusion of multiple hazards to the one individual DG. If one hazardous consequence of an incident is more extensive and severe than another, the lesser consequence need not be considered.
- Exclusion of vehicle accidents. In a motor vehicle incident, the cause of death or injury is the mechanical impact of the crash. Only DGV events for which a loss of containment (LOC) will occur are included in the study. Refer to Section 5.1 for details
- Exclusion of environmental impacts related to flows directly into drainage systems feeding Darling Harbour. It is assumed that there is no additional environmental impacts due to the CBP Development.

4 Step 0: Demonstrate risk is below TfNSW intolerability limit

4.1 Quantified Safety Risk Assessment (QSRA)

The CBP Technical & Design Team investigated the option of quantifying the current (baseline) risk level and the safety risks of DGVs, using TfNSW road assets, to determine the impact of the proposed landbridge development in accordance with ASA Standard T MU MD 20003 GU Quantified Safety Risk Assessment.

The following is stated in the ASA Standard T MU MD 20003 GU Quantified Safety Risk Assessment 'Generally, quantified methods are considered appropriate for system level assessment or for risks that are identified as high consequence but low likelihood by an initial qualitative assessment. Decisions that entail one or more of the following characteristics, should, among other appropriate techniques, consider applying a QSRA method:

- relatively high number of people potentially affected
- system level assessments considering a range of hazardous events
- decision commits TfNSW to a long-term outcome or arrangement
- novel outcomes with no relevant standards or guidance
- complex and wide range of variables affect the decision-making

This requires that most major procurements of fixed infrastructure and new services demonstrate that a QSRA was undertaken or at a minimum provide an assured argument as to why it was considered not relevant.'

The development is considered to meet the criteria listed above such that a QSRA should be undertaken or an assured argument as to why it was considered not relevant provided. The following sections provide this assurance argument.

4.2 Key Considerations for undertaking a QSRA

The following key considerations are noted in accordance with Section 8 of TfNSW Standard T MU MD 20003 GU *Quantified Safety Risk Assessment.*

4.2.1 Defining the scope and outcomes

The scope would be to quantify the current (baseline) risk level and the safety risks of DGVs, using TfNSW road assets, impacted by the proposed landbridge development. TfNSW is looking to achieve an understanding that the landbridge does not pose an intolerable level of risk.

In accordance with TfNSW Standard T MU MD 20003 GU *Quantified Safety Risk Assessment*, individual risk can be used to determine if a particular risk exposure is too high and deemed intolerable. This level of risk is defined as 1 in 10,000 fatalities per year for a member of the public. If an individual risk is assessed to be above this level, i.e. the risk is intolerable, then action must be taken to reduce the risk regardless of cost.

AS 4825 -2011 'Tunnel Fire Safety', commentary Section 6.4.4.2.1 notes that "the communities perception of fire hazard in tunnels is greater than on open roads. Target level of risk due to fire in tunnels may be compared to currently accepted risks from all causes on open roads. Suggested target due to fire death should be about two orders of magnitude lower than generally from all accidents for the particular mode of transport".

The outcomes of the QSRA would be to determine

- The absolute level of risk with the landbridge such that TfNSW can establish where the risk lies relative to its intolerable criteria, OR
- Where the absolute level of risk cannot be calculated, to quantify the cumulative risk change due to the development. It is noted that to complete a QRSA, the correct software package must first be selected in relation to available information and desired outputs, as detailed below.

4.2.2 Commit the resources to undertake the QSRA

As documented in ASA Standard T MU MD 20003 GU *Quantified Safety Risk Assessment,* specialist external resources as well as a significant commitment from Transport cluster specialist resources will likely be needed to source the data and validate a QSRA model.

4.2.3 Decide on the approach and any specialist software packages

4.2.3.1 Specialist chemical risk QRA software

To quantify the absolute level of risk of DGVs currently using the TfNSW road assets at the development location, specialist software packages are available to quantify the consequences of DGV events and incorporate the frequency of the events to quantify the risk level.

The following software packages are considered appropriate for quantitative analysis (while other models exist that are only deterministic)

- RWS-QRA Model (updated TunPrim)
- TNO-tunnel Model
- TUSI
- QRAM
- DNV SAFETI

4.2.3.1.1 Evaluation of appropriability of RWS-QRA

RWS-QRA is designed to calculate the internal safety in two bore tunnels with uni-directional traffic in each bore. This is not relevant to the landbridge scenario due to the geometry of the landbridge and the focus only on internal safety within the tunnel bore.

4.2.3.1.2 Evaluation of appropriability of TNO-tunnel model

The model is not applicable to determine risk acceptability criteria and is normally only applied to train tunnels. It is deemed not appropriate.

4.2.3.1.3 Evaluation of appropriability of TUSI

The model is not applicable to determine individual risk acceptability criteria and is normally only applied to calculate accident frequencies. The model is not applicable to determine individual risk to compare to acceptability criteria and is normally only applied to calculate accident frequencies. It is deemed not appropriate.

4.2.3.1.4 Evaluation of appropriability of QRAM

Quantitative Risk Assessment Model (QRAM) has been developed for specific use in EU countries. It has the advantage of a method suited for open air or tunnel sections and calculated societal risk and individual risk.

The model is however, limited to 13 representative scenarios of specific DGV quantities and leak scenarios. The permanent International Association of Roads Congress (PIARC) webpage notes[6] that "The algorithms, procedures and computer programs of QRAM were developed only for the assessment of risks due to road transportation of dangerous goods through given routes, especially with tunnels. They have been compiled from the best knowledge and understanding available at the initial development date (year 1998) but have important limitations that must be understood and considered by the user. The software package constitutes the QRA-model. For assessment of smoke propagation/ventilation, evacuation etc., there are other, more appropriate tools including 1D and 3D fluid dynamic models. Consequently, users are warned that whilst the QRA model may be used for dangerous goods risk assessment, it must not be the only tool used in the assessment of the acceptability of design proposals to achieve the required global tunnel safety levels."

The use of only 13 scenarios to represent all the number and types of DGVs at the project location was deemed by TfNSW not to demonstrate an accurate absolute level of risk and therefore could not be used to complete a SFARIP assessment of the acceptability of the proposed design. This is further supported by the QRAM user manual [Ref 23] which states "uncertainties in the model ranged from 250% to 400% with a 95% confidence interval due to the methodological simplifications".

The tool may have its usefulness as a comparative tool for particular scenarios, or comparative level of risk during detail design development, if the input data, assumptions and limitations are agreed and understood. This includes the actual number, type and quantities associated with DGVs on the landbridge route.

4.2.3.1.5 Evaluation of appropriability of SAFETI

The Det Norske Veritas (DNV) PHAST[7] and SAFETI software packages are recognized modelling tools used by safety specialists (within Australia and internationally) to conduct hazard analysis and quantified risk analysis associated with Major Hazard Facility chemical and petrochemical process plant. SAFETI is an additional quantitative risk assessment tool to the models identified in Section 1.3, which has not been used specifically for tunnels.

The DNV webpage[8] describes that SAFETI can be used for quantitative risk analysis for transporting hazardous chemicals (i.e. flammable and toxic materials), to optimize the transport route and identify specific areas along a route that requires additional mitigations. Therefore, SAFETI is suited to comparative risk analysis over various routes or along a single route. The impact of a structure at a single location would be considered novel.

Based on the input data, the model is able to calculate the cumulative risk level of multiple DGV events by performing dispersion and consequence modelling that then is translated into fatality consequences associated with fire, explosion and toxic impacts, multiplied by the frequency of the loss of containment (LOC) event occurring. PHAST modelling or CFD tools may be appropriate for single DGV events to determine the consequence of a LOC, but SAFETI is able to compute multiple scenarios simultaneously, through quantitative risk analysis.

Aurecon has the SAFETI model available, so it investigated its appropriateness, as it is not listed as a risk assessment tool by SafeT. Due to the limited footprint of the development, i.e. a total length and width of approximately 150m by 35m, Aurecon investigated ways in which the landbridge could be incorporated within a SAETI model. The landbridge development does not change any of the input criteria except possibly modelling the impact of the landbridge as a potential change in confinement or as a building release. Aurecon investigated these two options as follows:

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[6] https://www.piarc.org/en/PIARC-knowledge-base-Roads-and-Road-Transportation/Resilient-Road-Infrastructure/Road-Tunnels-Operations/qram_software

[7] https://brandcentral.dnvgl.com/original/gallery/dnv/files/original/58c12ce43b26496e891a09874dc91dfb_hi.pdf

[8] Chemical transportation safety analysis | Safeti (dnv.com)

- **Dispersion Modelling:** DGV events were modelled in PHAST as part of the study. The events were for loss of containment (LOC) from bulk or drummed chlorine DGV which were identified in the HAZID risk workshop as having potential impacts changed by the landbridge. The results showed a dispersion consequence or fatality impact criteria distance significantly greater than 80m (if the location of all events is approximately in the middle of the development footprint). This was based on a standard leak hole size of 25mm. Refer to Figure 15 and Figure 16 for further details.

An example of a simple dispersion model (such as PHAST) v's a more complex CPD modelling tool is shown in Figure 11 and Figure 12. The study modelled the release of a road tanker carrying ammonia (~38,000 L) resulting in the rapid release of its contents[9].

Figure 11 - Dense gas dispersion for simple dispersion model (red) vs CFD (blue), 2m/s wind (8 directions)

Figure 12 Dense gas dispersion for simple dispersion model (red) vs CFD (blue), 8m/s wind (8 directions)

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[9] https://www.gexcon.com/au/blog/modelling-dense-gas-dispersion-in-urban-environments/

The results show that the hazard footprint of such a release is predominately dependent on the meteorological conditions (wind speed, wind direction, and atmospheric stability). For a simple dispersion model at low wind speeds (calm conditions), the result may be overly conservative, but at higher wind speeds it may under-estimate the dispersion. As DNV SAFETI inputs a wind-rose for all wind speeds, these over and under estimations for different wind directions / speeds will be accounted for in the model. It is noted that the appropriate wind speeds would need to be determined to properly capture the change in wind speed and direction caused by the landbridge, The Gavelli study also demonstrates that for bulk DGV, dispersion and thus consequence effect distances are up to 1,000m from the source. This is in-line with the HIPAP 11[10] Appendix 6 results for LOC of road tankers containing toxic gas, with identifies a consequence effect distance to 1,000 m or more. As the length of the land bridge is approximately 150m, it can be concluded that the effect of the landbridge is immaterial within the scale of modelling these larger DGV events.

Incorporation of the landbridge:

The DNV SAFETI software provided an option to model the release inside a building (i.e. as if the void under the landbridge was a large building). It was found that for the DGV scenarios a change in level of confinement could not be defined within the scale of the model, as the model simulates the full contents of the DGV into the "building" and then conducts the dispersion modelling based on this diluted DGV. The model was found to then produce consequence results some distance from the building (i.e. the simulated landbridge) as the wind moved the dispersed cloud away from the event location.

Due to the diverse range of DGVs, reliable input data would be required by the DNV software and assumptions made regarding the frequency of transportation at the site location. Once the input data was available, the DNV modelling tool would only ever produce individual absolute risk results within an order of magnitude. Aurecon concluded that while this absolute level of risk could be determined by the model for the current level of risk, the tool could not appropriately incorporate the landbridge structure. As such the change in collective risk, or societal risk would also then not be able to be accurately determined.

*Hence, the DNV SAFETI tool is assessed **not to be appropriate** for novel chemical transport scenarios to determine the impact of a structure on the transport route, such that the change in individual fatality (and therefore societal) risk could be quantified. '*

4.2.4 Data sources and assumptions

All the software packages are based on the same theory of risk in relation to fatalities from thermal radiation, toxic release and explosion overpressure. Any QRA software requires a number of inputs to define the DGV events within the model. The basic inputs are the following

- Type and quantity of DGV i.e. the storage conditions of the dangerous goods. The modelling tools has a predefined list of chemical properties
- Frequency of events
- Weather (i.e. wind rose)
- Ignition probabilities
- Surface roughness of surrounding land-use e.g. open water vs urban
- Vulnerability of population (indoor vs outdoor) and population data
- Location of the event
- Level of confinement (impacting explosion consequences)

[10] NSW Government. (2011). *Hazardous Industry Planning Advisory Paper No 11*. Retrieved from https://www.planning.nsw.gov.au/-/media/Files/DPE/Other/hazardous-industry-planning-advisory-paper-no-11-route-selection-2011-01.pdf?la=en

- Building vs outdoor release (impacting toxic consequences)

No matter how good the model is, if the inputs are poor then the output will be poor and unreliable The QRA tools are assessed not to be appropriate for novel chemical transport scenarios where no reliable input data is available. The CBP Technical & Design Team considered what data is available and what would be required as inputs to the model and found the following in terms of input data

- The only current data source available is the TCA data in relation to possible order of magnitude quantities of flammable liquids transported at the development location. TCA and TfNSW have noted that this data is unreliable and is not appropriate for use in a quantitative risk model.
- A transport study would need to be conducted to collect the actual number, type and quantities associated with DGVs on the landbridge route. As this is a significant use of time, resources, and costs and would only provide the base or current risk level, within an order of magnitude, using a benchmark model was investigated as a feasible option to determine if TfNSW can establish where the risk lies relative to its intolerable criteria.

4.2.5 Identify if a benchmark model can be used.

As documented in TfNSW Standard T MU MD 20003 GU *Quantified Safety Risk Assessment Section 8.1.2,* it is appropriate to determine whether an existing model can be modified or used as a benchmark or whether a new model will have to be developed. No existing model to quantify the risk for the current DGV route is available.

4.2.5.1 Benchmark models

The CBP Technical & Design Team nor TfNSW has access to a QSRA associated with the current (baseline) risk level associated with the safety risk of DGVs currently using the TfNSW road assets at the development location.

At the time of writing this report, the Team has found two publicly available QSRAs associated with the safety risk of DGVs within the greater Sydney area. These QSRAs have not been verified by CBP Technical & Design Team nor TfNSW but have been submitted to NSW Department of Planning, Industry and Environment as part of planning applications and have been produced by specialist safety consultants. The QSRAs (both of which made use of the DNV SAFETI modeling tool) are

1. Intermodal Logistics centre at Enfield EIA Appendix K Preliminary Hazard Analysis, 2005 (See extracts in Appendix E)
2. ScottLister, Dangerous Goods Transport QRA, Denison Street, Hillsdale, Issue 3, 2015

The benchmark models are seen to be appropriate if it can be demonstrated that the number, type and quantities of DGVs in the benchmark studies are more conservative. To calculate risk, the DNV SAFETI model incorporates the consequence and the frequency of events. The consequences of events is based on the type and quantity of the DGVs and the frequency of the events is based on a combination of accident frequency data, probability of a loss of containment scenario e.g. BLEVE or 50mm hole size multiplied by the number of DGVs.

At the development location the following could be considered conservative relative to the benchmark models:

- **<u>Consequences</u>**: The types of DGVs in the benchmark models cover a wide range of classes of dangerous goods and could be considered a representative sample of the types of DG transported in and around Sydney. The quantities of the DGV associated with the benchmark models includes mainly bulk industrial chemicals which is considered conservative for the project location that is likely to have local package deliveries and is a route where B-double transport is excluded. During the HAZID identification risk workshop, it was recognised that Class 3 and Class 2 DGV events are likely to be the most common.

- **Frequency:** The accident frequency data is considered conservative in the benchmark models as it also includes a higher frequency for bidirectional roads and intersections. The development area is associated mainly with DGV on the western distributor which is a short section of one directional road and no intersections. The frequency of loss of containment scenarios is obtained from published data and would be the same for DGV events associated at the development. The number of DGVs associated with the development is considered less than those associated with the benchmark models which consider specific DGV routes associated with industries and dangerous goods transport hubs within greater Sydney.
- **Risk** To understand the risk level at the landbridge development location, a comparison can be made by using an order of magnitude assessment using the existing models.

4.2.5.2 Benchmark model 1: Enfield Intermodal Logistics Centre.

The model was undertaken to understand the level of risk associated with the proposed Enfield logistics centre in relation to the transport of dangerous goods. Information from the quantified risk assessment (extracts in Appendix E) at this location indicated the following:

- The DGV included all classes of dangerous goods in bulk cylinders and packages.
- There are estimated to be in the order of 5,614 DGV moments per year at Enfield. Of these movements,
  - 229 DGVs were modelled as 20 tonne Class 3 Flammable liquid movements
  - 3,963 DGVs were modelled as packaged Class 3 Flammable liquid movements
  - 595 DGVs were modelled as flammable or toxic gas – incorporating toxic releases from Class 6.1
  - 735 DGVs were modelled as ammonium nitrate (representing Class 1 and Class 5) (i.e. TNT)
  - 92 DGVs were modelled as acrylonitrile that represents toxic and flammable liquids as well as some flammable solids
- Assessment of risk of all DGV movements was calculated to be 5E-6 p.a. at any location and is generally less than 1E-6 p.a. for distances further than 30m (taken from the road centre).
- The benchmark model calculated the individual risk level to be 1 in 200,000 fatalities per year which is one and half orders of magnitude below the TfNSW intolerable risk criteria (1 in 10,000 fatalities per year for a member of the public). It is noted while the population at CBP is potentially higher (i.e. a greater societal risk), the larger number of DGV movements at Enfield is likely to result a higher individual risk level compared to the CBP development location.

4.2.5.3 Benchmark model 2: Dangerous Goods Transport QRA, Denison Street

The model was undertaken to understand the level of risk associated with the proposed change in logistics in relation to the transport of dangerous goods at Denison Street due to the development of a proposed Bunnings Warehouse. Information from the quantified risk assessment (extracts in Appendix F) at this location indicated the following:

- The DGV included all classes of dangerous goods in bulk cylinders and packages, but focused on Class 2 and Class 3 as having the greatest contribution.
- There are estimated to be in the order of 10,000 full DGV moments per year at Denison street, in 2012. Of these movements,
  - Approximately 4500 DGVs were modelled as Class 2.1 Flammable gas (LPG, PGP, Ethylene Oxide) and Class 2.3 toxic gas (Chlorine)
  - 4000 DGVs were modelled as Class 3 Flammable liquid (ULP, Hexane, Propylene Oxide)
- Assessment of risk related to the 2012 DGV movements was calculated to be 3.5E-6 p.a.

- The benchmark model calculated the individual risk level to be 1 in 285,714 fatalities per year which is approximately one and half orders of magnitude below the TfNSW intolerable risk criteria (1 in 10,000 fatalities per year for a member of the public). It is noted while the population at CBP is potentially higher, the large number of DGV movements at Denison Street is likely to result a higher individual risk level compared to the CBP development location.

4.2.5.4 Tolerable individual risk level

TfNSW Standard T MU MD 20003 GU *Quantified Safety Risk Assessment* does not cover the level of tolerable risk (it only defines intolerable risk). It also defines individual risk as "calculated by taking the collective risk, dividing that by the total number of journeys per year, then multiplying by 500 to represent the typical commuter". It is estimate that there are in the order of 6 million vehicles per year (TfNSW traffic survey done in 2017 for a typical day at the project location).

Both the benchmark models achieved an individual fatality risk level between 3.5 to 5 in a million fatalities per year. This as a contribution to the TfNSW individual risk level relates to an increase of approximately 3 to 4 in a million fatalities per year per typical commuter.

4.2.5.5 Tolerable individual risk level (Other criteria)

NSW HIPAP 4 Risk Criteria for Land Use Planning, 2011 is deemed an appropriate reference for DGV events as it relates to the hazardous chemical industry. The suggested criteria are given in Table 3 and can be used as the quantified basic safety objective level, i.e. the level of individual risk that is considered tolerable.

Table 3 – Individual Fatality Risk Criteria

Land Use	Suggest Criteria (risk in a million per year)	Suggest Criteria (risk per year)
Commercial developments including retail centres and offices	5	5×10^{-6}
Hotels	1	1×10^{-6}
Day-care and child-care facilities	0.5	5×10^{-7}

On assessment of the above, both the benchmark models achieved an individual fatality risk level between 3.5 to 5 in a million fatalities per year, aligning to appropriate land-use associated with commercial developments including retail centres and offices, as well as approximately one and half orders of magnitude below the TfNSW intolerable criteria of 1 in 10,000. It is estimated that the current level of risk at the proposed CBP development site is significantly lower than the benchmark models on the assumption that the benchmark models are conservative in both consequence impacts (mainly larger bulk industrial chemicals) and frequency of events (i.e. more DGV located on these routes). This aligns with the expected risk level associated with DGV events along DGV routes within the Sydney CBD that has associated hotels and childcare facilities in close proximity to the Western Distributor (Note: These hotels and childcare facilities are over 250m from the landbridge i.e. there are no hotels or childcare facilities currently located adjacent to the landbridge).

4.3 Reporting

The development is considered to meet the criteria such that a QSRA should be undertaken or an assured argument as to why it was considered not relevant provided. The outcomes of the investigation into conducting a QRSA concluded

1) An assurance argument has been provided which sets out justification as to why a benchmark QSRA is suited as a feasible option to determine if TfNSW can establish where the risk lies relative to its intolerable criteria
2) The absolute level of individual fatality risk with the land bridge installed is less than the intolerable criteria defined as 1 in 10,000 fatalities per year for a member of the public. This as a contribution to the TfNSW individual risk level relates to an increase of approximately 3 to 4 in a million fatalities per year per typical commuter. The residual risk is therefore compliant with TfNSW requirements
3) The DNV-SAFETI software is not deemed appropriate to quantify the change in risk level that would result from the CBP development.
4) The QRAM tool may have its usefulness as a comparative tool for particular scenarios, or comparative level of risk during detail design development, if the input data, assumptions and limitations are agreed and understood. This includes the actual number, type and quantities associated with DGVs on the landbridge route.

The DNV PHAST (currently available at Aurecon) or QRAM modelling software has been identified to assist in determining the consequences for specific identified DGV events to help evaluate various specific proposed mitigation controls. The use of the modelling tool maybe appropriate in Step 4: SFAIRP Demonstration to help quantify impacts from DGV events.

It is proposed that a SFAIRP demonstration is undertaken to identify the required control measures to be implemented

5 Step 1: Hazard Identification and Baseline Risk Assessment

The first step in the risk assessment process is to identify all potential hazards related to individual DGV events. This preliminary hazard analysis includes the following steps:

- List all types of Dangerous Goods (DG) and typical examples found in and around Sydney
- Screen out any regulated DG i.e. DG restricted from transport though Sydney CBD and along the western distributor
- Describe the consequence of each individual DGV event based on various material and package sizes (current risk consequence)

5.1 Types of Dangerous Goods (Step 1.1)

Dangerous goods are classified into nine classes as defined in the Australian Code for the Transport of Dangerous Goods by Road & Rail (ADG Code) [Ref 9]. For each class there may be different hazards (potential consequences). These hazards are grouped into sub-classes. The hazards associated with each subclass of dangerous good and typical examples that can be transported in and around Sydney are listed in Table 4:

A DGV event is defined as an incident which occurs as a result of the following initiating events. Refer to Appendix H for further details.

- Failure of packaging or bulk load - Valve failure, tanker failure, cylinder failure, change in storage conditions (breach of the load)
- Uncontrolled load movement - Adverse weather, road conditions, inappropriate driving, driver impairment
- Fire on Heavy Goods Vehicle - Spontaneous ignition following brakes, tyres, heating, leading to an HGV fire

Each incident can have different consequences as identified in Table 4.

Table 4 – Dangerous Goods

Dangerous Goods Class	Dangerous Goods Subclass	Name	Examples	Potential Consequence
Class 1: Explosives	Class 1.1, 1.2 or 1.5	High risk explosives	Explosives, ammunition, fireworks	Explosion
	Class 1.3, 1.4	Low risk explosives	Life saving devices, distress signals, blank ammunition, toy fireworks, etc.	
Class 2: Gases	2.1	Flammable Gas	LPG, Butylene, Dimethyl ether, Hydrogen, Acetylene	Jet Fire, Flash Fire, Vapour Cloud Explosion or "hot" BLEVE
	2.2	Non-flammable, non-toxic gases	Refrigerants, nitrogen, carbon dioxide, helium	"cold" BLEVE, asphyxiation, cryogenic burns
	2.2/5.1	Oxidising Gas	Oxygen, nitrous oxide	"cold" BLEVE, cryogenic burns
	2.3	Toxic Gas	Chlorine, ammonia, sulphur dioxide, carbon monoxide, ethylene oxide, methyl bromide (fumigant), hydrogen sulphide, hydrogen fluoride	cold" BLEVE or Toxic Gas Cloud
	Aerosols	Aerosols	Aerosol cans	Flash fire, Projectiles
Class 3: Flammable Liquids*	PG(I), Class 6.1	Extremely flammable Liquid, Poisonous material	Acrylonitrile, Acrolein	Jet fire, pool fire or flash fire, toxic gas cloud
	PG(II)	Highly Flammable Liquid	ULP/ Motor Sprit, Petroleum Distillates/ Octane, acetone, Methanol, ethanol, hexane (glues), ethyl acrylate, Ethyl acetate (nail polish and nail polish remover)	Jet fire, pool fire or flash fire
	PG(III)	Flammable Liquid	Methyl acrylates (acrylic nails, household paints), turpentine, Styrene (fibreglass gelcoat), Xylene (glues and thinners)	
Class 4: Flammable Solids	4.1	Self-reactive Substance	Matches	Solid material fire
	4.2	Pyrophoric Substances	Activated Carbon	Solid material fire
	4.3	Substances which in contact with water emit flammable gases	Sodium cyanide, lithium metal, aluminium phosphide	Flash Fire, Vapour Cloud Explosion

Dangerous Goods Class	Dangerous Goods Subclass	Name	Examples	Potential Consequence
Class 5: Oxidizing Substances and Organic Peroxides	5.1 (High Consequence Dangerous Goods)	Oxidising Substances - High Consequence Dangerous Goods	Ammonium nitrate, calcium ammonium nitrate containing more than 45% ammonium nitrate, ammonium nitrate emulsions and mixtures containing more than 45% ammonium nitrate.	Explosion
	5.1	Oxidising Substances	calcium hypochlorite, potassium permanganate, sodium nitrite, hydrogen peroxide	Contribute to Fire
	5.2	Organic Peroxides	Methyl ethyl ketone peroxide (MEKP), Benzoyl peroxide (fibreglass resin)	Explosive decomposition, fire, reactive with other substances
Class 6: Toxic and Infectious Substances	6.1	Toxic Substances	Carbamate pesticides, acrylamide, Organophosphorus pesticides, toluene diisocyanate, cresols, Trichloroethylene (degreasing solvent), dichloromethane (paint stripper), perchloroethylene (dry cleaning), toluene diisocyanate (foam production), formaldehyde, pentachlorophenol, cyanides, isocyanates (two pack paints)	Environmental damage, toxic, Fire involving this material leading to Toxic Gas Cloud
	6.2	Infectious substance	Medical and clinical waste, cytotoxic waste, genetically modified organisms	Environmental damage, infectious
Class 7: Radioactive Material	7	Radioactive substances	All Radioactive substances	Environmental damage, radioactive
Class 8: Corrosive Substances	8	Liquid, solid or gas acid	Acetic acid, hydrochloric acid, nitric acid, phosphoric acid, chromic acid, hydrofluoric acid, Hydrogen Fluoride	Environmental damage, Corrosive
		Liquid, solid or gas alkalis	Sodium hydroxide, potassium hydroxide, ammonium solution, ferric chloride, sodium hypochlorite, mercury	
Class 9: Miscellaneous Dangerous Substances	9	Miscellaneous Dangerous Substances	Environmentally hazardous substances which are not covered by other classes, elevated temperature substances elevated temperature substances, other genetically modified micro-organisms	Environmental damage

*Diesel is not considered a dangerous good in ADG Code (it is a combustible liquid).

An increasing variety of hazardous materials can be transported. Understanding the chemical properties of these materials is essential in order to determine the level of interaction that is possible between them, the packaging of the material, and the environment surrounding their containment.

An evaluation of a DGV event depends, in part, on the class of material being transported, the type of container, and the movement quantity and frequency. The following sections qualitatively assess the impact of a DGV event based on the class of material transported, the type of container and the movement quantity.

5.1.1 Class 1 explosives

5.1.1.1 Class 1 High risk explosives

Class 1 High risk explosive poses a mass explosion hazard. These explosives are regulated for transport by the NSW Explosive Regulation 2013. Division 4 Storage and transport of explosives Section 89 Transport of explosives by vehicle in certain areas Clause 3 notes that

A person must not transport explosives of Class 1.1, 1.2 or 1.5 in or on a vehicle in the following districts, on the following bridges or in the following road tunnels except with the approval of the regulatory authority—

(a) the central business districts of Sydney, North Sydney, Penrith, Newcastle and Wollongong,

(b) the Sydney Harbour Bridge, the Anzac Bridge and the Gladesville Bridge,

(c) any road tunnels in the Greater Sydney Metropolitan Area.

5.1.1.2 Class 1 Low risk explosives

The remaining subclasses of explosives are:

- Class 1.3: Substances and articles, which have a fire hazard and either a minor blast hazard or a minor projection hazard or both, but not a mass explosion hazard. This division comprises substances and articles: (i) which give rise to considerable radiant heat; or (ii) which burn one after another, producing minor blast or projection effects, or both e.g. small arms ammunition
- Class 1.4: Substances and articles which present no significant hazard. This division comprises substances and articles which present only a small hazard in the event of ignition or initiation during transport. The effects are largely confined to the package and no projection of fragments of appreciable size or range is to be expected. An external fire must cause a virtually instantaneous explosion of almost the entire contents of the load for this DGV Event to be considered a mass explosion hazard. Examples include railway detonators, cartridges (inert or blank), safety fuses and fireworks.
- Class 1.6 Extremely insensitive articles which do not have a mass explosion hazard this division comprises articles which contain only extremely insensitive detonating substances, and which demonstrate a negligible probability of accidental initiation or propagation. The risk from articles of Division 1.6 is limited to the explosion of a single article.

With the exception of Class 1.4 having a virtually instantaneous explosion, the consequences of a Class 1 Low risk DGV event are:

- Category 1 – Life safety – localised impact with a potential for minor blast endangering members of the emergency services or the public. – Possible fatality
- Category 2 – Significant localised damage to equipment and structural damage requiring repair and / or the asset out of commission for a short period (1 Month)
- Category 3 – No 'impact to the environment' -Limited damage to minimal area of low significance

For the Class 1.4 load to have a virtually instantaneous explosion, a coincidental DGV event would need to occur e.g. a fuel tanker and explosive truck event. Such a coincidental event is not considered reasonable. Hence, the Class 1.4 materials are proposed to be excluded from the assessment.

5.1.2 Class 2.1 Flammable Gas

Flammable gases, in the presence of oxygen and an ignition source will cause a combustion reaction (i.e. fire). This is a high-temperature exothermic (heat releasing) reaction and has the potential to cause fire events such as a jet fire, flash fire, vapour cloud or BLEVE. There are two main transport vessels (excluding aerosols: Refer to Section 5.1.6) used for Class 2.1 Flammable Gases: cylinders and bulk. The consequences of a Class 2.1 DGV event are outlined in Section 5.1.2.1 and Section 5.1.2.2.

5.1.2.1 Cylinders

The consequences of a Class 2.1 Cylinder DGV event are:

- Category 1 – Life safety – localised impact with a potential for minor blast, projectile hazard, jet fire or flash fire impacting members of the emergency services or the public – Possible Fatality
- Category 2 – Possible minor local impact to assets, including directly adjacent infrastructure – Significant localised damage to equipment not requiring major repair and / or the asset operates at reduced capability for a short period
- Category 3 – No 'impact to the environment' -Limited damage to minimal area of low significance

5.1.2.2 Bulk

The main consequence of a Class 2.1 Bulk DGV event is a potential for "hot BLEVE", jet fire, vapour cloud explosion or flash fire. The consequence distance of the thermal radiation and explosion effects is typically up to 250m for an LPG Road Tanker [11]. LPG is likely to be the most common bulk Class 2.1 DG.

- Category 1 – Life safety – localised and surrounding (approximately 250m) impact with potential endangering members of the emergency services or the public (road users and adjacent CBD area) – Possible Multiple Fatalities
- Category 2 – Possible major damage to equipment and/or localised structural failure impacting infrastructure. Asset out of commission for a significant period (>3 months)
- Category 3 – No 'impact to the environment' -Limited damage to minimal area of low significance

Size of LPG deliveries can range from 2000 L (~ 1 tonne) to 40 tonnes[12]. Generally smaller vehicles service domestic deliveries and large vehicles are used for commercial deliveries only. Two tonnes bulk Class 2.1 is considered a significant hazard according to HIPAP 11[13].

5.1.3 Class 2.2 Non-flammable, non-toxic gases

The storage and transport of a Class 2.2, non-flammable, non-toxic gas, creates an inherent risk in a system as it is under pressure and similarly, a build-up of stored potential energy. Class 2.2 includes: compressed, liquefied, pressurised cryogenic, compressed in solution and asphyxiant gases. The consequences of a DGV event are detailed in Section 5.1.3.1 and Section 5.1.3.2 and typical transport vessels include: cylinders and bulk storage tanks (excluding aerosols: Refer to Section 5.1.6).

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[11] NSW Government. (2011). *Hazardous Industry Planning Advisory Paper No 11*. Retrieved from https://www.planning.nsw.gov.au/-/media/Files/DPE/Other/hazardous-industry-planning-advisory-paper-no-11-route-selection-2011-01.pdf?la=en

[12] LIQUIP. (n.d.). *LPG/Gas Vehicles*. Retrieved from https://www.liquip-qld.com.au/products-services/lpg-gas-vehicles/

[13] NSW Government. (2011). *Hazardous Industry Planning Advisory Paper No 11*. Retrieved from https://www.planning.nsw.gov.au/-/media/Files/DPE/Other/hazardous-industry-planning-advisory-paper-no-11-route-selection-2011-01.pdf?la=en

5.1.3.1 Cylinders

The main consequence of a Class 2.2 Cylinder DGV event is a potential for minor blast or projectile hazard (no fire, no "hot explosion" or no toxic release)

- Category 1 – Life safety – localised impact with impacting members of the emergency services or the public – Possible Fatality
- Category 2 – Possible minor impact to assets – Limited localised damage not requiring repair or minor effect on assets
- Category 3 – No 'impact to the environment' -Limited damage to minimal area of low significance

5.1.3.2 Bulk

The main consequence of a Class 2.2 Bulk DGV event is a potential for "cold BLEVE" leading to a significant explosion, asphyxiation, and reduced driving visibility.

- Category 1 – Life safety – localised and surrounding impact with potential endangering members of the emergency services or the public (road users and adjacent CBD area) – Possible Multiple Fatalities
- Category 2 – Possible extensive damage to equipment and/or localised structural failure impacting infrastructure assets for a significant period (>1 but <3 months).
- Category 3 – No 'impact to the environment' -Limited damage to minimal area of low significance

Generally smaller vehicles service domestic deliveries and large vehicles are used for commercial deliveries. Five tonnes bulk Class 2.2 is considered a significant hazard[14]

5.1.4 Class 2.2/5.1 Oxidising Gas

When Class 2.2/5.1 gases yield oxygen, this gas will significantly exacerbate the combustion of other materials which causes the spread of fire. Some oxidising agents can be explosive if heated in the presence of carbon. The consequences associated with a Class 2.2/5.1 DGV event are described in Section 5.1.4.1 and Section 5.1.4.2. The typical units used when transporting these gases are cylinders and bulk storage tanks.

5.1.4.1 Cylinders

The main consequence of a Class 2.2/5.1 Cylinder DGV event is a potential for minor blast or projectile hazard (no fire, no "hot explosion" or no toxic release)

- Category 1 – Life safety – surrounding impact affecting members of the emergency services or the public – Possible Fatality
- Category 2 – Possible minor impact to assets – Limited localised damage not requiring repair or minor effect on assets
- Category 3 – No 'impact to the environment' -Limited damage to minimal area of low significance

5.1.4.2 Bulk

The main consequence of a Class 2.2/5.1 Bulk DGV event is a potential for major blast or projectile hazard (no fire, no "hot explosion" or no toxic release)

- Category 1 – Life safety – surrounding impact affecting members of the emergency services or the public – Possible Multiple Fatalities

[14] NSW Planning (2011). *Hazardous and Offensive Development Guidelines: Applying SEPP 33.*

- Category 2 – Possible extensive damage to equipment and/or localised structural failure impacting infrastructure assets for a significant period (>1 but <3 months).
- Category 3 – No 'impact to the environment' -Limited damage to minimal area of low significance

5.1.5 Class 2.3 Toxic Gas

Transporting Class 2.3 Toxic Gases could lead to a DGV incident harming human health through the dispersion of toxic gas cloud. Details of the consequences of a Class 2.3 DGV Event can be found in Section 5.1.5.1 and Section 5.1.5.2. Typical storage containers for the transport of these gases include cylinders and bulk storage tanks.

5.1.5.1 Cylinders

The consequences of a Class 2.3 Cylinder DGV event is a potential for minor blast or projectile hazard with toxic release.

- Category 1 – Life safety – surrounding impact affecting members of the emergency services or the public – Possible multiple fatalities
- Category 2 – Possible minor impact to assets – Limited localised damage not requiring repair or minor effect on assets
- Category 3 – No 'impact to the environment' -Limited damage to minimal area of low significance

5.1.5.2 Bulk

The consequence distance of toxic effects is typically up to 1km or more for a road tanker containing toxic gas [15]. Due to the significant consequence effect associated with bulk Class 2.3 transport, suppliers and importers should ensure that these chemicals are not transported through densely populated locations such as Sydney's CBD.

The consequences of a Class 2.3 bulk DGV event is a potential for minor blast or projectile hazard with toxic release.

- Category 1 – Life safety – surrounding impact affecting members of the emergency services or the public – Possible multiple fatalities
- Category 2 – Possible minor impact to assets – Limited localised damage not requiring repair or minor effect on assets
- Category 3 – No 'impact to the environment' -Limited damage to minimal area of low significance

5.1.6 Class 2.0 Aerosols

Aerosols (UN1950) may contain a variety of propellants with non-flammable, non-toxic Class 2.2. e.g. carbon dioxide and Nitrous oxide making up 10%. The remaining 90% are flammable hydrocarbons e.g. LPG. Only the hydrocarbon aerosols present a fire hazard. Aerosol receptacles are designed to contain the pressure generated by the hydrocarbons or LPG at temperatures below 54^{o}C. The size of the receptacles is small ranging from 50ml to 1L.

The consequences of an Aerosol DGV event are:

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[15] NSW Government. (2011). *Hazardous Industry Planning Advisory Paper No 11*. Retrieved from https://www.planning.nsw.gov.au/-/media/Files/DPE/Other/hazardous-industry-planning-advisory-paper-no-11-route-selection-2011-01.pdf?la=en

- Category 1 – Life safety – localised impact with a potential for minor blast endangering members of the emergency services or the public – Possible Fatality
- Category 2 – Possible minor local impact to assets, including directly adjacent infrastructure – Significant localised damage to equipment not requiring major repair and / or the asset operates at reduced capability for a short period
- Category 3 – No 'impact to the environment' -Limited damage to minimal area of low significance

For the Aerosol load to have a virtually instantaneous mass explosion of all aerosols, a coincidental DGV event would need to occur e.g. a fuel tanker and aerosol truck event. Such a coincidental event is not considered reasonable.

5.1.7 Class 3 (Extremely Flammable Liquid) and Class 6.1 (Poisonous Material)

Class 3/6.1 substances cause direct damage to human body and the effects of these materials can range from minor injuries to causing death within minutes. Liquids that are classified as Class 3/6.1 should be prevented from being swallowed, inhaled and/or absorbed into the skin. Since these materials are also Class 3, when there is a leak of this material, the liquid can easily transform into a vapour. It is the toxic vapour risk that is considered the greatest consequence in relation to a DGV event. A loss of containment can also lead to several fire scenarios such as a jet fire, pool fire or flash fire. When transporting these liquids, larger quantity of the liquids carried adds to the risk of a more severe consequence. The measures implemented to control the associated risks with the flammable liquids are available under the *Work Health and Safety Act 2011* and *AS1940*. Acrylonitrile is an example of a material that is both toxic and flammable.

5.1.7.1 Bulk

The consequences of a Class 3/6.1 materials bulk DGV event are:

- Category 1 – Life safety – localised impact with a potential for minor blast endangering members of the emergency services or the public – Possible Fatality
- Category 2 – Possible minor local impact to assets, including directly adjacent infrastructure – Significant localised damage to equipment not requiring major repair and / or the asset operates at reduced capability for a short period (1 month)
- Category 3 – No 'impact to the environment' -Limited damage to minimal area of low significance

5.1.7.2 Package

The consequences of a Class 3/6.1 materials package DGV event are:

- Category 1 – Life safety – localised impact with a potential for minor blast endangering members of the emergency services or the public – Possible Fatality
- Category 2 – Possible minor local impact to assets, including directly adjacent infrastructure – Significant localised damage to equipment not requiring major repair and / or the asset operates at reduced capability for a short period (1 month)
- Category 3 – No 'impact to the environment' -Limited damage to minimal area of low significance

5.1.8 Class 3 PG I Highly Flammable Liquid

Class 3 Packing Group (PG) I Liquids have a boiling point below 35°C and are highly reactive at ambient temperature. Hence, these liquids are highly susceptible to cause a combustion reaction in the presence of oxygen. Consequently, when a leak occurs, it turns into vapour easily. A loss of containment can lead to several fire scenarios such as a jet fire, pool fire or flash fire. When transporting these liquids, larger quantity of the liquids carried increases the risk of a more severe consequence. Typical transport container sizes are standard 200L drums, and less likely bulk.

5.1.8.1 Bulk

The consequences of a Class 3 PG I materials bulk DGV event are as shown below:

- Category 1 – Life safety – localised impact with a potential for minor blast endangering members of the emergency services or the public – Possible Fatality
- Category 2 – Possible minor local impact to assets, including directly adjacent infrastructure – Significant localised damage to equipment not requiring major repair and / or the asset operates at reduced capability for a short period (1 month)
- Category 3 – No 'impact to the environment' -Limited damage to minimal area of low significance

5.1.8.2 Package

The consequences of a Class 3 PG I materials package DGV event are as shown below:

- Category 1 – Life safety – localised impact with a potential for minor blast endangering members of the emergency services or the public – Possible Fatality
- Category 2 – Possible minor local impact to assets, including directly adjacent infrastructure – Significant localised damage to equipment not requiring major repair and / or the asset operates at reduced capability for a short period (1 month)
- Category 3 – No 'impact to the environment' -Limited damage to minimal area of low significance

5.1.9 Class 3 PG II and III Flammable Liquid

Class 3 PG II and III liquids have a boiling point higher than 35°C, while the flash point of the PG III liquids is between the range of 23°C and 60°C; PG II liquids with a flash point lower than 23°C.

In general, liquids that have a flash point below 60°C are categorised as flammable liquids. Also, the *ADG Code 7.7* defines flammable liquids as liquids that are transported at a temperature higher than the flash points and substances that can liberate flammable vapours at an elevated temperature during transport. A typical Class 3 PG II Flammable Liquid would be considered octane (petrol).

5.1.9.1 Bulk

The consequences of a Class 3 PG II and III materials bulk DGV event are as shown below:

- Category 1 – Life safety – localised impact with a potential for minor blast endangering members of the emergency services or the public – Possible Fatality
- Category 2 – Possible minor local impact to assets, including directly adjacent infrastructure – Significant localised damage to equipment not requiring major repair and / or the asset operates at reduced capability for a short period (1 month)
- Category 3 – No 'impact to the environment' -Limited damage to minimal area of low significance

5.1.9.2 Package

The consequences of a Class 3 PG II and III materials package DGV event are as shown below:

- Category 1 – Life safety – localised impact with a potential for minor blast endangering members of the emergency services or the public – Possible Fatality

- Category 2 – Possible minor local impact to assets, including directly adjacent infrastructure – Significant localised damage to equipment not requiring major repair and / or the asset operates at reduced capability for a short period (1 month)
- Category 3 – No 'impact to the environment' -Limited damage to minimal area of low significance

5.1.10 Class 4.1 Self-reactive Substance

Self-reactive substances, including liquids and solids, can undergo exothermic reactions, even without the presence of air. The exothermic reactions can occur when the solids are transported due to friction or reactions with any catalytic impurities. The rate of reaction is strongly dependent on the temperature and the types of substances. The exothermic reactions may cause explosions when there is a high concentration of the substances mentioned. Also, when there is no ignition, it is possible to produce toxic vapours or gases.

These substances have a self-accelerating decomposition temperature (SADT) lower or equal to 55°C for a 50kg package and are susceptible to ignition or even explosion under confinement for transportation. While there are various substances classified under Class 4.1, some of the materials are highly reactive and can release gases under reactions.

There are seven generic types of self-reactive materials, which are described as below:

Generic types	Description	Transport measures
Type A	Self-reactive materials that detonate and deflagrate rapidly.	Prohibited from transport.
Type B	Self-reactive materials that do not detonate and deflagrate but can lead to major explosions in a package.	Maximum allowable load is 25kg per package.
Type C	Relatively safer materials that do not detonate, deflagrate, or explode although ignition is possible.	Maximum allowable load is 50kg per package.
Type D	Materials that do not detonate and deflagrate in a package, and only medium effects are expected when heated.	Maximum allowable load is 50kg per package.
Type E	Materials that do not detonate or deflagrate. The effects when being heated are minimal.	Maximum allowable load is 400kg/ 450L
Type F	Materials that do not detonate or deflagrate and has low or no explosive power.	Can be transported in tanks/ intermediate bulk containers (IBCs)
Type G	Materials that neither detonate nor deflagrate. These materials have no explosive power and are thermally stable with a SADT higher than 50°C.	

The other transport safety standards to be complied to minimise the associated risks include:

- Temperature control of the substances if the SADT is equal to or lower than 55°C.
- Compatible diluents can be used to desensitise the self-reactive substances to reduce the reactivity of the substances in accordance with Section 2.4.2.3.5 as stated in *ADG Code 7.7*[16].

The consequences of a Class 4.1 DGV event are:

- Category 1- Life safety- localised impact with a potential for minor blast endangering members of the emergency services or the public- Possible fatality

[16] National Transport Commission. (2020). *Australian Code for the Transport of Dangerous Goods by Road and Rail (Edition 7.7.).*

- Category 2- Asset- Possible minor local impact to assets, including directly adjacent infrastructure – Significant localised damage to equipment not requiring major repair and / or the asset operates at reduced capability for a short period (1 month)
- Category 3- Environment- Limited damage to minimal area of low significance.

5.1.11 Class 4.2 Pyrophoric Substances

According to *ADG Code 7.7*, pyrophoric substances are defined as substances, including solids, liquids and gases (UN 3391, UN 3392, UN 3393, UN 3394)[17], that can ignite within five minutes of contact with air[18]. These substances are highly reactive and can induce spontaneous combustion by producing heat and hydrogen. Most of the pyrophoric substances are metals which react spontaneously with atmospheric oxygen. These substances must be kept away from air and ignition sources to prevent the potential explosion hazards.

The consequences of a Class 4.2 DGV event are:

- Category 1- Life safety- Localised impact of explosions, causing burns and injuries to personnel handling the substances – Possible fatality
- Category 2- Asset- Minimal damage to the infrastructure due to explosions. – Significant localised damage to equipment and structural damage requiring repair and / or the assets out of commission for a short period. (1 month)
- Category 3- Environment- Limited damage to minimal area of low significance.

5.1.12 Class 4.3 Substances which in contact with water emit flammable gases

Substances that emit flammable gases when in contact with water are liable to explosion at ambient temperatures. The flammable gases formed can react with air to form explosive mixtures. These mixtures can react spontaneously with various ignition sources, which liberates blast wave and flames under such circumstances. There are three categories classified according to the spontaneity of combustion. Category 1 includes any substances that form flammable gases with a rate of evolution equal or higher than 10 litres per kilogram of substance over one minute. On the other hand, Category 2 includes any other substances that produce flammable gases with a lower rate of evolution, which is equal or higher than 20 litres per kilogram of substances per hour.

The consequences of a Class 4.3 DGV event are:

- Category 1- Life safety- Formation of blast waves and flames can cause burns and injuries to the personnel- Possible fatality
- Category 2- Asset- Possible minor local impact to assets, including directly adjacent infrastructure – Significant localised damage to equipment not requiring major repair and / or the asset operates at reduced capability for a short period (1 month)
- Category 3- Environment- Limited damage to minimal area of low significance.

[17] Speight, J. G. (2019). *Handbook of industrial hydrocarbon processes*. Gulf Professional Publishing.

[18] National Transport Commission. (2020). *Australian Code for the Transport of Dangerous Goods by Road and Rail (Edition 7.7.)*.

5.1.13 Class 5.1 Oxidising Substances - High Consequence Dangerous Goods (HCDG)

According to WorkSafe Victoria[19], high consequence dangerous goods include the following that are defined as Class 5.1:

- Ammonium nitrate
- Calcium ammonium nitrate which contains more than 45% ammonium nitrate
- Ammonium nitrate emulsions and mixtures which contains more than 45% ammonium nitrate

These materials are usually fertilisers and explosives that are used in the agriculture and mining industry. Ammonium nitrate melts at 170°C and starts decomposing to produce toxic gases at a temperature higher than 210°C. Also, it is an oxidising agent which can cause ignition without the presence of air. In the event of fire, the reactive ammonium nitrate liquefies and if confined (for example, in a drain), may explode.

Due to the highly hazardous nature of the materials, and additional HCDG transport licence required, the transport of such goods passing through the project location is unforeseeable as suppliers and importers would look for alternative transport routes away from the Sydney CBD. Hence, it is assumed that these goods will not be transported at the project location.

5.1.14 Class 5.1 Oxidising Substances

These substances, including solids and liquids, are not necessarily combustible in nature, but they can cause the combustion of materials through oxidation, in which oxygen is produced. With the tendency to oxidise combustible substances, these substances are susceptible in intensifying the fire, and inducing the combustion of combustible materials without the presence of obvious ignition sources. The hazards associate with Class 5.1 materials predominately relate to the potential for explosions or initiating/escalating fires. Examples of bulk transport would be tanks of hydrogen peroxide, while packages would be associated with chemicals such as calcium hypochlorite (pool chemicals). Package transport would dominate this DGV.

5.1.14.1 Bulk

The consequences of a Class 5.1 DGV bulk event are:

- Category 1- Life safety- Localised impact with a potential for fire and minor blast/ release of toxic or corrosive materials, endangering members of the emergency services or the public- Possible fatality
- Category 2- Asset- Possible significant local impact to assets, including directly adjacent infrastructure – Significant localised damage to equipment not requiring major repair and / or the asset operates at reduced capability for a short period (1 month)
- Category 3- Environment- Minor effects on biological or physical environment

5.1.14.2 Package

The consequences of a Class 5.1 DGV package event are:

- Category 1- Life safety- Localised impact with a potential for fire and minor blast/ release of toxic or corrosive materials, endangering members of the emergency services or the public- Possible fatality
- Category 2- Asset- Possible significant local impact to assets, including directly adjacent infrastructure – Significant localised damage to equipment not requiring major repair and / or the asset operates at reduced capability for a short period

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[19] WorkSafe Victoria. (2020). *High consequence dangerous goods (HCDG): Safety basics*. Retrieved from https://www.worksafe.vic.gov.au/high-consequence-dangerous-goods-hcdg-safety-basics

- Category 3- Environment- No 'impact to the environment' -Limited damage to minimal area of low significance

5.1.15 Class 5.2 Organic Peroxides

Organic peroxides are thermally unstable and can undergo exothermic self-accelerating decomposition and can burn rapidly at normal or elevated temperatures. The decomposition of organic peroxides can form flammable and harmful gases or vapours. The confinement of these materials can potentially cause explosion during decomposition of substances.

The materials can be categorised into seven types in which Type A are substances that are not suitable for transport under any circumstances, while Type G includes substances that are least destructive. According to *ADG Code 7.7*, organic peroxides do not detonate or deflagrate rapidly can be transported in packages provided that they are not more than 50 kg.

There are seven generic types of organic peroxides, which are described as below:

Generic types	Description	Transport measures
Type A	Materials that detonate and deflagrate rapidly.	Prohibited from transport.
Type B	Materials that do not detonate and deflagrate but can lead to major explosions in a package.	Maximum allowable load is 25 kg per package
Type C	Possess explosive properties, but do not detonate/deflagrate/undergo thermal explosion	Maximum allowable load is 50 kg per package
Type D	Materials that detonate/deflagrate partially, and only medium effects are expected when heated.	Maximum allowable load is 50 kg per package
Type E	Materials that do not detonate or deflagrate. The effects when being heated are minimal.	Maximum allowable load is 400kg/ 450L
Type F	Materials that do not detonate or deflagrate in cavitated state and has low or no explosive power.	Can be transported in tanks/ intermediate bulk containers (IBCs)
Type G	Materials that neither detonate nor deflagrate. These materials have no explosive power and are thermally stable with a SADT higher than 60°C.	

5.1.15.1 Bulk

The consequences of a bulk Class 5.2 DGV event are mainly to due to the potential for an explosion:

- Category 1- Life safety- Localised impact with a potential for fire and minor blast endangering members of the emergency services or the public- Possible fatality
- Category 2- Asset- Possible significant local impact to assets, including directly adjacent infrastructure – Significant localised damage to equipment not requiring major repair and / or the asset operates at reduced capability for a short period (1 month)
- Category 3- Environment- Minor effects on biological or physical environment

5.1.15.2 Package

The consequences of a package Class 5.2 DGV event are mainly to due to the potential for an explosion:

- Category 1- Life safety- Localised impact with a potential for fire and minor blast endangering members of the emergency services or the public- Possible fatality
- Category 2- Asset- Possible significant local impact to assets, including directly adjacent infrastructure – Significant localised damage to equipment not requiring major repair and / or the asset operates at reduced capability for a short period

- Category 3- Environment- No ‘impact to the environment’ -Limited damage to minimal area of low significance

5.1.16 Class 6.1 Toxic Substances

Toxic substances include materials that can cause death or severe impacts to human health through oral ingestion, dermal contact or inhalation of dusts or vapours[20]. The substances under this class are further categorised into three different packing groups according to their toxicity. The degree of the toxicity is indicated by the LD_{50} value, which is the median lethal dose, and the LC_{50} value, which is the lethal concentration. Examples are PG I, sodium cyanide (used in mining), PG II, toluene diisocyanate, and PGII dichloromethane and sodium fluorosilicate, all transported normally in drums within a container (i.e. bulk transport is normally associated with these chemicals near Port Botany).

According to the *ADG Code 7.7*, any toxic substances that are chemically unstable should not be transported due to the high possibility of decomposition and polymerisation. Otherwise, precautions must be taken and any substances that are reactive with the toxins should be removed to eliminate the potential risks.

5.1.16.1 Bulk

The main consequence of a Class 6.1 Bulk DGV event is a potential for a major toxic release. The consequence distance of toxic effects is typically up to 1km or more for a road tanker containing toxic gas [21], but could be considered equivalent for vapour or toxic smoke from a bulk Class 6.1 DGV event. Due to the significant consequence effect associated with bulk Class 6.1 transport, suppliers and importers should ensure that these chemicals are not transported through densely populated locations such as Sydney’s CBD.

The consequences of a Class 6.1 materials bulk DGV event are:

- Category 1 – Life safety – Localised impact due to toxicity endangering the health and safety of personnel- Possible fatality. It is noted that this risk can be elevated where these materials are involved in fires such that the smoke produces toxic compounds.
- Category 2 – Asset- Limited localised damaged not requiring repair or minor effect on assets.
- Category 3 – Very serious long-term environmental impairment of eco-system.

5.1.16.2 Package

The consequences of a Class 6.1 materials package DGV event are:

- Category 1 – Life safety – Localised impact due to toxicity endangering the health and safety of personnel- Possible fatality. It is noted that this risk can be elevated where these materials are involved in fires such that the smoke produces toxic compounds.
- Category 2 – Asset- Limited localised damaged not requiring repair or minor effect on assets.
- Category 3 – Moderate short-term effects but not affecting eco-systems.

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[20] National Transport Commission. (2020). *Australian Code for the Transport of Dangerous Goods by Road and Rail (Edition 7.7.)*.
[21] NSW Government. (2011). *Hazardous Industry Planning Advisory Paper No 11*. Retrieved from https://www.planning.nsw.gov.au/-/media/Files/DPE/Other/hazardous-industry-planning-advisory-paper-no-11-route-selection-2011-01.pdf?la=en

5.1.17 Class 6.2 Infectious substance

There are four main types of infectious substances[22]. These include

1. clinical waste (UN3291)
2. infectious substances affecting humans or animals (UN2814/UN2900): Category A medical waste
3. cytotoxic waste (where classified and transported as UN2810)
4. genetically modified organisms (GMO) (UN3245/UN3373)

These are substances known or reasonably expected to contain pathogens or GMO. Pathogens are defined as micro-organisms (including bacteria, viruses, rickettsia, parasites, fungi) and other agents such as prions, which can cause disease in humans or animals. However, GMOs that are not likely to cause human or animal diseases are not classified as Class 6.2 substances, and are, instead, classified under Class 9.

Cytotoxic waste includes any residual cytotoxic drug following a patient's treatment and the materials or equipment associated with the drug therapy that are toxic to cells principally through action on cell reproduction.

The following packing and transport safety standards are applied in order to minimise the possibility of spills that could endanger members of the emergency services or the public and the environment

1. Clinical waste (UN3291)
    a. Packaging in portable bins (20 L to 80 L capacity) and mobile bins (50 L to over 600 L capacity) in line with packing instruction P62A in the *ADG Code*
    b. Dedicated transport vehicle with separate cabin with enclosed strong, ridged leak proof or bunded body.
    c. Vehicle must carry a spill kit that complies with the *Biohazard Waste Industry Code of Practice for the Management of Biohazardous Waste (including Clinical and Related Wastes, (BWI Code)*
    d. Compliance with other safety requirements listed in the *ADG Code*, Dangerous Goods (Road and Rail) Transport Regulation and BWI Code
2. Infectious substances affecting humans or animals (UN2814/UN2900): Category A medical waste
    a. In NSW, under *Exemption Order No. 007/17* published by SafeWork NSW, Category A medical waste must be packed for road transport in a triple packaging system.
3. Cytotoxic waste (where classified and transported as UN2810)
    a. Transport regulated by NSW Environment Protection Authority, especially bulk
    b. Use of designated transport vehicles for clinical or cytotoxic waste
    c. Transport in a rigid-walled, puncture-resistant container with a secure lid
    d. Development of emergency procedures in the case of a spill or vehicle accident
    e. Where waste transported from a premise is over 200 kg in quantity per load, the waste must be transported by a licensed transporter.
4. Genetically modified organisms (GMO) (UN3245/UN3373)
    a. The *Gene Technology Regulations 2001* (amended 2011), requires that any notifiable low risk dealing (NLRD) involving transportation, storage or disposal of a GMO outside of certified

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[22] NSW Government SafeWork. (n.d.). *Packing and transporting clinical waste*. Retrieved from https://www.safework.nsw.gov.au/resource-library/health-care-and-social-assistance/packing-and-transporting-clinical-waste

facilities be conducted in accordance with the *Guidelines for the Transport, Storage and Disposal of GMOs*

b. In the event of a spill, or leak of GMOs, during transport efforts must be implemented as soon as reasonably practicable to locate and/or retrieve the GMOs and return the GMOs to containment or render them nonviable.

The consequence of a Class 6.2 DGV event are:

- Category 1 – Life safety – localised (near field) impact with a potential for infectious contact with members of the emergency services or the public
- Category 2 – No impact to assets, including adjacent infrastructure and surrounding networks
- Category 3 'impact to the environment' is the key consequence.

5.1.18 Class 7 Radioactive substances

Radioactive materials refer to any material containing radionuclides where both the activity concentration and the total activity in the consignment exceed the values specified in Sections 2.7.2.2.1 to 2.7.2.2.6 of the *ADG Code*. Although the *ADG Code* can be used for the classification limits of Radioactive Materials, the transportation of Class 7's is not subject to the *ADG Code*. Requirements for the transport of Radioactive Substances are regulated by EPA in conjunction with the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA). Transport of Radioactive substances are highly regulated such that any approved transport route of radioactive material through the Sydney CBD would require special consent and assessment. Also, the transport of radioactive materials needs to be complied with the Code of Practice for the Safe Transport of Radioactive Substances.

- The transport safety standards that are applicable to radioactive substances are listed below:
- The containers with a design pressure higher than 35kPa must be designed in accordance with the approved requirements to maintain the container integrity.
- The packages used for the radioactive materials must not be used to contain/ transport any other items unless the containers are decontaminated below the level of 0.4Bq/cm^2 for beta and gamma eithers, and low toxicity alpha emitters[23].

5.1.18.1 Bulk

As these dangerous goods are likely restricted from being transported on the Western Distributor in bulk, they are proposed to be screened out from the assessment.

- There is no material change to the current (baseline) risk profile.

5.1.18.2 Package

As there is no established regulations for the smaller packaged Class 7 goods, the transport of packaged Class 7 goods is probable and hence, is included in this assessment. The main control for the containment of radioactive package materials is the packaging. This packaging is made to withstand significant impact to prevent a loss of containment event. The consequence of a Class 7 materials package DGV event are:

- Category 1 – Life safety – Localised impact with a potential for high-level radiation exposure leading to acute/long-term health effects of the emergency services or the public- Possible fatality
- Category 2 – Major damage to equipment and/or localised structural failure impacting infrastructure. Assets out of commission for a significant period (>3 months)

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[23] Low toxicity alpha emitters include natural uranium, depleted uranium, thorium or alpha emitters with a half-life of less than 10 days.

- Category 3- Very serious long-term environmental impairment of eco-system.

5.1.19 Class 8 Liquid, solid or gas acid and alkalis

There are two main types of corrosives, acids (low pH) and alkalis (high pH). Both substances through chemical reaction, can cause severe damage when being in contact with living tissues, or, in the case of leakage, will materially damage, or even destroy, the vehicle or other infrastructure. These chemicals react on direct contact.

The consequences of a Class 8 DGV event are:

- Category 1 – Life safety – Potential for local (near field) severe damage if in direct contact with members of the emergency services or the public
- Category 2 – Potential local severe impact to direct assets – Significant localised damage to equipment not requiring major repair and/ or the asset operates at reduced capacity for a short period.
- Category 3 – Impact to the environment may be possible – Moderate short-term effects but not affecting eco-systems.

5.1.20 Class 9 Miscellaneous – usually Environmental impact

This includes any substances that present a danger during transport but are not covered under any other classes. The list of the substances is as stated in Section 2.9.2 under *ADG Code 7.7*.

The potential hazards of these substances include environmental hazards, particularly pollution of aquatic environment. While there is potentially bioaccumulation and degradability due to aquatic toxicity, the long-term effects to the aquatic environment are not available due to the difficulty in data interpretation.

The potential consequence of a Class 9 DGV event are:

- Category 1 – Life safety – localised (near field) impact with a potential for infectious contact with members of the emergency services or the public
- Category 2 – No impact to assets, including adjacent infrastructure and surrounding networks
- Category 3 'impact to the environment' is the key consequence- Moderate short-term effects but not affecting eco-system.
- As these dangerous goods are regulated, posing only a local life safety impact and an environmental impact following a DGV event, they are proposed to be screened out from the assessment.
- The Class 9 DGV events pose no material change to the current (baseline) risk profile.

5.1.21 Mixed Loads

Where incompatible dangerous goods are mixed, this can result in a vigorous reaction (explosion or fire) or gas evolution (flammable or toxic). To prevent such an incident from occurring the *ADG Code* has specific requirements around the principles of separation and segregation. In particular, *ADG Code 7.7 Chapter 9.1 Incompatible goods* provides the details on the compatibility for land transport purposes based on Classes, Division, Subsidiary Hazards and some specific types of goods. *ADG Code 7.7 Chapter 9.2* provides details of the segregation such that dangerous goods must not be transported on the same road vehicle with incompatible goods unless they are segregated by:

- Separate road vehicles or freight containers (Note: no B-doubles are allowed to travel on this route)
- Packaged with three levels of containment with "Approved Packaging for Segregation"

It is noted that the reactions of "very high hazardous dangerous goods" are controlled by elimination, ensuring these goods are not transported on the same vehicle. Nevertheless, the transport of mixed dangerous goods in different quantities on the same vehicle is not completely improbable. Hence, the DGV events associated with mixed class goods are assessed and the potential consequences are as below:

- Category 1 – Localised impact with a potential for fire and minor blast/ release of toxic substances/ radiation exposure/ spread of infectious substances, endangering members of the emergency services or the public- Possible fatality
- Category 2 – Major damage to equipment and/or localised structural failure impacting infrastructure. Assets out of commission for a significant period (>3 months)
- Category 3 – Very serious long-term environmental impairment of eco-system.

6 Step 2: Risk Assessment (Workshop)

A hazard identification workshop was conducted on 26th March 2021. Appropriate structured and systematic approach were used to identify DGV hazards, which included inputs from subject matter experts (SMEs) and stakeholders. The list of attendees can be found in Appendix C.

The workshop acted as a forum to systematically identify all credible safety risks of DGVs using TfNSW road assets with the intent to qualitatively assess the risks (Step 1 & 2). The workshop methodology was as follows

- Identify the current DGV safety risks and the current controls from managing safety risks of DGVs using TfNSW road assets without the landbridge.
- Evaluate if a DGV event consequence is impacted by the proposed landbridge development or the propose landbridge is impacted by a DGV event.
- Where DGV events are not impacted by the CBP development, and no further controls are identified, it was evaluated if the risk is managed to SFAIRP.

The identification of DGV safety risks was assessed based on the potential change in safety risk of fire, explosion and toxic release as a consequence of the change created by the new landbridge. All dangerous goods were systematically considered, but the workshop concluded that the risk evaluation should be based on only credible hazards.

A complete assessment of the all the risks involved in transporting all dangerous goods would require the consideration of all types of hazardous chemicals, all plausible incidents, all sizes of quantities released, and many other variables. Since it is impossible to consider all the risks of every circumstance, simplifications were made to consider only the credible events. These simplifications were implemented based on the known dangerous goods transported in the Sydney area as presented in Appendix I.

The workshop conducted a qualitative assessment of the safety risk for each identified DGV hazard against the appropriate risk criteria. This included assessing the severity of the consequences if the risk occurs and the likelihood of that consequence occurring.

The following risk matrices were available for the qualitative safety risk assessment:

- TfNSW Risk Criteria for Use by Organisations Providing Engineering Services, 2020 (T MU MD 20002 ST) – only considers scenarios that have a greater frequency of occurrence than 1 in 50 years (i.e. more than 1 event is expected every 50 years).
- Austroads Research Report AP-R590-19, Dangerous Goods in Tunnels, Application and Methodology – considers – considers scenarios which are defined as "high challenge" scenarios and extreme events that have a low frequency of occurring (more or less than one event is expected every 10,000 years). Refer to Figure 13 for details.

The Austroads Research Report Risk matrix was therefore selected for the workshop, to ensure low frequency DGV events could be identified and the risk assessment completed.

Severity Level	Consequences Type		
	Category 1	Category 2	Category 3
	Life safety	Asset and operational continuity	Environment
V	Fatality / multiple fatalities, or severe irreversible disability (>30%) to one or more persons	Major damage to equipment and / or localised structural failure impacting infrastructure. Assets out of commission for a significant period (>3 months).	Very serious long term environmental impairment of eco-system.
IV	Incapacitation, or moderate irreversible disability or impairment (<30%) to one or more persons.	Extensive damage to equipment and / or localised structural damage impacting infrastructure. Assets out of commission for a significant period (>1 but < 3 months).	Serious medium term environmental effects.
III	Partial incapacitation Objective but reversible disability requiring hospitalisation	Significant localised damage to equipment and structural damage requiring repair and / or the assets out of commission for a short period (1 month)	Moderate short term effects but not affecting eco-system.
II	Discomfort or low visibility. Objective but reversible disability which may require hospitalisation	Significant localised damage to equipment not requiring major repair and / or the asset operates at reduced capacity for a short period.	Minor effects on biological or physical environment.
I	Minor Injury, first aid may be required	Limited localised damage not requiring repair or minor effect on assets.	Limited damage to minimal area of low significance.

Risk Category	Level	Descriptor	Frequency
Base Case Scenarios	A	Frequent	More frequently than a year
	B	Likely	More frequently than every 3 years
	C	Possible	More frequently than every 10 years
	D	Unlikely	More frequently than every 30 years
	E	Rare	More frequently than every 100 years
High Challenge Scenarios	F	Very Rare	More frequently than once in 1,000 years
	G	Almost incredible	More frequently than once in 10,000 years
Extreme Event	Extreme Event		Less frequently than once in 10,000 years

Likelihood	Consequence				
	I	II	III	IV	V
A	Med	High	High	V High	V High
B	Med	Med	High	V High	V High
C	Low	Med	High	High	V High
D	Low	Low	Med	High	High
E	Low	Low	Med	Med	High
F	Low	Low	Low	Med	Med
G	Low	Low	Low	Low	Med

Figure 13 – Risk categories and matrix from Austroads Research Report AP-R590-19

Where further clarification in relation to consequence or likelihood was noted in the workshop, actions were identified to complete a more detailed risk analysis as required. Methods identified for further analysis included consequence modelling (Section 8.2), event tree analysis (Appendix J)) to confirm the future risk level.

7 Step 3: Risk Evaluation

Several scenarios identified in the workshop were carried forward for further analysis. These were identified as actions during the workshop, where the current risk (baseline risk) may be impacted by the CBP development

- Action 1: Include Terrorism event in project risk register. Project team to seek advice on security and critical infrastructure input (this action is outside the scope of this assessment)
- Action 2: Undertake flammable gas risk analysis and evaluate additional proposed controls
- Action 3: Undertake toxic and asphyxiant gas risk analysis and evaluate additional proposed controls
- Action 4: Undertake flammable and toxic liquid fire Class 3/6.1 risk analysis and evaluate additional proposed controls in a whole of life context
- Action 5: As part of the risk analysis note that any automated deluge or sprinkler system may pose additional risks for Class 4.3 chemicals
- Action 6: Undertake oxidising Class 5.1 risk analysis and evaluate additional proposed controls in a whole of life context

The workshop noted that all these risks can be controlled via restricted access to the project location. Following completion of the project, residual risks pertaining to the operation of existing TfNSW assets (Western Distributor, Harbour St and on-ramps) should be inserted into the TfNSW operational risk register for ongoing management throughout the operating life of the asset. The project risk register is a live document and requires continuous updates. It shall include the controls agreed with TfNSW.

The CBP Technical & Design Team will set up governance arrangements for the review and closure of identified design safety risks and hazards. These arrangements will involve appropriate stakeholders and subject matter experts (SMEs) in the review and closure of hazards. It will further include input, review and approval by TfNSW.

The current project risk register can be found in Appendix I. A bowtie diagram of the current controls for DGV events is documents in Appendix H.

It is acknowledged that the Western Distributor is the closest road to the landbridge structure and the road that is most likely to contain DGV.

8 Step 4: SFAIRP Demonstration

8.1 SFAIRP Demonstration

8.1.1 Methodology

SFAIRP assessments can be carried out using either qualitative or quantitative approach. In line with accepted good practice as stated in the TfNSW System Safety Standard for New or Altered Assets (T MU MD 20001 ST), each proposed safety control is evaluated using the following SFAIRP principles described below:

SFAIRP Principles

- **Legal requirements:** A control must be applied, and considered to be reasonably practicable, if it is implemented in compliance with legal requirements, e.g. legislation, etc. Compliance is not optional

- **Contemporary good engineering practice**: A control should be applied, and considered reasonably practicable if it represents current, relevant and established good practice, e.g. application of existing standards, rules and procedures, use of type approved equipment, etc.
- **Comparison with similar reference systems**: A system proven in use that has an acceptable safety level and against which the acceptability of the risks from a system under assessment can be evaluated by comparison
- **Engineering judgement**: A control should be considered reasonably practicable if an appropriate group of stakeholders has established that it has a clear safety benefit, and the costs associated with implementing the control are not grossly disproportionate to the risks considered. Engineering judgement will be made through a consensus agreement. It is based on the following principles
  - What the person concerned knows, or ought to reasonably know, about the hazard or risk and any ways of eliminating or reducing the hazard or risk. This is a way of considering the basis for the additional control and its influence on implementation. The hierarchy of controls (Section 8.1.3) apply.
  - The likelihood of the hazard or risk concerned eventuating
  - The degree of harm that would result if the hazard or risk eventuated
  - Calculation of the current risk, considering existing recovery measures in eliminating or reducing the hazard or risk- and subsequent risk reduction determined using information provided calculations or standard industry documentation
  - The cost of eliminating or reducing the hazard or risk and the risk reduction benefit gained. This can be completed via a cost benefit analysis (CBA[24]) , which can help the asset owner make judgements on whether further risk reduction measures are reasonably practicable. It cannot be used as an argument against relevant good engineering practice though. A sensitivity analysis on the result is required to support any conclusions that the costs are disproportionate to the benefits of implementing a measure. If required, a semi-quantitative risk assessment can be undertaken to assess the additional level of safety risk presented by the landbridge in relation to DGV hazards.

It is recognised that a zero-risk level is not possible and the reduction of any residual risk or the safety benefit has costs and practicality implications. A purely utilitarian cost-benefit based risk criterion could result in life safety provisions not meeting community expectations; however, a zero-risk level realisation is not possible and attempts to attain it will result in an unaffordable or unduly expensive design of the development.

The quantification can be used to determine the level of risk reduction that could be achieved if additional safety measures are introduced. This can then be used to assess whether the time, cost or effort of introducing those safety measures would be grossly disproportionate given the risk reduction benefit that they would achieve and demonstrate that the risks are managed to SFAIRP.

A sole cost benefit argument cannot justify a safety related decision and it is up to the duty holder to determine their own approach to determining gross disproportion. To err on the side of safety, the following will be built into the review as required:

- Conservative assumptions
- Increasing the safety benefit by a factor of two or three
- Evaluation is on a case by case basis relevant to the context of the risk

A semi-quantitative CBA, if required, will include

- Commonwealth value of a statistical life (VoSL) = $4.9 Mil Oct 2018

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[24] The CBA methodology has been defined by the UK Health and Safety Executive (HSE). Further details on the theory of this methodology can be found at **https://www.hse.gov.uk/managing/theory/alarpcheck.htm**

- Sensitivity case for NSW VoSL = $6.42 Mil June 2018
- Australian Consumer price index to be used to increase the figure to today value of preventing a fatality (VPF)
- Societal concerns are made at the government or transport cluster level and do not need to be considered.

- **Quantitative assessment:** Where it is determined that no clear evidence is present to determine reasonable practicability based on the above four SFAIRP Principles (legal requirements, contemporary good practice, comparison with similar reference systems and engineering judgement), it may be necessary to follow a quantitative approach by undertaking a QSRA. It is not anticipated that quantitative assessment will be undertaken often (if at all) for this type of development, as through engineering judgement, controls can be shown to represent legal requirements and/or contemporary good engineering practice and this will generally be deemed to satisfy the reasonably practicable test. Section 4 also discusses the practicalities of a QSRA for this novel scenario.

A SFAIRP statement will be included for each of the DGV Events and it will be based on one or more of the ***SFAIRP Principles*** listed above. Details describing where additional controls were considered but rejected will also be recorded against each hazard in the risk register.

8.1.2 Decision making process

The person or people nominated to make a safety decision should be one with sufficient authority and expertise. This is the role of TfNSW under the Transport Act and Roads Act to determine the acceptability of safety risk on the roadway

Any safety decisions related to the design of the CBP structure should be made by a qualified and competent designer based on the evidence developed from the analysis and stakeholders review. The decision will take due regard of safety SFAIRP and of legal requirements as well as considering the objectives.

The objective is to take a risk-based, transparent and defendable decision. This will be achieved by properly considering the evidence from the analysis within the decision, recording and documenting the decision and the rationale for the decision as well as recording the demonstration of why the decision ensures safety SFAIRP.

8.1.3 Hierarchy of controls

Where new measures and improvements to the existing control measures are identified, these will be assessed to determine whether they are required to achieve SFAIRP for any given DGV Event. A hierarchy of controls as well as engineering good practice will be implemented while the measures are being developed.

The hierarchy of controls will be considered in descending order and in consultation will stakeholders (Figure 14):

1. Elimination
2. Substitution
3. Engineering controls
4. Administrative controls
5. Personal protective equipment (PPE)

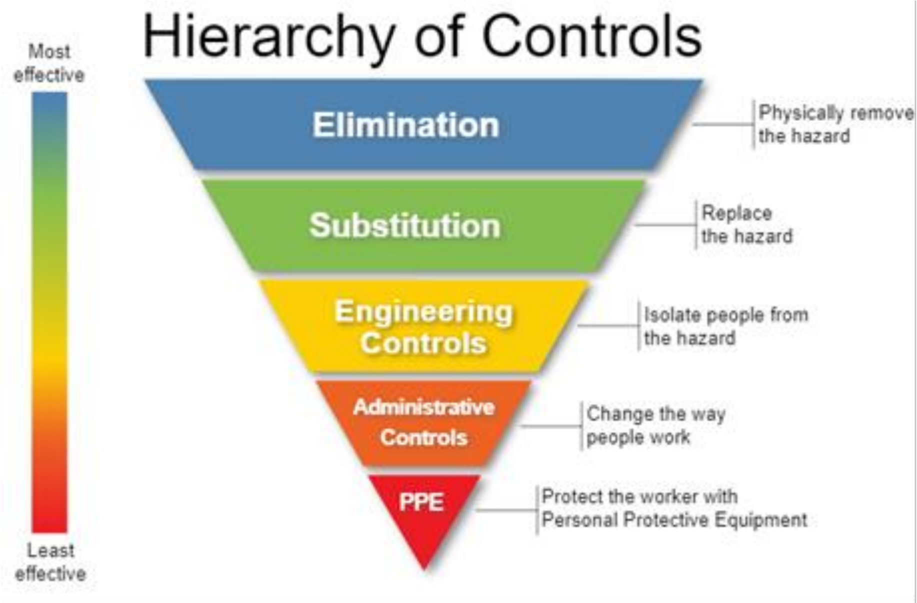


Figure 14 – Hierarchy of Controls

Controls may either be;

- Preventative, which are systems designed to eliminate or reduce the likelihood of an event occurring and referred to as "Preventative Controls" or
- Mitigative, which are systems in place to mitigate the consequences of the event as "Mitigation Controls"

8.2 SFAIRP Assessment – Landbridge

The Western Distributor is the closest road to the landbridge structure. While there is more than one road under the Western Distributor, it is the road that is most likely to contain DGV. The focus on the SFAIRP Assessment for the landbridge is in relation to the Western Distributor and DGV events at this location, unless specifically referenced otherwise.

8.2.1 Legal requirements

8.2.1.1 Regulations

Australian safety legislation has generally moved away from prescriptive requirements to requirement that duty holders manage risk through all 'reasonably practical' measures.

In NSW, dangerous goods transport is administered under the

- Explosives Act 2003 for Class 1 (explosives) and administered by Safework NSW
- Radiation Control Act 1990 for Class 7 (radioactive substances) and administered by the EPA
- Dangerous Goods (Road and Rail Transport) Act 2008 and administered by the EPA.

DGV Operators are responsible for the safe transport of Dangerous Goods. Typical transport of dangerous goods requirements are covered in the ADG Code and listed in Appendix H.

The Work Health and Safety Act defines the legal requirements for various person conducting a business or undertaking (PCBU) having a primary duty of care to ensure health and safety. There are three main PCBUs that can impact health and safety associated with DGV events under the land bridge

- TfNSW: Responsible for the design, maintenance and operations of the road assets e.g. Western Distributor

- DGV Operators: Responsible for the safe transport of dangerous goods through activities prior to transport including, including correct classification, packaging and labelling.
- CPB Designers: Responsible for the safe design of the landbridge. The details of the regulations, codes of practice and standards applied to the design of the landbridge is detailed in the basis of design for each discipline.

8.2.1.2 Standards

A road tunnel is defined in AS 4825, "Tunnel Fire Safety", as being a substantially enclosed roadway greater than 80m in length (ref AS4825:2011, Cl 1.6.32). Enclosed roadways less than 80m are not defined in AS 4825 but can be considered as over/underpasses. The landbridge is not considered to result in a substantial enclosure of the Western Distributor, but is greater than 80m in length.

The AS 4825, "Tunnel Fire Safety", standard states that it does not cover the transportation of dangerous goods through tunnels. *"Transportation of dangerous goods usually involves a comprehensive risk assessment as to the optimum transportation route and other safety considerations. If dangerous goods or bulk fuels are to be transported through a tunnel, consideration should be given to any additional fire safety measures or precautions required"* as identified in the standard.

Passage of DGV's under the land bridge is the primary concern, and any subsequent consequences resulting in a fire event will require a fire safety strategy. An initial feasibility fire safety strategy was investigated including a hydrocarbon fire, but no additional DG (detail of this study) was considered. The specific mitigations incorporated in the fire safety design and the acceptance criteria for each is given in Appendix G for the landbridge design (without including dangerous goods).

As the design develops, during the schematic design stage, the fire safety strategy and fire safety measures should be developed and documented in a Fire Engineering Brief (FEB). The purpose of the Fire Engineering Brief is to document the identified typical fire scenarios, the frequencies of such events, design parameters, practicalities of mitigations and acceptance criteria to gain agreement, in principle, from the key stakeholders of the benefit, effectiveness and practicality of the strategy and safety measures. It is understood that the functional requirements for the landbridge are unique and as such there is no specific direct design standards so that the fire safety measures are evaluated SFAIRP.

8.2.1.3 Australian Dangerous Goods Tunnels

Austroads Research Report AP-R590-19, Dangerous Goods in Tunnels Application and Methodology, 2019 applies to the potential transport of DG through road tunnels and underpasses. It notes that *"Enclosed roadways less than 80m are not defined in AS 4825 but can be considered as underpasses. As such, the normal design practices and requirements for underpasses that would apply under the jurisdiction of the study apply".* The length of the landbridge is approximately 150m, varies in height above particular sections of road and is not an enclosed structure. Hence the landbridge is a unique structure (neither defined as a tunnel nor an underpass). The Austroads Research Report AP-R590-19, Appendix B, lists a number of additional mitigation measures suggested in relation to DG in tunnels. These are listed below with a comparison to the landbridge, and in particular the Western Distributor, and if they are suitable to be considered as additional mitigations to be carried forward for the SFAIRP assessment.

Area	Reference No.	Austroads Research Report AP-R590-19 Design Guidance	Reason	Comparison to the landbridge	Investigate as a possible mitigation
Drainage System	1a	Flame traps and gullies at maximum 30m centres	Where flammable liquids are flowing from a DG vehicle onto the road pavement it is important to remove the flammable liquids from the roadway as soon as possible. This will limit the amount of fuel available for the fire from the flammable liquid and from vehicles that may become involved in the fire as a secondary fuel source.	In tunnels, it is important to remove the flammable liquids from a roadway as soon as possible. The Western Distributor viaducts have large drainage catchments on the roadway kerb at approx. 30 m intervals.	The extent and spacing of current drainage on the Western Distributor would be considered equivalent to the required spacing required of a tunnel.
	1b	Main tunnel drainage pipe to be minimum 300 mm diameter	The sizing of the main drainage tunnel needs to account for flow from a ruptured fuel tanker plus flow from the deluge system when activated. Pipe diameters less than that suggested may mean that the drainage pipe cannot handle the total flow requirements. The consequence of this would be that individual flame traps and gullies may become overloaded with fluids, potentially on fire and containing flammable liquids, flowing down the road pavement to the next available gully and thereby spreading the fire.	Drainage pipes on the Western Distributor viaducts would typically be 300 mm diameter pipes, which lead to sumps at street level, embedded in the structural columns.	The size of drainage on the Western Distributor would be considered equivalent to the required sizing of drainage required of a tunnel.
	1c	Sump accidental spillage capacity to be a minimum 40 m^3	The sump capacity needs to be designed to account for deluge system flows, and surface water where appropriate. This consideration could be in the form of the sump design or the sump capacity. In addition, and as a minimum, the sump capacity needs to be sufficient to account for a fuel tanker	It is unlikely that the Western Distributor contains sumps of 40 m^3 for accidental spillage. The Western Distributor is existing infrastructure and the fire risk is existing. Drainage systems are only expected to have an effect on pool fire spread and Vapour Cloud Explosion scenario. The OECD Safety in Tunnels [Reference 13] notes that there is not a noticeable (overall) effect on the probability to have a given number of victims, between no drainage and drainage.	Not considered practicable. The Western Distributor drainage system needs to be better understood to qualify the environmental risk of a DGV event with fire water.

Area	Reference No.	Austroads Research Report AP-R590-19 Design Guidance	Reason	Comparison to the landbridge	Investigate as a possible mitigation
	1d	Foam suppression system and appropriate initiating sensor at the tunnel sump. Initiation to be on detection of a fire at the sump	This item protects the sump from any fire at that location.	It is unlikely that the Western Distributor contains sumps of with fire detection. The Western Distributor is existing infrastructure and the fire risk is existing.	Not considered practicable
Marshalling Areas	2a	Location of Marshalling Area	An Emergency Services Marshalling Area is required to be at a location that is safe from any effect of the fire. This means that the area provided must be sufficiently far away from the tunnel portals to not be affected by smoke or any noxious gases that may occur as a consequence of any emergency event (note that an emergency event may emit noxious gases without the presence of a fire) and not directly in line with the portals so that any explosion or jet fire emission from the tunnel will not impact the Emergency Services Marshalling Area.	There are no tunnel portals, so the design of an Emergency Services Marshalling Area is not considered appropriate.	Not considered practicable
Fire Resistance Levels	3a	All tunnel structures (including cross passage linings) and separating elements (including walls separating each cross passage from the carriageway) to be designed to the modified hydrocarbon (HCinc) fire curve with the duration as determined through the Fire Engineering Brief (FEB) process, but in any event, no less than 2 hours	The modified hydrocarbon curve addresses the impact of a sharp heat rise on the structure. Having the cross passage linings designed to the modified hydrocarbon curve provides greater resilience to the structure and acknowledges that it may be possible for the cross passage doors to fail before the fire is contained and controlled as they are only rated to the cellulosic curve.	The landbridge does not have cross passages. The design of the landbridge structure to the modified hydrocarbon curve would provide additional protection to the structure.	The landbridge designed to the modified hydrocarbon (HCinc) fire curve with a minimum of 2 hours duration, is considered reasonably practicable.

Area	Reference No.	Austroads Research Report AP-R590-19 Design Guidance	Reason	Comparison to the landbridge	Investigate as a possible mitigation
	3b	Any electrical, control or communications equipment located within cross passages to be in a space that is fire separated from the cross passage	While the cross passage doors provide some protection to the cross passage, they are only rated to the cellulosic curve. Consequently, additional protection is required to any equipment housed in the cross passages. This is achieved by adding a layer of fire protection to this equipment and housing it in a separate fire rated space.	The Western Distributor does not currently have cross passages designed. The landbridge structure does not enclose the road like a tunnel. CFD modelling shows that the openness means that people can escape along the road.	Not applicable
	3c	All doors to cross passages to have a minimum FRL of -/120/120 to AS1530.4 standard fire curve	The fire rating of the cross passage doors provides some protection to the cross passage and the other tunnel bore as two cross passage doors are deemed to provide approximately -/240/240 FRL protection.	The landbridge does not have cross passages.	Not applicable
	3d	Where equipment is located within the tunnel, the separation from the carriageway to be a minimum FRL of 240/240/240 to AS1530.4 standard fire curve	This requirement allows equipment in the tunnel to have similar protection from a fire event as any equipment housed within a cross passage.	There is no additional equipment associated with the landbridge.	Not considered practicable
Heat Release Rate	4a	The design fire heat release rate for the smoke management system to be a minimum 100MW.	The design fire size acknowledges the possible presence of hydrocarbons in a fire and hence a higher heat release rate.	CFD study did a fire scenario for a natural ventilated void, at 157MW and 250 MW (these values are higher than typical models done for fuel fires)	Already included in the fire study and design of the landbridge
	4b	The smoke management system to account for the presence of ambient wind.	Adverse ambient wind may affect the operation of the smoke management system, particularly for shorter tunnels. This requirement maintains the efficacy of the smoke management system even with adverse ambient wind.	Natural ventilation is the only effective solution available for a large cross sectional area	Not considered practicable

Area	Reference No.	Austroads Research Report AP-R590-19 Design Guidance	Reason	Comparison to the landbridge	Investigate as a possible mitigation
	4c	The number of redundant fans required to be determined by analysis assuming a minimum 100MW heat release rate.	Fans may be destroyed by a fire event and therefore it is necessary to have redundant fans. This requirement stipulates that the efficacy of the smoke management system must be maintained even with a 100 MW heat release rate.	Mechanical ventilation in large cross sectional voids, such as the landbridge, is ineffective.	Not considered practicable
Deluge System	5a	The duration of deluge operation to be as determined through the FEB process, but in any event, no less than 1 hour	This item acknowledges that for a DG fire, the deluge system may need to operate for a longer duration than the standard 1 hour generally specified. The duration of deluge operation is to be determined through the FEB process and therefore if justified, the period of operation may be 1 hour, or a greater time period.	Deluge systems in a tunnel to ensure achievement of the functional requirements need appropriate discharge density and coverage, a mode of activation e.g. via tunnel operator and/or automation, set up in various zones, air flow impact on performance, supply design and maintenance of the system.	Deluge is one of many fire safety and protection measures. It is carried forward for further investigation with other proposed measures.
Possible Procedural Mitigations	6a	The passage of any vehicle carrying Class 1 or 2 DGs through the tunnel to be undertaken using suitable procedures that require the vehicle to proceed through the tunnel at a time when no other vehicles are present in the tunnel	Incidents involving higher risk DGs (i.e. Class 1 and/or Class 2.1) may have significant resultant consequences. By having procedures that require Class 1 or 2 DGs to travel through the tunnel at a time when no other vehicles are present in the tunnel, while the risk is not affected, the consequence of any event is mitigated.	Operational mitigations to restrict the movement of DG. through route selection, type of DG or time on the Western Distributor, is excluded from the scope of this assessment.	Operational mitigation. Carried forward (Owner: TfNSW)
	6b	Posted speeds may be reduced at times when higher risk DGs are allowed to travel through the tunnel.	This would reduce the likelihood of incidents resulting from collisions. Note that data from operational tunnels has confirmed that collisions occur less frequently in tunnels than on the open road.	Operational mitigations to control the movement of DG is excluded from the scope of this assessment	Operational mitigation. Carried forward (Owner: TfNSW)
	6c	DGVs may be prohibited from changing lanes in the tunnel	One of the recommendations of the Burnley Tunnel fire coronial enquiry was that HGVs should not be allowed to change lanes in the tunnels	Operational mitigations to control the movement of DG is excluded from the scope of this assessment	Operational mitigation. Carried forward (Owner: TfNSW)

Area	Reference No.	Austroads Research Report AP-R590-19 Design Guidance	Reason	Comparison to the landbridge	Investigate as a possible mitigation
	6d	Documentation and implementation of a procedure requiring enhanced Operator surveillance when DGVs transit the tunnel. The presence of the DGV to be notified by a DGV detector prior to the tunnel entrance portal.	Incidents involving Class 1 or 2 DGs may have significant resultant consequences. This item is intended to reduce the consequence of an event by making the passage of DGs safer by operation rather than purely safer by design. As a consequence, when undertaking a risk analysis enhanced reaction times may be adopted	Operational mitigations for an Operator to monitor the movement of DG is excluded from the scope of this assessment	Operational mitigation. Carried forward (Owner: TfNSW)
	6e	Consideration such that when an oversize vehicle proceeds through the tunnel, allowance is provided for a vehicle of standard size (including a fire truck) to overtake.	Some oversize vehicles may take up the entire width of the tunnel preventing any other vehicles from passing. Where the tunnel portals are remote, and access to both portals is difficult or constrained, during some emergency events, Emergency Services may need to pass by the oversize vehicle. This item allows Emergency Services to pass the oversize vehicle in a timely manner. It is noted that the Guidance states that this item only be considered and therefore provided access requirements are appropriate, this item may not be required.	No change in use. For oversized vehicles route selection occurs. There are currently pedestrian bridges over the Western Distributor and the landbridge design is at the same height as these existing structures.	Already included
Training	7a	Training provided to DGV drivers as to how to respond should they be aware of an issue with their vehicle in, or adjacent to, a tunnel	Drivers may be able to mitigate the consequence of a DGV incident.	Administrative controls are considered low cost so are reasonably practical to implement	Operational mitigation. Carried forward (Owner: DGV operators)
	7b	Training provided to incident responders with respect to DGVs in, or adjacent to, tunnels.	Incident responders should be trained regarding risks resulting from DGVs	Administrative controls are considered low cost so are reasonably practical to implement	Operational mitigation. Carried forward (Owner: Incident Responders)

Area	Reference No.	Austroads Research Report AP-R590-19 Design Guidance	Reason	Comparison to the landbridge	Investigate as a possible mitigation
	7c	Training provided to emergency services with respect to DGVs in tunnels.	Emergency services personnel should be trained regarding risks resulting from DGVs.	Administrative controls are considered low cost so are reasonably practical to implement	Operational mitigation. Carried forward (Owner: Emergency Services)

8.2.2 Contemporary good practice

Contemporary good practice is that all avoidable risk should be avoided. The risk workshop noted that all DGV hazards can be controlled via restricted access to the project location, reducing the risk of both the current (baseline) risk and change in level of risk (future risk). As listed in Section 3, the following assumptions, constraints and dependencies exist with proposed additional controls

- It is recognised that DGV events can occur under the current circumstances. There is a current level of risk (baseline risk) associated with DGV hazards. It is assumed that this baseline risk level is acceptable and managed to SFAIRP through current practices such as transport regulations and ADG Code practices. An assessment of mitigation measures to prevent or mitigate the baseline risk associated with DGV hazards is not within the scope of this assessment.
- This assessment is specifically in relation to the potential change in risk in relation to DGV hazards due to the CBP development, including the landbridge.
- Elimination of DGV events under the landbridge development is not within the control of the CBP Team. Only TfNSW, EPA and SafeWork NSW has the authority to eliminate DGV events under the landbridge.

Contemporary primary good practice of any road structure in relation to an adequate level of fire and life safety include

- Safety of occupants (reduce fire, toxic and explosion risk to acceptable level)
- Facilitate effective emergency services intervention
- Protection of adjoining properties and third parties.

Other secondary good practice would be to

- Minimise the interruption of the road operations
- Minimise property damage
- Minimise fire, explosion and toxic release incidents
- Minimise adverse effects on the environment
- Minimise capital and life cycle costs

The SFAIRP assessment will consider the primary objectives.

8.2.3 Comparison with similar reference systems

The following similar reference systems are sections of roads in and around the proposed landbridge location. Any mitigations that are installed as part of these similar reference systems are considered reasonably practicable mitigation measures. Google Map images of these locations can be viewed in Appendix K.

8.2.3.1 Western Distributor beneath 161 Sussex Street

The closest reference system is part of the Western Distributor beneath 161 Sussex Street. From google maps the following controls are visually seen as part of the design in relation to protecting the Western Distributor

- A fixed fire fighting system (foam)
- A fire hydrant system
- Lighting
- Wayfinding e.g. Emergency signage

- Video surveillance
- Communication e.g. speakers, call points

It is considered reasonably practical to implement these additional control measures for the Western Distributor under the landbridge. An exception is the foam fixed firefighting system. New facilities are not encouraged to install foam fixed firefighting systems, due to the environmental risks associated with the foam. It is noted that the following controls are already available on the Western Distributor and the design of the landbridge

- A fire hydrant system
- Lighting
- Communication e.g. CCTVs and Speakers

It is considered reasonably practical to include wayfinding e.g. emergency signage in the landbridge design.

It is considered reasonably practical to understand how the communication equipment could be used to facilitate effective emergency services intervention.

8.2.3.2 Western Distributor (100m south of the landbridge)

Currently there is significant glass infrastructure associated with various buildings a few meters from the Western Distributor, 100m south of the proposed landbridge location. Any fire or explosion DGV event, especially a BLEVE or explosion along this section of the road will have a catastrophic impact to the surrounding assets and buildings. Glass poses a particular high-risk hazard for explosions. There are no additional fire protection measures identified associated for DGV events on the Western Distributor, beyond fire hydrants. These hydrants are existing. By comparing the risk of a BLEVE or explosion DGV event 100m before the landbridge, the risk to people near glass poses a greater risk than those outdoors, e.g. on the landbridge.

Through direct comparison with a similar reference, no mitigation for a BLEVE or explosions, beyond fire hydrants is comparable for the landbridge.

8.2.3.3 South Bound A4 into the Darling Park Underpass

The South Bound A4 enters under the Market Street viaduct. This is a short underpass of less than 20m with no fire protection. The road enters a 40m section of road that will have, when the proposed landbridge is constructed, the structure approximately 16m above the road. The South Bound A4 then enters the Darling Park underpass. From google maps the following controls are visually seen as part of the design in relation to protecting the South Bound A4 in the Darling Park underpass

- A fire sprinkler system
- A fire hydrant system
- Lighting

The South Bound A4 is divided into three distinct sections that through direct comparison the following mitigations could be proposed as reasonably practicable

-For short sections of road <40m with an underpass <10m above the road, no fire protection is reasonably practicable

-For short sections of road <40m with an underpass >10m above the road, no fire protection is reasonably practicable

-For long sections of road >40m with an underpass <10m above the road, a fire sprinkler system, fire hydrant system and lighting maybe considered appropriate mitigations.

8.2.3.4 Harbour, Wheat and Market Street

Harbour Street, similar to the South Bound A4, can be divided into different sections. The two longest sections are Harbour Street running south bound under the Western Distributor for approximately 100m at a height of <10m and north bound for approximately 150m, when the proposed landbridge is constructed, with the structure approximately 16m above the road. There is no identified fire protection. Due to Harbour Street diverting into the CBD and is not a throughfare, DGVs are unlikely to be on this section of road. Continuing with no fire protection maybe considered reasonable. The same can be said for Market Street that feeds from the CBD and Wheat street that feeds into the CBD.

8.2.4 Engineering judgement

8.2.4.1 Additional Controls to be assessed

Following Step 2, Risk Assessment workshop, the following main recommendations considering controls were made

- Action 2: Undertake flammable gas risk analysis and evaluate additional proposed controls
- Action 3: Undertake toxic and asphyxiant gas risk analysis and evaluate additional proposed controls
- Action 4: Undertake flammable and toxic liquid fire Class 3/6.1 risk analysis and evaluate additional proposed controls in a whole of life context
- Action 6: Undertake oxidising Class 5.1 risk analysis and evaluate additional proposed controls in a whole of life context

Each of the DGV Events identified were mapped as an event tree (Appendix J), to understand the pathway to various impacts and map what additional controls could be proposed.

The controls proposed can be summarised below

Impacts	DGV Events	Action No	Current Controls	Additional Preventative Control	Additional Mitigation Control
Toxic Vapour / Smoke	Toxic gas, asphyxiant gas, toxic liquid	Action 3 and 4	▪ DGV operations: Bowtie (Appendix H) ▪ Design: As per fire and life safety mitigations (Appendix G) ▪ Design: Structure geometry: large void ventilation (Volume is 150m x 35 m x 15m = 78750 m^3)	None	Item A: Additional ventilation
Hot or cold BLEVE	Flammable or asphyxiant gas	Action 2 and 3	▪ DGV operations: Bowtie (Appendix H) ▪ Design: As per fire and life safety mitigations (Appendix G)	Item B: Additional extinguishing systems (specifically to prevent escalation through HGV fire)	Item C: Additional structural protection for explosions

Impacts	DGV Events	Action No	Current Controls	Additional Preventative Control	Additional Mitigation Control
Explosion	Class 5.1, Class 4	Action 6	▪ DGV operations: Bowtie (Appendix H) ▪ Design: As per fire and life safety mitigations (Appendix G)	Item B: Additional extinguishing systems (specifically to prevent escalation through HGV fire)	Item C: Additional structural protection for explosions
Vapour cloud explosion	Flammable gas, Flammable liquid, Class 4	Action 2 and 4	▪ DGV operations: Bowtie (Appendix H) ▪ Design: As per fire and life safety mitigations (Appendix G)	Item D: Ignition control	Item C: Additional structural protection for explosions
Flash Fire	Flammable gas, Flammable liquid, Class 4	Action 2 and 4	▪ DGV operations: Bowtie (Appendix H) ▪ Design: As per fire and life safety mitigations (Appendix G)	None	Item B: Additional extinguishing system
Pool Fire	Flammable liquid, Class 9, combustible liquids	Action 4	▪ DGV operations: Bowtie (Appendix H) ▪ Design: As per fire and life safety mitigations (Appendix G)	None	Item B: Additional extinguishing system
Jet Fire	Flammable gas, Flammable liquid	Action 2 and 4	▪ DGV operations: Bowtie (Appendix H) ▪ Design: As per fire and life safety mitigations (Appendix G)	None	Item B: Additional extinguishing system

8.2.4.1.1 Item A: Additional Ventilation

A control should be considered reasonably practicable if an appropriate group of stakeholders has established that it has a clear safety benefit.

The following is reasonably known around toxic DGV events and the ventilation associated with the landbridge development at the time of this report

- The geometry of the landbridge is such that a large void is created
- Mechanical ventilation in large cross-sectional voids, such as the landbridge, is ineffective.
- Urban environments create obstacles and channelling to toxic DGV events. The landbridge contributes to this change in dispersion, which in calm conditions is likely to increase concentrations of releases and in high wind scenarios, help disperse the release through channelling. Emergency services should be aware of wind direction and conditions before responding to any toxic DGV event within an urban environment.
- Natural ventilation is the only effective solution available for a large cross-sectional area portal.

- Acceptance criteria of CFD Modelling (Appendix G) noted that natural ventilation was adequate for life safety associated with egress from typical smoke hazards.

The following is known of the likelihood of the hazard or risk concerned eventuating

- For toxic releases, especially denser than air hazardous chemicals, calm wind conditions result in less mixing and thus the greatest risk scenario. The likelihood of calm wind conditions occurs for approximately 16% at the development location (13% at 9am and 3% at 3pm)[25]. Calm wind conditions are conservative for simple dispersion modelling, as indicated in Figure 11.

The following is known of the degree of harm that would result if the hazard or risk eventuated

- Taken from The OECD Safety in Tunnels [Reference 13], “For toxic releases in the open, the physical effects are assessed with a dense gas dispersion model. In tunnels, the pre-conditioner calculates the drift of a toxic plug along the tunnel as a function of the incident location and the tunnel characteristic.”
- To determine the degree of harm due (toxic effects) due to a release, DNV PHAST software was used to simulate an outdoor leak (during calm weather) from a chlorine drum and an ammonia cylinder as two typical examples. It is noted that the DNV software was not suitable to calculate dispersion relative to the landbridge and surrounding structures. Toxic effect results for individuals outdoors (without taking into account any impact from adjacent structures) for a typical 25mm leak hole size at calm wind conditions (1.5 / F) are shown in Figure 15 below.
  - **Chlorine:** The results show around a 100% chance of fatality within 60m of the release, and a greater than 10% chance of fatality 200m from the release.
  - **Ammonia:** The results show approximately 100% chance of fatality within 5 m of the release, and greater than 10% chance of fatality 55m from the release

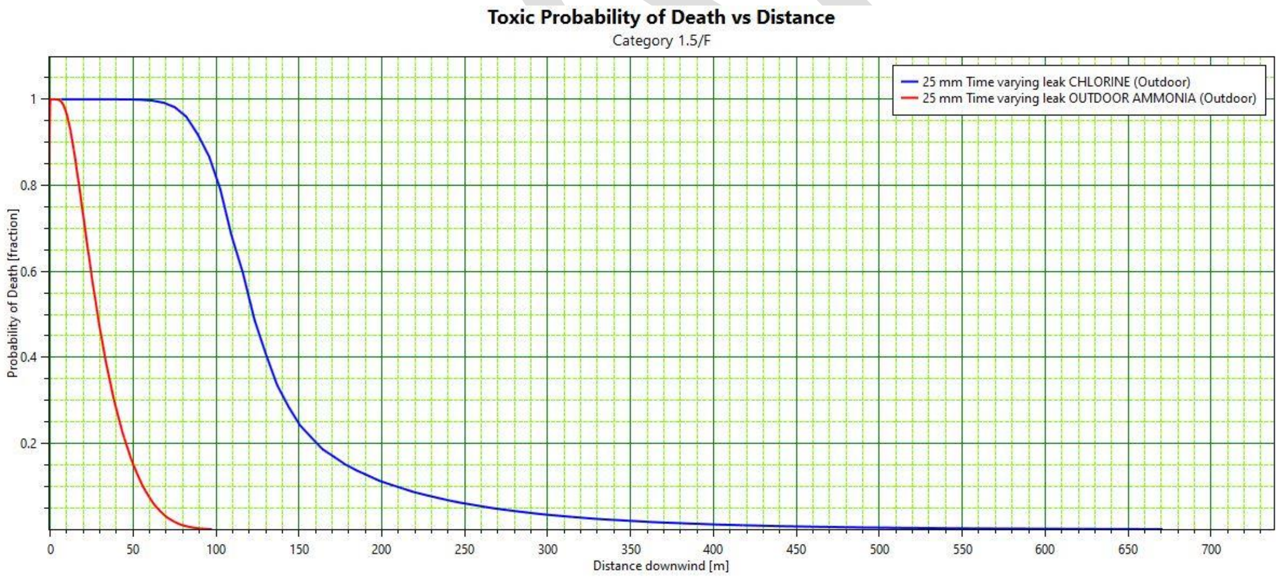


Figure 15 – Toxic Probability of Death vs Distance, 25mm Leak

- The impact of a toxic release from the centre of the landbridge (worst case) is shown in Figure 16, displayed over a contour representing a 0.1% chance of fatality. The results show the 0.1% ammonia fatality contour is within the geometry of the landbridge, whereas the chlorine toxic release contour has an effect distance greater than the size of the landbridge. Both cases the impact is within the geometry of the

[25] Australian Government, Bureau of Meteorology. Climate Statistics for Australian locations – Sydney, Observatory Hill [Online] [Cited: 27 04 2021.] http://www.bom.gov.au/climate/averages/tables/cw_066062.shtml

landbridge. However, the landbridge may provide a level of protection for pedestrians to toxic releases compared with the current open unprotected pedestrian walkway This protection is greater for the more likely toxic cylinder releases as opposed to toxic drum scenarios.

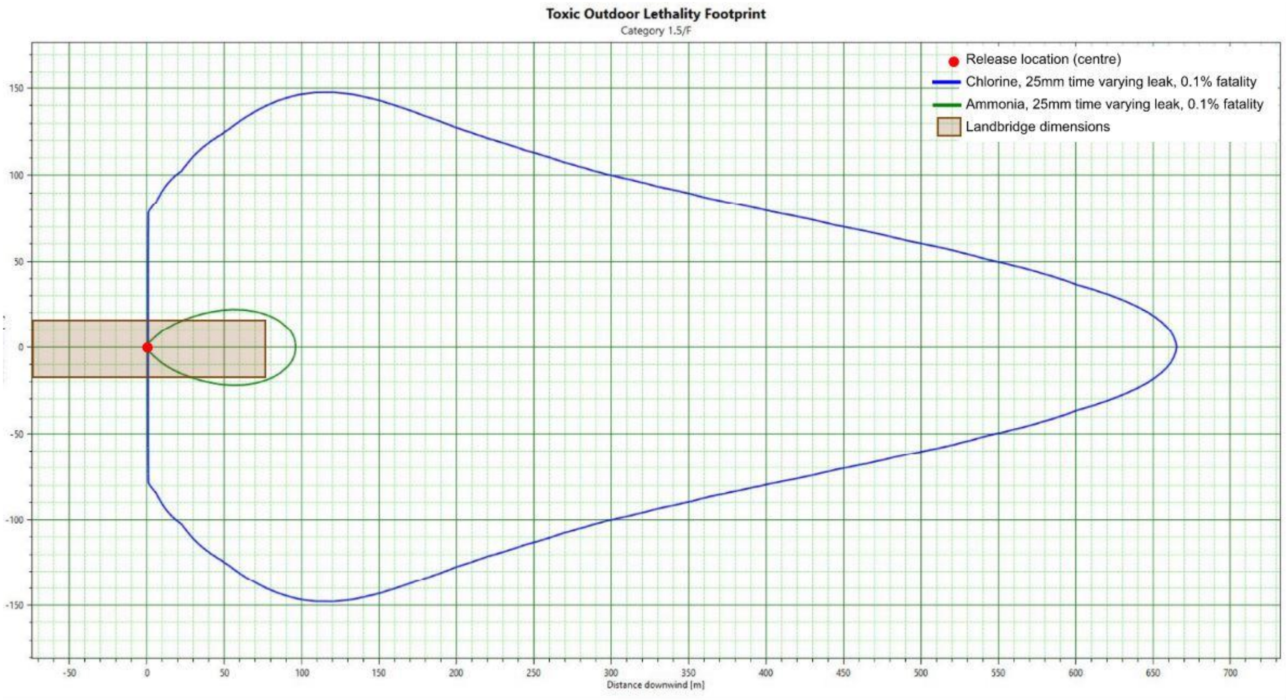


Figure 16 Toxic release contour representing 0.1% fatality, elevation of 1m

The estimation of the current risk is that the risk of toxic DGV events is reduced as far as reasonably practicable considering

- The risk cannot be eliminated
- There is no substitution control
- An engineering control through the design of a mechanical ventilation system is not reasonably practical for the geometry void under the landbridge.
- Additional administrative and PPE controls are considered appropriate especially for emergency services to response to a toxic DGV event.

There is no clear safety benefit identified for additional mechanical ventilation and as such a CBA is not required.

8.2.4.1.2 Item B: Additional Extinguishing Systems and Sufficient Drainage

Contemporary primary good practice of any road structure in relation to an adequate level of fire and life safety include

- Safety of occupants (reduce fire to acceptable level)
- Facilitate effective emergency services intervention
- Protection of adjoining properties and third parties.

Additional extinguishing systems could help improve the level of fire and life safety, but only if they are managed and used appropriately.

The SFAIRP assessment has already assessed that fire hydrants are existing and are reasonably practical (refer to Section 8.2.3.1), as well as appropriate training for DGV drivers and fire extinguishers on DGV (reference 7a, Ausroads research report, Section 8.2.1.3). It is noted that EPA have previously advised that current training requirements for DGV drivers could be improved. It is therefore recommended to ensure sufficient DGV driver training is in place to respond to a DGV event.

The National Fire Protection Association NFPA Code 502-46 [Reference 21] notes that fixed fire fighting systems (FFFS) have over the last 10 to 15 years had their efficacy demonstrated through multiple full-scale fire tests and published data. It states, "It is now acknowledged that fixed water-based fire- fighting systems are highly regarded by fire protection professionals and fire fighters and can be effective in controlling a fuel road tunnel fire by actually limiting the spread of the fire."

While the initial fire safety study for the project focused on safety of occupants, it is now understood that FFFS could be considered reasonably practicable for facilitate effective emergency services intervention and additional protection of adjoining properties and third parties.

This section investigates further what additional extinguishing systems are reasonably practicable for the DGV Events as documented in the HAZID workshop. The expected fire loads, peak heat release rates, are listed in order of qualitative evaluation of the expected frequency of the events,

- HGV Fire (and as a precursor to a BLEVE), Typically 20 to 100 MW
- Flammable Liquid, Class 9, combustible liquids; pool fire, 100MW (NFPA 502), but up to 200MW
- Flammable gas, Flammable liquid or Class 4; flash fire
- Flammable gas, Flammable liquid; jet fire

Due to the lack of statistical data at this time, the fire scenarios can't be evaluated through a risk analysis approach. Further work is also being undertaken to compile sufficient data such that a risk analysis can be performed.

8.2.4.1.2.1 Extinguishing medium

Examples of fixed water-based fire-fighting systems include deluge systems, mist systems and foam system. Foam is not recommended, generally for new installations, due to its environmental hazard and the location of the landbridge near Darling Harbour. It is also not effective for LPG fires. Water may pose a risk to some Class 4 goods, but these are rare in comparison to LPG DGVs.

Water is therefore considered a reasonably practicable extinguishing medium.

8.2.4.1.2.2 Extinguishing system location

The conclusion from the comparison with similar reference systems in Section 8.2.3 is that the only location that is reasonable practicable to investigate locating a FFFS would be along the Western Distributor, below the land bridge. This is mainly driven by the length of this section of road and the landbridge height at this location relative to the road.

8.2.4.1.2.3 Application: Sprinklers vs Deluge vs Mist

According to the NFPA, the following countries now have FFFS installed in road tunnels: Austria, France, the Netherlands, the UK, and Italy (high-pressure water mist); Denmark (low-pressure water mist), Spain, UAE, Singapore, Korea, China and Finland (deluge and high-pressure water mist) and America, Sweden and Australia (deluge). In Japan, FFFS are required in all tunnels longer than 10,000 m, and in shorter tunnels longer than 3000 m with heavy traffic.

The NFPA details that the choice in application that feeds into the detailed design of the system requires a consideration of a range of specific factors and their interactions to optimise the performance, including:

- Ventilation
- Geometry of the area under the landbridge
- Nozzle installation height and location

- Expected fire load
- The time for operation
- Environmental and drainage conditions
- Water supply and constraints on available storage design
- Water application rate
- Other performance criteria (e.g. structural protection and tenability)

Fixed Fire Fighting systems' performance, have the following design constraints in line with the factors to consider from NFPA above:

- Mechanical ventilation is not reasonably practical for the landbridge as covered in Section 8.2.4.1.1. Fire design is based on natural ventilation.
- Geometry of the area under the landbridge is complex. Only the Western Distributor is considered reasonably practical as a location for a FFFS as this is where DGV are most likely to travel and where the landbridge is less than 10 m from the road (refer to Section 8.2.3).
- Wet pipe sprinklers would activate in an uncontrolled manner due to large amount of heat produced in an open space for a large fuel fire. Air movement will push heat from one end to the other and as the sprinklers rely on heat activation, all sprinklers would activate, reducing performance.
- Expected fire load is typically 100MW (i.e. normal road users), but up to 250MW should be considered as a test case for DGV events. The DGV events are considered rare events in relation to normal road user fires.
- Nozzle installation height and location should be design for optimum performance with separate zones. Due to the area to be covered, it is estimated at least four zones are required for the Western Distributor under the landbridge. Design should include activation of up to at least two zones as per NFPA 504, although modern Australian tunnel designs recommend three where an operator is available. This should be investigated in the context of manual and automatic activation as well as an understanding that B-Doubles (i.e. long vehicles) do not use this route.
- An hour (60min) operation is considered typical operation time for a deluge system[26]. Fire studies show that early activation (i.e. within three mins) of a deluge system can reduce the peak heat release rates of a fire significantly within 20mins[27].
- NFPA 502 assumes that a full-time attended control room is available for any facility in which a FFFS is installed. This provides a layer of protection against false alarms and accidental discharge. As TfNSW is not considering the 24/7 monitoring of the Western Distributor, the benefits of a manual operation to reduce the overall water supply demand by activating individual zones cannot be realised and the difficulties in false alarms and accidental discharge will need to be considered.
- The water application rate will be limited by the existing drainage design and comparing the benefit of the application rate to the hazard of environmental impact. The current drainage design is fixed as it is existing infrastructure.
- The water supply will be constrained by available storage location and sizing of storage tanks design in relation to the load bearing of the landbridge structure.
- Water application rate is typically 10 mm/min as per AS2118.3-2010 Deluge Systems, but NFPA 502 for fires greater than 100MW range from 8 to 12 mm/min

[26] Fire incident data for Australia road tunnels, Nigel Casey, 2019

[27] Fire Heat Release Rates of Heavy Goods Vehicles (mosen.global)

- Other performance criteria (e.g. structural protection and tenability). If the landbridge is designed to the modified hydrocarbon (HCinc) fire curve with a minimum of 2 hours, reduction in performance of the FFFS is further justified from an asset protection strategy.

These design constraints need to be evaluated and understood in the context of typical fire scenarios, the frequencies of such events, design parameters, practicalities of mitigations and acceptance criteria to gain agreement, in principle, from the key stakeholders of the benefit, effectiveness and practicality of the fire strategy and safety measures. Any additional fixed fire safety mist, spray or deluge system can then be evaluated in the context of the design performance and practicality of operating, installing and maintaining such a system above the Western Distributor.

8.2.4.1.2.4 Conclusion

Based on industry guidelines and engineering practice at some of the surrounding underpasses, it is reasonably practicable that at a minimum a fixed water-based firefighting system is installed above the Western Distributor. For any FFFS to be designed, there are various reasonably practical criteria and limitations required to be considered within the detailed design to optimise the performance of the system and derive its benefit.

As per Section 8.2.1.2, it is recommended that a qualified fire safety engineer should through the schematic design stage, develop and document the fire safety strategy and fire safety measures in a Fire Engineering Brief (FEB). Any additional fixed fire safety mist, spray or deluge systems can then be evaluated in the context of the design performance and practicality of operating, installing and maintaining such a system above the Western Distributor.

8.2.4.1.3 Item C: Additional structural protection for explosions

Explosions have already been considered in Section 8.2.3.2, as not reasonably practicable to require any additional structural protection. The OECD Safety in Tunnels [Reference 13] as quoted below, also notes that an explosion-resistant structure is not an appropriate mitigation for such events.

“An explosion-resistant structure is not needed for safety reasons because an explosion capable of damaging the tunnel will not leave any survivors. However, when “all DG” is allowed, the stability of the possible second tube in case of an explosion in the first one should be checked. Apart from this specific point, explosion resistance is only aimed at protecting the tunnel itself. Its high cost generally prevents it from being cost-effective if protection against very serious explosions is sought”. Similar to tunnels an explosion under the landbridge would be catastrophic such that it would damage the landbridge and have catastrophic impacts to safety not only to the occupants, but nearby buildings, vehicles and pedestrians.

For the CBP development, explosion resistance from the structure would be intended to protect the asset itself. It would provide little to no benefit to safety i.e. the public surrounding the structure (i.e. in nearby buildings, vehicles and pedestrians). There is also no second tube (or emergency tube) designed for the landbridge to protect.

Due to the size of the land bridge (i.e. high structural protection cost) and minimal benefit gained (little to no protection to the public-especially occupants, nearby buildings and vehicles), explosion resistance is a potential mitigation measure but it is (as highlighted in OECD Safety in Tunnels [Reference 13]) anticipated that the cost would be greatly disproportionate to the benefit. This qualitative evaluation can be confirmed if further data is obtained to quantify the frequency of such events to provide a quantitative cost benefit analysis.

8.2.4.1.4 Item D: Ignition control

Providing a design with ignition control is not appropriate as vehicles provide a source of ignition and cannot be eliminated. Ignition control is not considered a reasonably practical mitigation measure.

8.3 Conclusions

All DGV hazards can be controlled via restricted access to the project location, reducing the risk of both the current (baseline) risk and change in level of risk (future risk). Notwithstanding this control, this Safety Assessment Report has followed a risk assessment process and SFAIRP demonstration to investigate appropriate mitigation measures.

While the initial fire safety study for the project focused on safety of occupants, it is now understood that FFFS could be considered reasonably practicable for facilitate effective emergency services intervention and additional protection of adjoining properties and third parties.

The report concludes and recommends the following engineering controls are identified and incorporated into the design of the landbridge, to reduce the risks to SFAIRP

- The landbridge is to be designed to provide 2 hours fire resistance against the modified hydrocarbon fire curve (HCinc). The modified hydrocarbon curve addresses the impact of a sharp heat rise on the structure and is reasonably practicable especially for the sections of the landbridge without additional water fire safety protection.
- Based on industry guidelines and engineering practice at some of the surrounding underpasses, it is reasonably practicable that at a minimum a fixed water-based firefighting system is installed above the Western Distributor. For a FFFS to be designed the following are considered reasonably practical criteria and limitations within the detailed design to optimise the performance of the system;
  - Natural Ventilation
  - Geometry of the area under the landbridge
  - Nozzle installation height and location
  - Expected fire load
  - The time for operation
  - Environmental and drainage conditions
  - Water supply and constraints on available storage design
  - Water application rate
  - Other performance criteria (e.g. structural protection and tenability)

  Any additional fixed fire safety mist, spray or deluge systems can then be evaluated in the context of the design performance and practicality of operating, installing and maintaining such a system above the Western Distributor.
- Design to include Wayfinding e.g. emergency signage for personnel located underneath the landbridge to know the direction to evacuate during an emergency.
- Design to allow for communication equipment to facilitate effective emergency services intervention including public address systems and CCTVs for early response time
- The Western Distributor drainage system needs to be better understood to qualify the environmental risk of a DGV event with fire water.

The following administrative controls have been identified which are outside the scope of the design of the landbridge, but should be considered before DGV operations are permitted with the landbridge in place

- TfNSW operational controls
  - Mitigations to restrict the movement of DG through route selection, type of DG or time on the Western Distributor
  - Mitigation to reduce speeds along the Western Distributor
  - Mitigation to prohibit changing of lanes by HGVs along the Western Distributor

- Mitigation for an Operator to monitor the movement of DGs through enhanced surveillance

- DGV Operators operational controls
  - Driver training - It is noted that EPA have previously advised that current training requirements for DGV drivers could be improved. It is therefore recommended DGV Operators ensure sufficient DGV driver training is in place to respond to a DGV event.
- First responders and emergency services operational controls
  - Incident responders to be trained regarding risks from DGVs and how to approach an event under or near the landbridge.
  - The access strategy and incident response for emergency services, is recommended to be workshopped with the relevant emergency services as part of the safe design of the facility.
  - The return to service requirements are to be determined by TfNSW, which may include emergency services identifying that the site is free of a DGV risk.

As the design develops, during the schematic design stage, the fire safety strategy and fire safety measures should be developed and documented. The purpose is to document the identified typical fire scenarios and frequencies of such events, design parameters, practicalities of mitigations and acceptance criteria to gain agreement, in principle, from the key stakeholders of the benefit or effectiveness of the strategy and safety measures.

Appendix A: Referenced documents

As mutually agreed with TfNSW, we will be utilising the following standards, guidelines and principles for the assessment throughout the report:

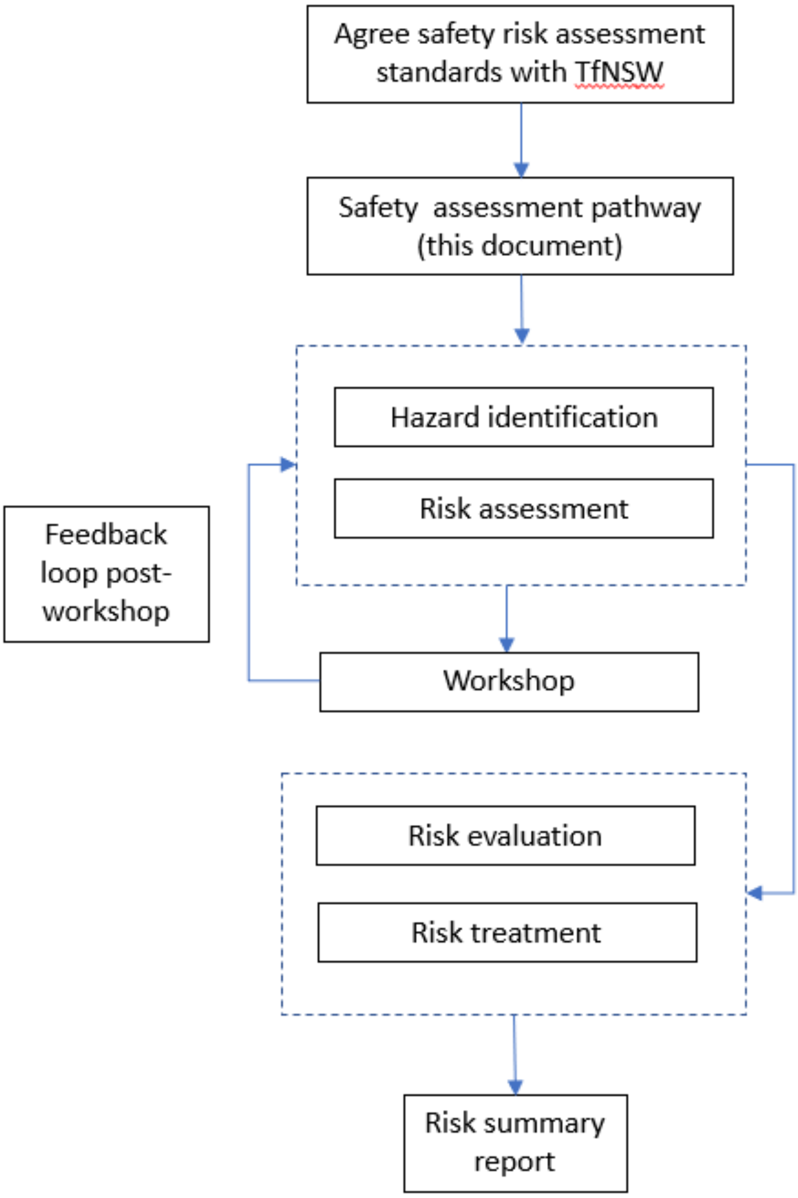
1. ASA Standard T MU MD 20001 ST *System Safety Standard for New or Altered Assets*
2. ASA Standard T MU MD 20002 ST *Risk Criteria for use by Organisations Providing Engineering Services.*
3. ASA Standard T MU MD 20003 GU *Quantified Safety Risk Assessment*
4. AS/NZS ISO 31000:2018 *Risk Management – Principles and guidelines*
5. Austroads Research Report AP-R590-19, *Dangerous Goods in Tunnels, Application and Methodology*
6. PIARC *(Risk Analysis for Road Tunnels & Current Practice for Risk Evaluation for Road Tunnels)*
7. NSW HIPAP 4 *Risk Criteria for Land Use Planning*, 2011
8. AS 4825-2011 *Tunnel fire safety*
9. National Transport Commission, *Australian Code for the Transport of Dangerous Goods by Road & Rail (ADG Code),* Edition 7.7, 2020
10. NSW HIPAP 11, Route Selection, 2011, Fire, explosion and toxic release Hazard Identification Table
11. Intermodal Logistics centre at Enfield EIA Appendix K Preliminary Hazard Analysis, 2005
12. Dangerous Goods Movement Study by Transport Certification Australia along the route
13. OECD Safety in Tunnels - Transport of dangerous goods through road tunnels, 2001.
14. PIARC (World Road Association) (2012). Risk evaluation, current practice for risk evaluation in road tunnels
15. NSW Government SafeWork. (n.d.). *Packing and transporting clinical waste*. Retrieved from https://www.safework.nsw.gov.au/resource-library/health-care-and-social-assistance/packing-and-transporting-clinical-waste
16. Ntzeremes, P., & Kirytopoulos, K. (2019). Evaluating the role of risk assessment for road tunnel fire safety: A comparative review within the EU. *Journal of traffic and transportation engineering (English edition)*, *6*(3), 282-296.
17. ScottLister, Dangerous Goods Transport QRA, Denison Street, Hillsdale, Issue 3, 2015
18. DNV chemical transport safety and risk analysis software; **https://www.dnv.com/services/chemical-transportation-safety-and-risk-analysis-software-safeti-chemical-transport-risk-analysis-74743**
19. **https://www.gexcon.com/au/blog/modelling-dense-gas-dispersion-in-urban-environments/** with images taken from Gavelli, Filippo, et al. "CFD Simulation of Gas Dispersion From Large-Scale

Toxic Chemical Releases In Complex Environments." Mary Kay O'Connor Process Safety Center, 2011 International Symposium. 2011

20. https://www.hse.gov.uk/managing/theory/alarpcheck.htm
21. National Fire Protection Association NFPA Code 502-46 Road Tunnels, Bridges and other Limited Access Highways 2020
22. Australian Government, Bureau of Meteorology. Climate Statistics for Australian locations – Sydney, Observatory Hill [Online] [Cited: 27 04 2021.] http://www.bom.gov.au/climate/averages/tables/cw_066062.shtml
23. Q-RAM: Transport of Dangerous Goods through road tunnels: Quantitative Risk Assessment Model (v. 4.04) User's Guide https://www.piarc.org/ressources/documents/logiciel_eqr/bac8f24-35924-2019-01-15-QRAM-User-Guide-CETU-PIARC.pdf

Appendix B: Flowchart Steps

A flowchart of the steps to complete the Safety Assessment Pathway



Appendix C: Workshop Attendees

Name	Organisation
Allegra Bauchinger	Thelem
Amanda Tarbotton	TfNSW
Bryce Picot	NSW Ambulance
Carlo Laba	TSA
Carolina Buil	Aurecon
Colin Odbert	Architectus
Dan Solomon	Architectus
David Chircop	TfNSW
David Moore	Aurecon
Delene Kock	Aurecon
Greg Mannes	GPT
Jarrod Grimshaw	Enstruct
John Hawes	FRNSW
Jonathan Donnelly	TfNSW
Justin Woodcock	Thelem
Matt Arkell	EPA
Matt Lilley	Enstruct
Nial O'Brien	Aurecon
Nigel Casey	TfNSW
Peter Scott	NSW Police
Prakash Sabapathy	Aurecon
Sri Srikantharajah	TfNSW
Tim Boulton	Enstruct
Vic Naidu	TfNSW
Yves Goarin	Thelem

Appendix D: SEPP 33 DG Transport screening

Movement quantities may vary greatly even between bulk and packages consignments. Applying SEPP33 [Ref X] provides transport screening thresholds for each class of dangerous good. It notes that if quantities are below the screening threshold quantity limit then the potential risk is unlikely to be significant unless the number of traffic movements is high. These screening thresholds are listed in Table 5. Class 1, 6.2 and 7 are not listed as these materials pose specific risk and require regulated controls. Class 2.2 is generally not considered hazardous during transport.

Table 4 – SEPP 33 DG Transport Screening

Class DG	Minimum quantity per bulk load [tonne]	Minimum quantity per package load [tonne]
2.1	2	5
2.3	1	2
3PGI	1	1
3PGII	3	10
3PGIII	10	No limit
4.1	1	2
4.2	2	5
4.3	5	10
5	2	5
6.1	1	3
8	2	5
9	No limit	No limit

Appendix E: Extracts from QSRA: Port Botany and Intermodal Study

(http://nswports.clickcreative.net.au/assets/Uploads/AppK.pdf) available January 2021

II.4. SELECTION OF REPRESENTATIVE MATERIALS

Table II.4.1 summarise the representative materials used in the modelling of accident scenarios.

Table II.4.1 Representative Materials per Dangerous Goods Class

Dangerous Goods Class	Description	Representative Material	Unit Size
1	Explosives	TNT	3 tonnes, 13 tonnes and 23 tonnes
2.1	Flammable Gases	Propane Butylene Dimethyl ether	100 kg and 500 kg propane, 12.5 te butylene, 23 te dimethyl ether
2.2	Non-flammable Gases	Screened out	
2.3	Toxic Gases	Chlorine, Hydrogen sulphide Carbon monoxide Ethylene oxide Methyl Bromide Sulphur dioxide Ammonia Hydrogen fluoride	70 kg chlorine 33 kg hydrogen sulphide 10 kg carbon monoxide 23 kg and 750 kg ethylene oxide 100 kg methyl bromide 61 kg sulphur dioxide 10 kg, 34 kg, 100 kg and 500 kg ammonia. 50 kg hydrogen fluoride
3	Flammable Liquids	Acrylonitrile Octane	200 kg and 20 te acrylonitrile 200 kg and 20 te octane
4	Flammable Solids, Spontaneously Combustible, Dangerous When Wet	As per Class 3	200 kg and 20 te acrylonitrile 200 kg and 20 te octane
5.1	Oxidising Materials	TNT	2 te TNT
5.2	Organic Peroxides	TNT	2 te TNT
6.1	Toxic Materials	See Smoke Analysis	
7	Radioactive Materials	Screened out – see II.3.9	
8	Corrosive Materials	Screened out – see II.3.10	
9	Miscellaneous Materials	Screened out – see II.3.11	

The number of movements of the various dangerous goods through Port Botany in 2004 have been aggregated to produce the following list of movements of the various surrogate materials.

Table 5.3 Dangerous Goods Trade Estimate for the Intermodal Terminal*

Dangerous Goods Class	Description	Representative Material	Modelled Unit size (te)	Annual No. of Container Movements Port Botany 2004	Intermodal 2007	Intermodal 2017
5.1	Ammonium Nitrate	TNT	2	3027	225	675
1	Explosives	TNT	3	200	15	45
1	Explosives	TNT	13	56	4	12
1	Explosives	TNT	22	13	1	3
2.1	Flam. Gases	propane	0.1	2338	174	521
2.1	Flam. Gases	propane	0.5	82	6	18
2.1	Flam. Gases	butylene	12.5	2	0	0
2.1	Flam. Gases	dimethyl ether	23	12	1	3
2.3	Toxic Gases	chlorine	0.07	11	1	2
2.3	Toxic Gases	hydrogen sulphide	0.033	7	1	2
2.3	Toxic Gases	carbon monoxide	0.01	19	1	4
2.3	Toxic Gases	ammonia	0.01	39	3	9
2.3	Toxic Gases	ethylene oxide	0.023	26	2	6
2.3	Toxic Gases	ammonia	0.034	4	0	1
2.3	Toxic Gases	sulphur dioxide	0.061	16	1	4
2.3	Toxic Gases	methyl bromide	0.1	13	1	3
2.3	Toxic Gases	ammonia	0.1	60	4	13
2.3	Toxic Gases	ammonia	0.5	13	1	3
2.3	Toxic Gases	ethylene oxide	0.75	5	0	1
8	Corrosive with Toxic Gases	hydrogen fluoride	0.05	21	2	5
3	Flam. Liquids	acrylonitrile	0.2	401	30	89
3	Flam. Liquids	acrylonitrile	20	14	1	3
3	Flam. Liquids	octane	0.2	17770	1321	3963
3	Flam. Liquids	octane	20	1028	76	229
ALL	TOTAL			25177	1871	5614

* Refer to Appendix II

Table III.6.2 Modelling for Road Transport on Wentworth St

DG Class	Description	Representative Material	Quantity	Moves p.a.	Leak Frequency per vehicle km			Total Leak Frequency (per road km p.a.)[3]		
					25 mm	100 mm	Rupture/ Explosion	25 mm	100 mm	Rupture/ Explosion
1	Explosives	TNT (for AN)	2 tonnes				7.8E-12			5.3E-09
		TNT	3 tonnes				5.4E-9			2.4E-07
		TNT	13 tonnes				5.4E-9			6.5E-08
		TNT	23 tonnes				5.4E-9			1.6E-08
2.1	Flammable Gases	propane	100 kg		5.4E-9	-	5.4E-10	2.8E-06	-	2.8E-07
		propane	500 kg		5.4E-9	-	5.4E-10	9.7E-08	-	9.7E-09
		butylene	12.5 te		1.2E-6	8.6E-7	6.5E-7	4.8E-07	3.4E-07	2.6E-07
		dimethyl ether	23 te		1.2E-6	8.6E-7	6.5E-7	3.6E-06	2.6E-06	2.0E-06
2.3	Toxic Gases	chlorine	70 kg		5.4E-9	-	5.4E-10	1.1E-08	-	1.1E-09
		hydrogen sulphide	33 kg		5.4E-9	-	5.4E-10	1.1E-08	-	1.1E-09
		carbon monoxide	10 kg		5.4E-9	-	5.4E-10	2.2E-08	-	2.2E-09
		ammonia	10 kg		5.4E-9	-	5.4E-10	4.9E-08	-	4.9E-09
		ethylene oxide	23 kg		5.4E-9	-	5.4E-10	3.2E-08	-	3.2E-09
		ammonia	34 kg		5.4E-9	-	5.4E-10	5.4E-09	-	5.4E-10
		sulphur dioxide	61 kg		5.4E-9	-	5.4E-10	2.2E-08	-	2.2E-09
		methyl bromide	100 kg		5.4E-9	-	5.4E-10	1.6E-08	-	1.6E-09
		ammonia	100 kg		5.4E-9	-	5.4E-10	7.0E-08	-	7.0E-09
		ammonia	500 kg		5.4E-9	-	5.4E-10	1.6E-08	-	1.6E-09
		ethylene oxide	750 kg		5.4E-9	-	5.4E-10	5.4E-09	-	5.4E-10
		hydrogen fluoride	50 kg		5.4E-9	-	5.4E-10	2.7E-08	-	2.7E-09
3	Flammable Liquids	acrylonitrile	200 kg		5.4E-9	-	5.4E-10	4.8E-07	-	4.8E-08
		acrylonitrile	20 te		1.2E-6	8.6E-7	6.5E-7	3.6E-06	2.6E-06	2.0E-06
		octane	200 kg		5.4E-9	-	5.4E-10	2.1E-05	-	2.1E-06
		octane	20 te		1.2E-6	8.6E-7	6.5E-7	2.7E-04	2.0E-04	1.5E-04

[3] The Total Leak Frequency (per road km p.a.) is calculated by the multiplication of the Moves p.a. with the leak frequency per vehicle kilometre

Table 5.6 Class 6.1 Toxic Material Fire Modelling

Material	Common Package	Annual Movements at Capacity	Likelihood of Fire Involving Part of the Container	Likelihood of Fire Involving All of the Container
Carbamate Pesticides	IBC	22	3.42E-06	3.80E-07
Acrylamide	bags	25	3.87E-06	4.30E-07
Organophosphorous Pesticides	drums	19	2.88E-06	3.20E-07
Toluene Diisocyanate	drums & tanks	73	1.08E-05	1.20E-06
Total		139	2.16E-05	2.40E-06

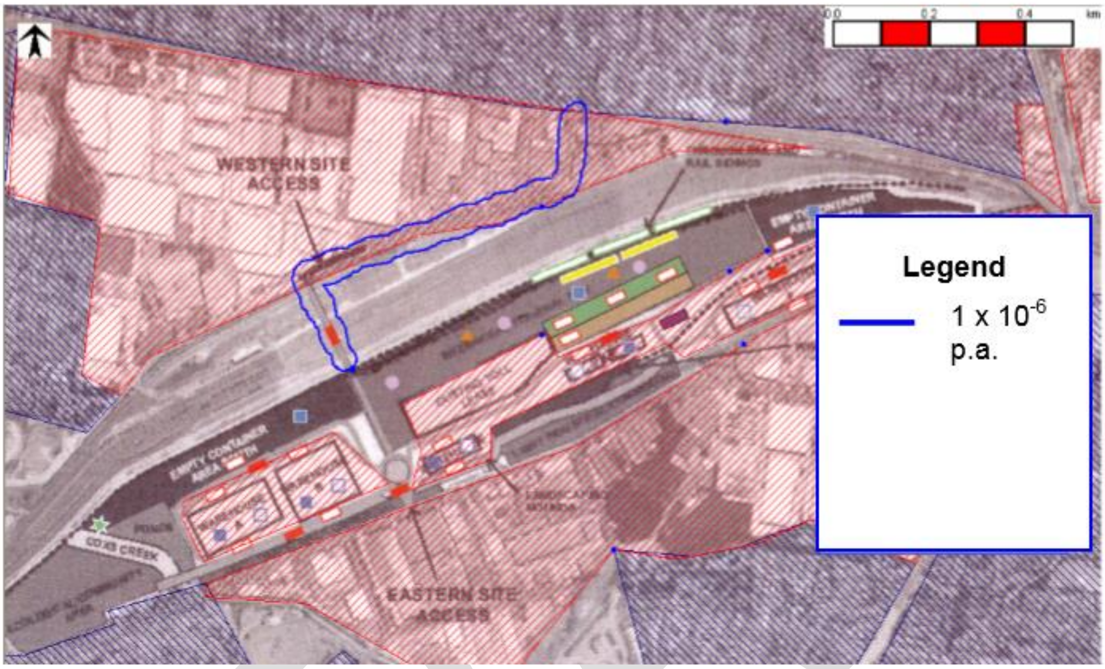
In the process of undertaking the quantitative risk assessment of the intermodal terminal a number of key modelling assumptions have been identified, which affect the risk results. These assumptions are listed below.

1. The study focus is on release events capable of producing an off-site fatality risk; not all events that pose only an on-site fatality risk were analysed.
2. The manifest provided by Sydney Ports Corporation for Port Botany for 2004 was analysed by QEST. This dangerous goods trade profile has been used as the basis for the PHA.
3. As an exception to Assumption 2, all tank containers or isotainers of Class 2.3 and hydrogen fluoride were excluded from the analysis because they will not be permitted to pass through the intermodal terminal.
4. The package sizes for each of the dangerous goods classes was estimated based on the dangerous goods transported during 2004.
5. Class 1 – Explosives have been modelled in three package sizes: 3 tonnes, 13 tonnes and 23 tonnes. In the event of an incident involving Class 1 goods the entire inventory has been assumed to be involved in a single explosion.
6. Class 1 – Explosives. In the event of a dropped container, 1 in a thousand incidents have been assumed to result in a detonation.
7. Class 2.1 – Flammable Gases have been modelled in four package sizes: 23 tonne isotainers of dimethyl ether, 12.5 tonne isotainers of butylene, 500 kg of propane and 100 kg of propane.
8. Class 2.2 – Non-flammable Gases have been screened out of the analysis on the bases that they will have no off-site consequences.
9. Class 2.3 – Toxic Gases have been modelled in numerous package sizes based on the actual sizes of goods transported through Port Botany in 2004. All movements of isotainers of toxic gases has been excluded from the analysis as they will be prohibited from transport through the intermodal terminal.
10. All class 2.3 materials not modelled specifically and included as "Other" have been modelled as ammonia.
11. Class 5.1 – Oxidising Materials. Explosions of ammonia nitrate (AN) have been identified as a hazard associated with the transportation of ammonium nitrate. An explosion of two tonnes of ammonium nitrate has been assumed to be the largest credible accidental explosion scenario.
12. Explosions are modelled with two fatal effect-zones:

9.5. Road Transportation Risk Assessment

The risk of fatality associated with road transport was modelled as is shown in Figure 9.6. This shows that the fatality risk caused by trucks carrying dangerous goods to people located in areas adjoining the road is low. The risk level does not exceed 5×10^{-6} p.a. at any location and is generally less than 1×10^{-6} p.a. for distances further than 30 m from the centre of the roadway. The width of the corridor around the road is approximately 60 m.

Figure 9.6 Individual Fatality Risk Associated with Road Transport

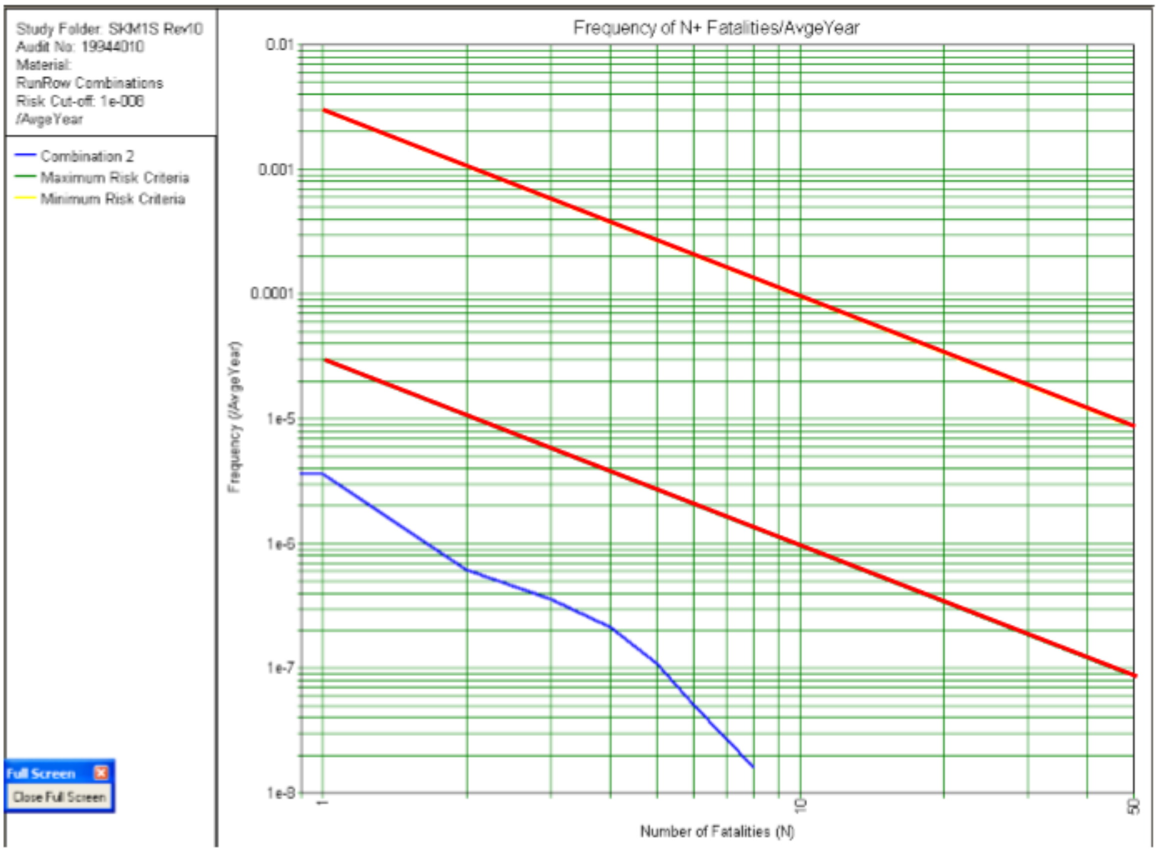


10.5. Transportation Risk

The risks from rail transportation was assessed to be adequately low based on the very low likelihood of loss of containment incidents involving containers on rail cars.

The risk from trucks carrying containers of dangerous goods on the access road to/from the site was considered. The analysis calculated the risk level to be significantly below the average road fatality rate in NSW and generally below the acceptable limit for risk exposures to the public in residential areas from fixed installations. Currently there are no quantitative risk criteria for the assessment of the risk to the public from transportation activities in New South Wales. Based on the relatively low risk levels, the risk to the public from the road transportation of dangerous goods should be considered acceptable.

Figure 9.4 Proposed Intermodal Terminal Societal Risk Curve



III.4. ROAD TRANSPORT FREQUENCY DATA

III.4.1. Introduction

This section presents data drawn from NSW and overseas sources on the likelihood of dangerous goods incidents initiated by road accidents.

III.4.2. Vehicle Accident Rate Data

Data obtained from the various sources are discussed in this section.

III.4.2.1. Truck Accident Rates in NSW

The City South Freight Strategy published by Department of Urban Affairs & Planning (DUAP) in 1998, quotes truck accident rate targets of a maximum of 80 crashes per 100 million vehicle kilometres. This is equivalent to 8×10^{-7} crashes per vehicle km. This estimate is compared below with experience in the UK.

The M5 East Motorway Environmental Impact Statement (EIS) conservatively estimated the truck accident rate to be 5.4×10^{-6} per vehicle km. This is a factor of 7 greater than the target published by DUAP. The difference is considered to be due to the conservatism applied in the EIS because of the uncertainty of the estimates.

The M5 East Motorway EIS also considered the potential for leaks from a tanker following an accident. It reported that 95% of accidents would not result in a leak, 4.5% of accidents would result in a pinhole leak, 0.35% would result in a 50 mm hole and 0.15% would result in a complete rupture of the container.

The conservative accident rate for trucks in NSW developed as part of the M5 East Motorway EIS (5.4×10^{-6} per truck km) is considered an appropriate estimate of the total accident rate for trucks carrying dangerous goods travelling to and from the intermodal terminal at Enfield.

Following an accident, the likelihood of a release of material from a drum or cylinder within the shipping container is discussed in the M5 East Motorway EIS and is estimated to be 10%. This likelihood of release is broken down into minor leaks, 10mm hole leaks and 25mm hole leaks. The probability of a minor leak from a cylinder was considered to be 9%, the probability of a 10 mm leak was considered to be 0.9% and the probability of a 25 mm leak was considered to be 0.1%. Using the truck accident rate in the EIS, the leak rate from a truck is estimated to be 5.4×10^{-7} per vehicle km (5.4×10^{-6} per vehicle km x 10% = 5.4×10^{-7} per vehicle km.)

III.1.1.1. UK Heavy Vehicle Accident Rates

Table III.4.1 presents traffic accident data for the UK, for which an analysis was published (Department of Environment, Transport and Regions 1998). The table gives the involvement rates for different classes of vehicles and severity of road traffic accident.

Table III.4.1 Road Traffic Accident Frequency, 1997 (per 100 million vehicle km)

VEHICLE TYPE	ALL CASUALTY ACCIDENTS	SERIOUS/FATAL ACCIDENTS	FATAL ACCIDENTS
Cars	92	13	1.1
Buses/coaches	230	31	2.6
Light goods vehicles	50	7.8	0.8
Heavy goods vehicles	45	10	1.8
All motor vehicles	92	14	1.3

This table shows that the likelihood of all casualty accidents involving heavy goods vehicles is 4.5×10^{-7} per vehicle km in the UK.

III.1.1.2. The Netherlands Vehicle Accident Rates

The TNO Purple book provides guidance on the frequency of vehicle accidents involving leaks of material from vehicles carrying dangerous goods inside a built up area is 3.5×10^{-9} per vehicle km for cylinders and 1.2×10^{-8} per vehicle km for drums.

III.1.1.3. Bulk Compressed or Liquefied Gases Tanker Accidents

The UK HSC (1991)[1] published rates of puncture/rupture of bulk gas tankers: 4.8×10^{-10} per tanker km. for LPG/ammonia tankers and 8×10^{-11} per tanker km for chlorine tankers. The lower rates for bulk compressed or liquefied gas tankers take account of the lower probability of accidents involving these vehicles due to more stringent scrutiny of the drivers by the authorities and the transporters. The lower rates also take account of the protection of the tanker to resist leakage even when involved in an accident.

DNV Technica (c1996) compared various sources of leak frequency data for LPG road tankers, and developed a fault tree model to take account of the main influences. Table III.4.2 gives the failure case frequencies for a road tanker with passive fire protection.

Table III.4.2 LPG Road Tanker Leak Frequencies

FAILURE CASE	LEAK FREQUENCY (per loaded vehicle km)
BLEVE	2.7×10^{-12}
Cold rupture	2.6×10^{-9}
Large liquid leak	1.8×10^{-8}
Large vapour leak	2.1×10^{-9}
Brief liquid leak	6.8×10^{-9}
TOTAL	3.0×10^{-8}

This table shows a much higher estimate of the leakage rate compared to that estimated by the UK HSC – a factor of 60 higher.

[1] Quoted in M5 East Motorway EIS, 1995.

III.4.3. Explosion of Class 1 Materials Due to Road Accident

If a vehicle transporting Class 1 material is involved in an accident, there is a potential for it to be detonated.

Using the same reasoning as applied in Section III.2.1, if a shipping container with Class 1 material is involved in a road accident, it is assumed that there is a 0.001 chance of it detonating the explosives.

Combining the likelihood of a container being involved in a road accident (5.4×10^{-6} per truck km) and the likelihood of it exploding, the likelihood of a container carrying explosives detonating during road transport to the intermodal terminal was estimated at 5.4×10^{-9} per truck km.

The likelihood of an explosion associated with a vehicle transporting ammonium nitrate is extremely low. The same fault tree given in Figure III.3.1 is used with the term for a drop of a container of ammonium nitrate is replace by the term for a road accident of a vehicle carrying a container of ammonium nitrate. The explosion likelihood is 7.8×10^{-12} per vehicle km. This likelihood is sufficiently low to exclude it from any further risk analysis.

III.4.4. Loss of Containment from Isotainers

For trucks travelling to and from the intermodal terminal at Enfield, bulk liquid tankers will not be used. Isotainers (tank containers) will be used where bulk liquids are to be transported. These will be loaded onto trucks appropriate for carrying isotainers of dangerous goods.

Even in the event of a vehicle accident, there may not be a release of dangerous goods. The likelihood of a release of dangerous goods from a road tanker is considered appropriate to apply to a truck carrying an isotainer of dangerous goods.

The following frequencies are applied to truck movements of isotainers:

Table III.4.3 Truck Movements of Isotainers Leak Frequencies

FAILURE CASE[2]	LEAK FREQUENCY (per loaded vehicle km)
25 mm leak	1.2×10^{-6}
100 mm leak	8.6×10^{-7}
Rupture	6.5×10^{-7}

III.4.5. Loss of Containment from Containers of Drums or Cylinders

The M5 East Motorway EIS estimate of leak likelihood is significantly greater than the generic value given in the TNO Purple Book of 1.2×10^{-8} per vehicle km for drums and 3.5×10^{-9} per vehicle km for cylinders. These discrepancies are significant – a factor of 45 lower for drums and a factor of 150 for cylinders.

The reasons for the significant differences may be:

- higher accident rates in NSW compared to The Netherlands,
- high conservatism applied to the estimate of accident rate in the M5 East Motorway EIS,

[2] This has been revised slightly to provide data for 25 mm holes and 100 mm holes rather than only 50 mm holes.

- high conservatism applied to the estimate of the likelihood of leakage from a package following an accident, but is most likely due to
- the definition of significant leak used in the TNO data is a leak of >100 kg.

In addition, the above release rates take no account of the protection provided by the shipping container. In this study, the protection provided by a shipping container has been assumed to reduce the leak frequency of drums and cylinders travelling within a container by a factor of 10.

In this assessment the following leak likelihoods have been applied to truck movements of cylinders and drums in containers based on the conservative leak rates assumed in the M5 East Motorway EIS.

Table III.4.4 Leak Frequencies of Cylinders and Drums Carried in Containers in Trucks

FAILURE CASE	Cylinder or Drum Leak Frequency (per loaded vehicle km)	
Vehicle Accident Rate	5.4×10^{-6} per vehicle km	
Protection provided by shipping container	90%	5.4×10^{-7} per vehicle km
Negligible leaks	98.9%	5.35×10^{-7} per vehicle km
25 mm leak	1%	5.4×10^{-9} per vehicle km
Rupture	0.1%	5.4×10^{-10} per vehicle km

Appendix F: Extracts from QSRA: Denison Street DG transport

https://portbotany.files.wordpress.com/2015/06/denison-st-dg-transport-report-v03-sm20150210.pdf

Executive Summary

An application for development of a Bunnings Warehouse on Denison St, Hillsdale, is currently being considered by the Joint Regional Planning Panel (JRPP). To assist in the evaluation of the proposal, Scott Lister has undertaken, on behalf of the Department of Planning and Environment (DPE) and City of Botany Bay Council (CBBC), a Quantitative Risk Assessment (QRA) of the movement of Dangerous Goods (DG) along Denison St.

The purpose is to understand the level of risk associated with DG transport on Denison Street to inform determinations on the proposed Bunnings Warehouse as well as other potential future developments around the Botany Industrial Park (BIP). This responds to any potential concern that the number of people attracted to the area by the new store could result in unacceptable levels of risk due to the volume of DG traffic.

The study analysed DG movements along Denison St and cross referenced this with plant throughput data from the BIP. DG movements were then combined with vehicle crash rates to determine the likelihood of hazardous incident scenarios (fires, explosions, toxic gas releases). Using risk modelling software (Phast™ and Safeti™), the consequences of these scenarios were modelled and combined with likelihood data to generate detailed risk profiles for the area.

The results of the study show that the risks satisfy the adopted risk criteria for the study, which are based on those enunciated in the Department's Hazardous Industry Planning Advisory Paper No. 4, *Risk Criteria for Land Use Safety Planning* (HIPAP 4)). As such, it is concluded that risks associated with DG transport on Denison St should not present a barrier to the Bunnings development proceeding.

Table 1 Bulk BIP Dangerous Goods Movements

Material	DG class	Hazardous Attributes
Polymer Grade Propylene (PGP)	2.1	Flammable gas, denser than air.
Liquid Petroleum Gas (LPG)	2.1	Hydrocarbon fluid composed predominantly of any of the following hydrocarbons or mixtures of any or all of them: propane (C3H8), propylene (C3H6), butane (C4H10) or butylenes (C4H8). Flammable gas, denser than air.
Ethylene Oxide	2.3, 2.1	Toxic gas with a perceptible (ether-like) odour. Flammable. Gas denser than air.
Propylene Oxide	3	Colourless with an ethereal odour. Miscible with water. Flammable liquid. Vapour denser than air.
Iso hexane	3	Flammable liquid. Vapour denser than air.
Hex-1-ene	3	Colourless liquid. Immiscible with water. Flammable liquid. Vapour denser than air.
Chlorine	2.3, 8	Non-flammable yellow-green gas, with a perceptible odour (pungent). Highly toxic. Corrosive in the presence of moisture. Much denser than air. Oxidizing agent which may cause fire with organic materials.
HCL	8	Colourless liquid. Aqueous solution of the gas hydrogen chloride. Highly corrosive to most metals. Vapour irritates mucous membranes.
Hypochlorite Solid	5.1	Solid with chlorine odour. Evolves very toxic and corrosive gases on contact with acid.
Hypochlorite Liquid	8	Liquid with chlorine odour. Evolves very toxic and corrosive gases on contact with acid. Mildly corrosive to most metals. Not to be transported in unlined metal drums.
Sodium Hydroxide (Caustic soda) Solid	8	White pellets, flakes, lumps or solid blocks. Deliquescent. In the presence of moisture corrosive to aluminium, zinc and tin. Reacts vigorously with acids. Reacts with ammonium

Table 8 2012 Scenario Inferred Dangerous Goods Traffic

Full			Empty		
Direction	**Class**	**Movements [pa]**	**Direction**	**Class**	**Movements [pa]**
Heading north of gate 3 full			**Heading north of gate 3 empty**		
	2	4453		**3**	180
Heading north full			**Heading south empty**		
	2	415		2	4954
	3	4406		3	6127
Heading north to gate 3 full			**Heading south to gate 3 empty**		
	3	388		2	4142
Heading south of gate 3 full			**Heading south of gate 3 empty**		
	2	200		3	382
Heading south to gate 3 full			**Heading north to gate 3 empty**		
	3	174		2	509

Table 4 Release Cases Modelled

Materials Modelled	Release Cases	Model Used
Class 3 Flammable liquids. **ULP, Hexane, Hexene, Propylene Oxide**	5-15 kg, 15-150kg, 150-1500 kg and >1500 kg	Instant release, with rainout. Pool Fire, Flash Fire, VCE.

Class 2.1 Flammable gases	BLEVE	Fireball Model
LPG,PGP Ethylene Oxide	Large 50mm bottom leak	Continuous release, with rainout. Fireball, Pool Fire, Jet Fire, Flash Fire, VCE Toxic impact of EO also modelled
	Large 50mm top leak	Continuous release, without rainout. Fireball, Jet fire, Flash Fire, VCE Toxic impact of EO also modelled
	Vessel Rupture	Instant release, with rainout. Fireball, Pool Fire, Jet Fire, Flash Fire, VCE Toxic impact of EO also modelled
Class 2.3 Toxic gases	50mm bottom leak	Impinging liquid jet, with rainout.
Chlorine	50mm top leak	Impinging gas jet, without rainout.
	Rupture	Instant release, with rainout.

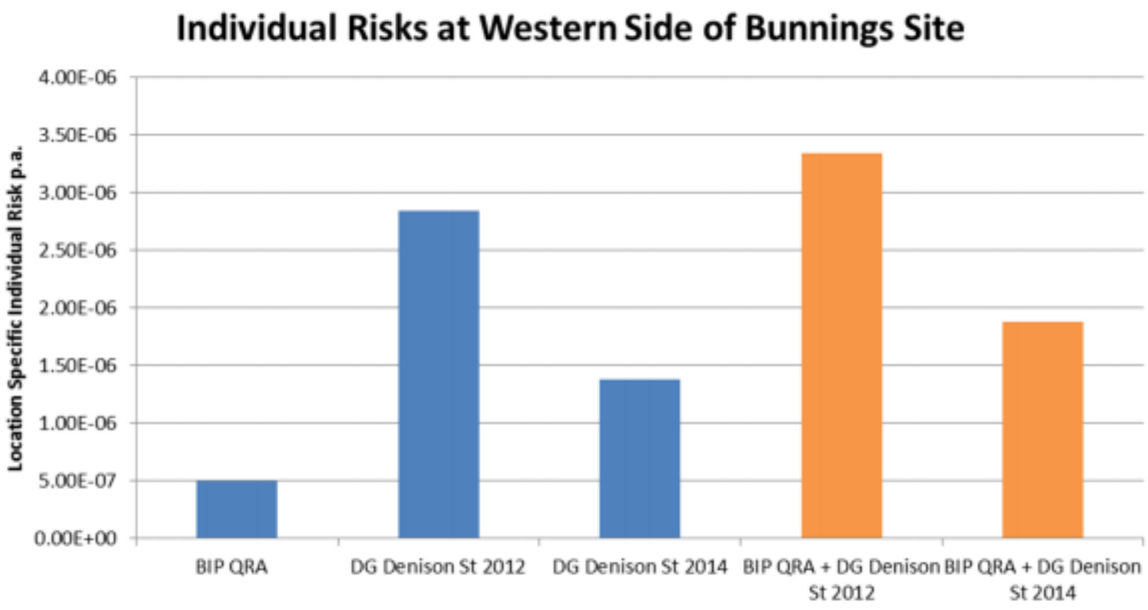


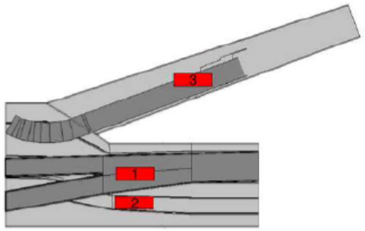
Figure 6 Individual risks at Western Side of Bunnings Site

Appendix G: Extracts from Fire and Life Safety, Air Quality and Lighting Co-ordination Review

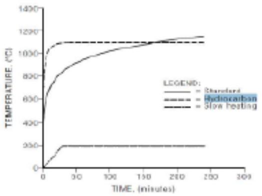
COCKLE BAY PARK SYDNEY

6.4 Fire Safety – Design Criteria (1 of 3)

NSW GOVERNMENT | Transport for NSW

Discipline and Design Item	Design Parameters	Acceptance Criteria	Reference
Fire Safety			
1. Fire Load for Tenability	• Heavy Goods Vehicle (HGV) • Peak heat release rate (HRR) 157MW • Peak value reached after 14 minutes at which point it remains constant • 82% wood pallets, 18% polyurethane plastic • • Soot yield 0.1g/g • Heat transfer: radiation 35%, convection 65% • Ambient temperature 20°C • Three fire locations to be assessed separately: ○ 1. Mid-length of the enclosure on the elevated Western Distributor viaduct ○ 2. Mid-length of the enclosure on the northbound Harbour St ○ 3. Mid length of the existing Darling Park underpass 	Computational Fluid Dynamics (CFD) assessment and egress modelling to demonstrate tenable conditions such that the Available Safe Egress Time (AEST) is greater than the Required Safe Egress Time (RSET) based on the below criteria: • Visibility greater than 10m (2m above the evacuation surface) • Temperature less than 60°C (2m above the evacuation surface) • Fractional effective dose of toxic gases, FED_{co} less than 0.3	• Based on findings from the large scale fire test in Runehamar Tunnel in 2003 by Technical Research Institute of Sweden (SP) • Buchanan, April 2001

6.4 Fire Safety –Design Criteria (2 of 3)

Discipline and Design Item	Design Parameters	Acceptance Criteria	Reference
Fire Safety			
2. Egress Conditions	• Cars approximately 4.9 – 5.2 m in length queuing at 6.7 m centres in all lanes • Average 1.5 people per car • One passenger bus with 50 passengers • Population distribution and travel speeds: 90% adults 1.2m/s, 5% children 0.5m/s, 5% disabled 0.5m/s • Combined cue time and pre-movement time is taken to be 1-4 minutes uniformly distributed over the occupants • Egress path via the existing roadways with safe places to be nominated in conjunction with the assessment • The conditions in non-incident areas such as within the existing Darling Park underpass during a fire incident on the elevated roadway within the new enclosure and vice versa are to be assessed • The ability of the road user to identify their location in the event of a fire incident is to be addressed in the assessment	Computational Fluid Dynamics (CFD) assessment and egress modelling to demonstrate tenable conditions such that the Available Safe Egress Time (AEST) is greater than the Required Safe Egress Time (RSET) based on the below criteria: • Visibility greater than 10m (2m above the evacuation surface) • Temperature less than 60°C (2m above the evacuation surface) • Fractional effective dose of toxic gases, FED_{co} less than 0.3	NFPA 502
3. Emergency Services Response	The access strategy and incident response for emergency services, and the return to service requirements after a fire event are to be workshopped with RMS and the relevant emergency services once they become involved in the design development	To be workshopped with RMS and emergency services	
4. Hydrocarbon Fire Load Event	Fire Resistance Level (FRL) 120/120/120 to the hydrocarbon curve 	Demonstrate that the land bridge structure can avoid collapse and explosive concrete spalling	AS 1530.4: 2014
5. Fire Detection		Under NFPA 502, fire detection is not a mandatory requirement for an enclosure less than 240m long with the exception of a means to stop approaching traffic from entering the underpass. The extent of fire detection is to be agreed between Fire and Rescue NSW (FRNSW), RMS and the Developer during the FER process.	NFPA 502: Table A.7.2
6. Fire Suppression	Provision for FRNSW firefighting connections and means of containment and collection of water required for FRNSW firefighting.	The fire engineering solution proposed above will be provided to demonstrate tenable conditions without the requirement for a fixed suppression system such as deluge. Under NFPA 502, a fixed suppression system is not a mandatory requirement for an enclosure less than 240m long. Demonstration of adequate facility for FRNSW firefighting of the above fire loads including provision of adequate water supply, hydrants etc..	NFPA 502: Table A.7.2

6.4 Fire Safety – Design Criteria (3 of 3)

Discipline and Design Item	Design Parameters	Acceptance Criteria	Reference
Fire Safety			
7. Smoke Ventilation	Flow of smoke within the enclosure.	CFD assessment to demonstrate that reliance on natural ventilation will allow tenable conditions to the criteria described in item 1.	Refer to item 1
8. Smoke Flow and Air Temperature Outside the Enclosure	Parameters as described in item 1 except that the fire event occurs at the ends of the enclosure.	CFD assessment to show the flow of smoke as it exits the portals and demonstrate that the air temperature and smoke content at adjacent infrastructure (including the 161 Sussex St underpass) is below limits appropriate to the façade materials and functionality of space during a fire event.	

Appendix H: Bowtie of Current Controls

Appendix I: Project Risk Register

Appendix J: Event Trees

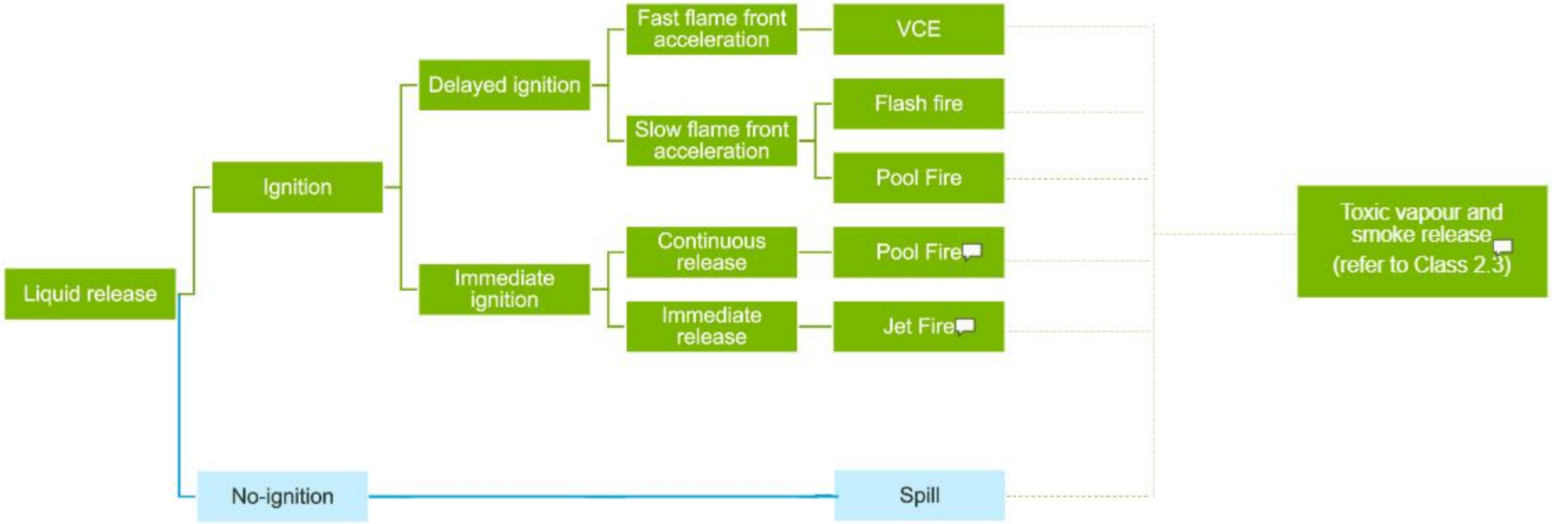
Class 3: Flammable Liquid

Methyl acrylates (acrylic nails, household paints), turpentine, Styrene (fibreglass gelcoat), Xylene (glues and thinners)

Class 6.1/ 3: Flammable Toxic Liquid

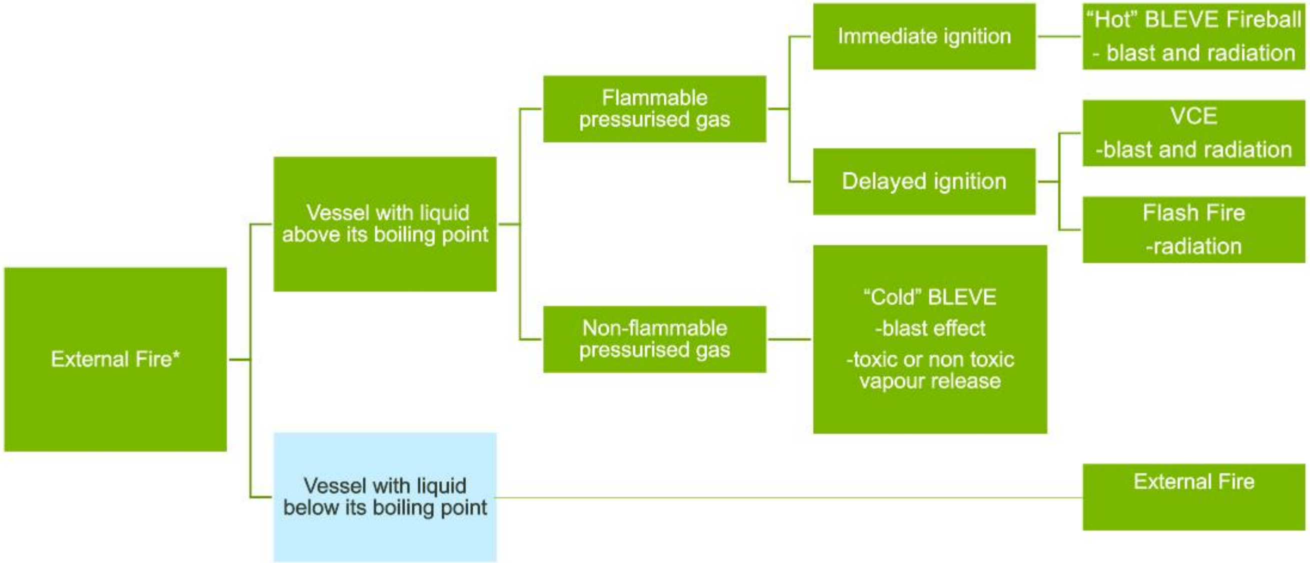
Acrylonitrile, Acrolein

Bringing ideas to life



Pressurised vessel:

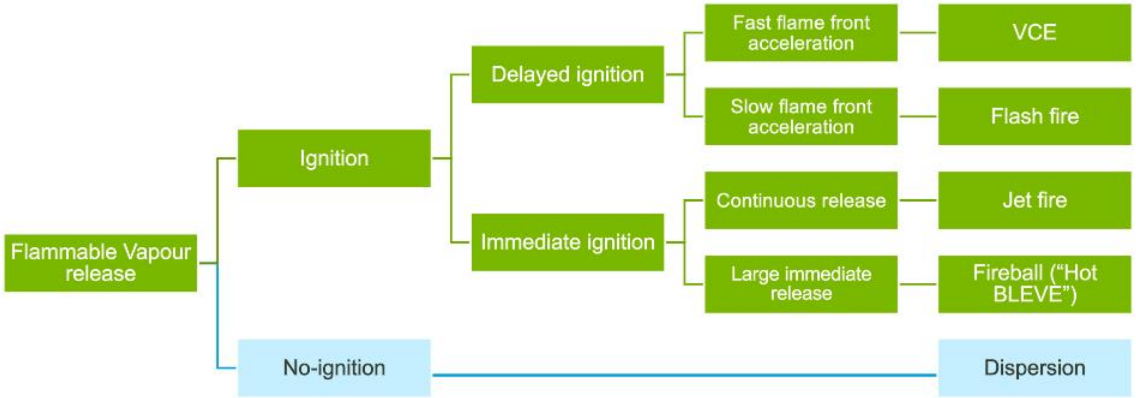
All liquified gases: LPG, Nitrogen, Oxygen, Carbon dioxide



*The most common type of BLEVE is caused when the external wall of the tank is exposed to a fire

Class 2.1: Flammable Gas

LPG, Hydrogen, butylene, dimethyl ether, (ammonia)



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Class 2.3: Toxic Gas

Chlorine, ammonia (bulk), sulphur dioxide, (most likely)
carbon monoxide, ethylene oxide, methyl bromide (fumigant), hydrogen sulphide, hydrogen fluoride (cylinders)

Class 2.2: Non-flammable, non-toxic gases

Refrigerants, nitrogen, carbon dioxide

Bringing ideas to life

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Class 5.1: Oxidising substances

Hydrogen Peroxide

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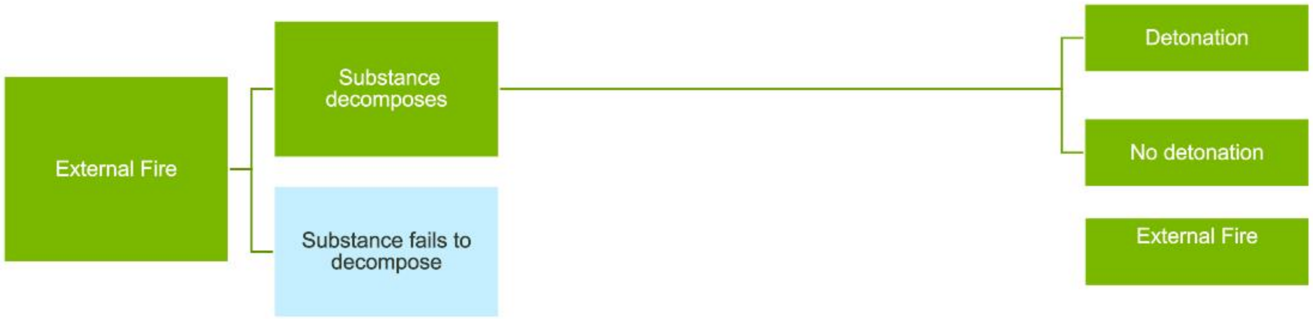

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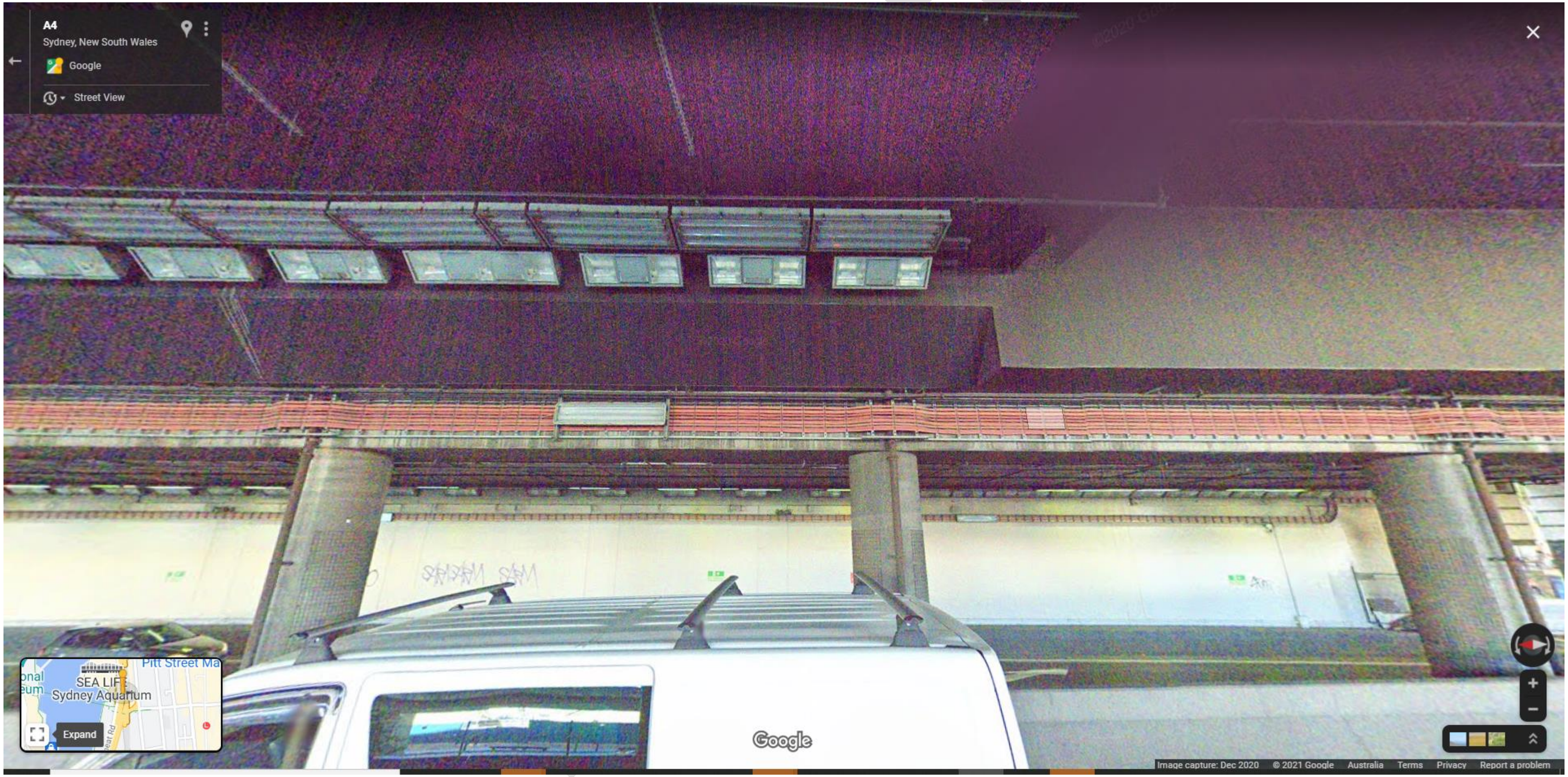
Appendix K: Google Images for Reference

Western Distributor beneath 161 Sussex Street




A4
Millers Point, New South Wales
Google
Street View
Pyrmont Bridge
Heritage swing bridge with city views
Darling
Google
Image capture: Dec 2020
© 2021 Google
Australia
Terms
Privacy
Report a problem

Western Distributor (100m South of the landbridge location)


A4
Sydney, New South Wales
Google
Street View
SEA LIFE
Sydney Aquarium
Expand
A4
Google
Image capture: Dec 2020
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Privacy
Report a problem

South Bound A4 under market street viaduct

South Bound A4 between Market Street viaduct and Darling Park underpass

South Bound A4 Darling Park underpass

Harbour Street


Sydney, New South Wales
Google
Street View
Rabobank
Invictu
Officia
Sydney T
Google
Image capture: Nov 2020
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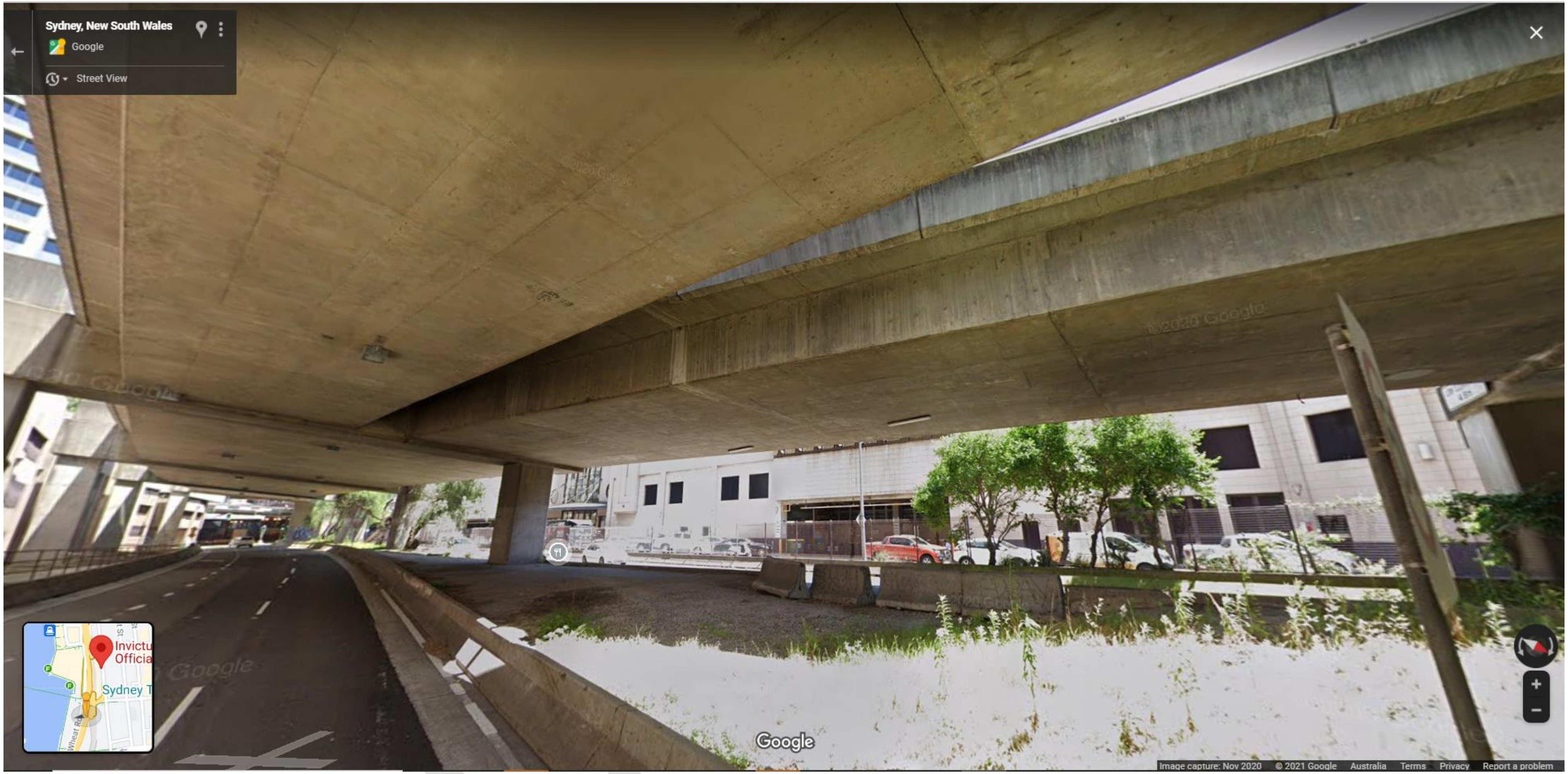
Report a problem



Sydney, New South Wales
Google
Street View
Google
Image capture: Nov 2020
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Report a problem

Appendix D

Reflectivity Assessment Report

Prepared for: DPT Operator Pty Ltd and DPPT Operator Pty Ltd, c/o Darling Park Management JLL, 201 Sussex Street, Sydney NSW 2000

Cockle Bay Park Redevelopment

State Significant Development, Development Application (SSD DA) Appendix Z - Reflectivity Report

Revision A | 24 September 2021

This report takes into account the particular instructions and requirements of our client.

It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party.

Job number 238566-10

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Reference Information

1 Introduction

This report has been prepared to accompany a detailed State Significant Development (SSD) Development Application (DA) (Stage 2) for a commercial mixed-use development, Cockle Bay Park, which is submitted to the Minister for Planning and Public Spaces pursuant to Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act). The development is being conducted in stages comprising the following planning applications:

- Stage 1 – Concept Proposal setting the overall 'vision' for the redevelopment of the site including the building envelope and land uses, as well as development consent for the carrying out of early works including demolition of the existing buildings and structures. This stage was determined on 13 May 2019, and is proposed to be modified to align with the Stage 2 SSD DA.
- Stage 2 – Detailed design, construction, and operation of Cockle Bay Park pursuant to the Concept Proposal.

2 The Site

The site is located at 241-249 Wheat Road, Sydney to the immediate south of Pyrmont Bridge, within the Sydney CBD, on the eastern side of the Darling Harbour precinct. The site encompasses the Cockle Bay Wharf development, parts of the Eastern Distributor and Wheat Road, Darling Park and Pyrmont Bridge.

The Darling Harbour Precinct is undergoing significant redevelopment as part of the Sydney International Convention, Exhibition and Entertainment Precinct (SICEEP) including Darling Square and the W Hotel. More broadly, the western edge of the Sydney CBD has been subject to significant change following the development of the Barangaroo precinct.

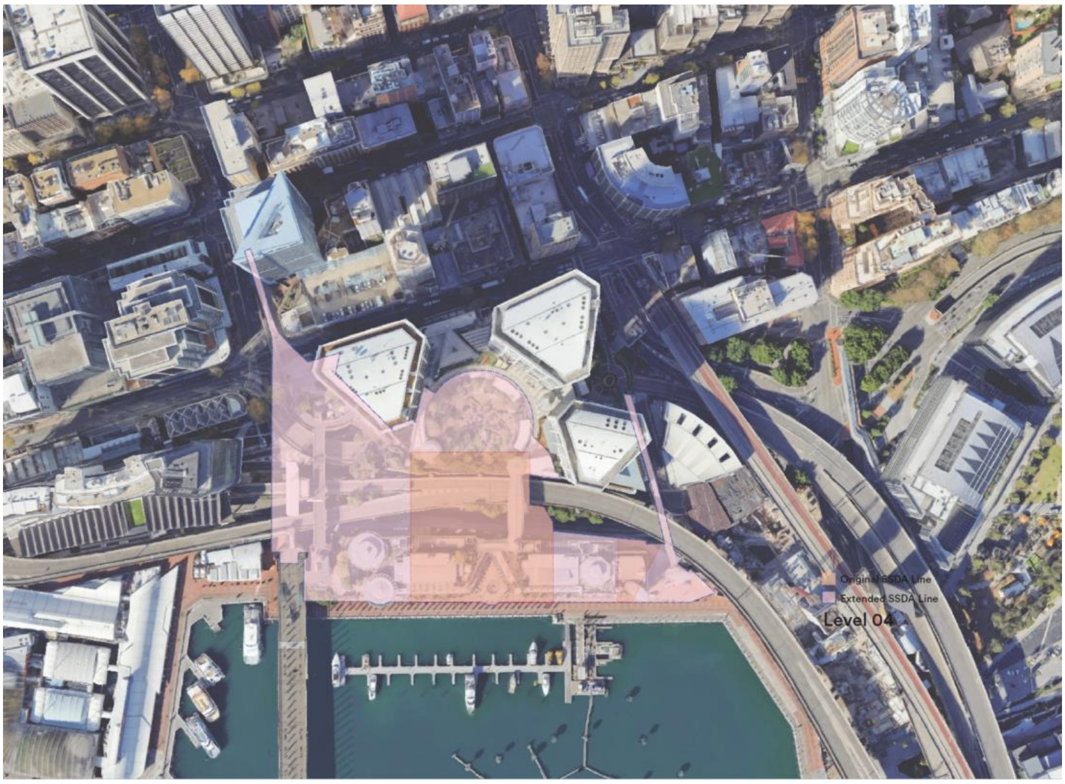

Figure 1: Location Plan

This report has been prepared in response to the Secretary's Environmental Assessment Requirements (SEARS) dated 12 November 2020 for SSD-9978934. Specifically, this report has been prepared to respond to those SEARS summarised in Table 1.

Table 1: SEARS requirements

Item	Description of Requirement	Section Reference (this report)
7	**Amenity** The EIS must: […] • detail the reflectivity levels of chosen materials of the façade and the inclusion of various passive solar design measures within the development	7

This report has also been prepared in response to the following Stage 1 (SSD 7684) conditions of consent summarised in Table 2.

Table 2: Concept approval of Conditions of Consent

Item	Description of Requirement	Section Reference (this report)
C2	**Building Design** Future Development Application(s) shall include a Reflectivity Analysis demonstrating that the external treatments, materials and finishes of the development do not cause adverse or excessive glare.	6, 7

3 Assessment locations

The Reflectivity Assessment is concerned with roads from which the proposed development is prominently visible, in particular where its glazed facades are visible at low angle above the plane of view and close to the dominant direction of travel. In addition to the streets immediately surrounding and leading up to the site, the assessment includes roads in Pyrmont and the Western Distributor.

Table 3 summarises the main roads and travel directions in proximity of the site.

Table 3: Roads and travel directions for assessment

Reference	Road	Direction
1	Union St / Darling St	East
2	Western Distributor	East / North
3	Pier St	East
4	Harbour St	North
5	Park St / Druitt St	West
6	Market St	West
7	Western Distributor	South
8	Sussex St / Shelley St / Lime St	South

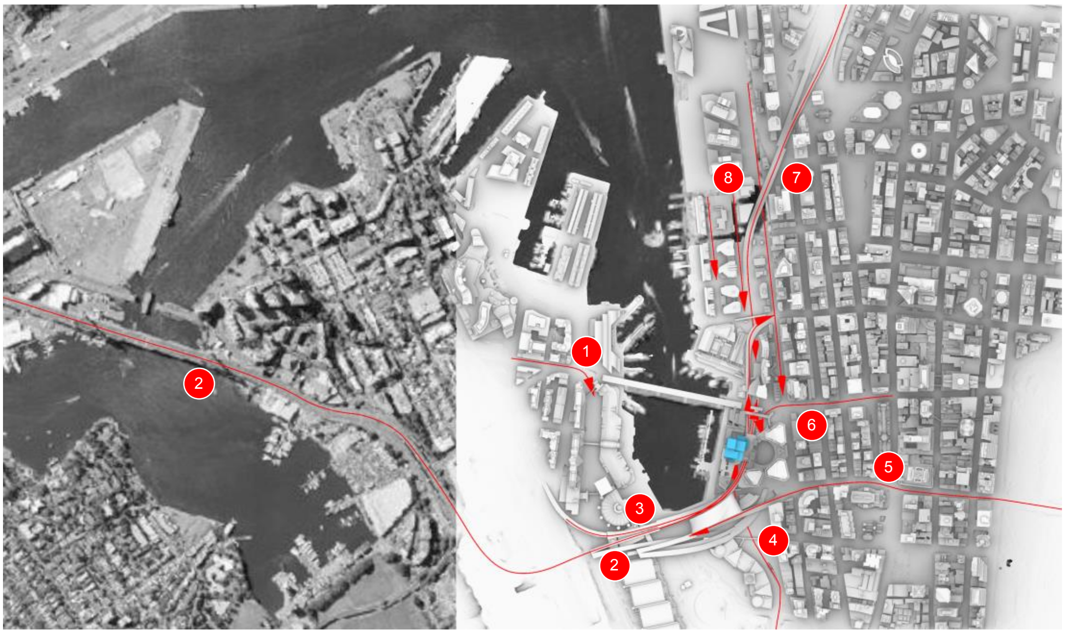

Figure 2: Map of assessed roads. Locations are taken into account at closely spaced intervals along indicated lines

4 Façade description

Tower

The building has a rectilinear floor plate with the elevations aligned close to cardinal directions.

The tower façade consists of curtain wall modules of which some are faceted. Spandrels at the edge of floor slabs are proposed to have 'shadow box' arrangements with cladding of glass that is the same as the vision glass.

There are three main types of façade panels:

- Flat glazed panels with horizontal and vertical shading blades
- Panels with diagonal split in the vision glazing, with the upper half tilted outwards
- Panels with a diagonal split, with the upper half as spandrel with solid non-specular reflective cladding

This design approach has two effects on the façade reflectivity:

- In addition to reflection from the main vertical plane of façade, the sun incident on one elevation is reflected into two other directions (from the tilted halves of one type of glazing panel, which may be pointed either left or right)
- The percentage of façade surface that reflects specularly into a single direction is reduced, both by the solid cladding triangles and the tilted glazing reflecting sunlight into a different direction

In addition, the tower façade features external horizontal and vertical shading elements and protrusions of the tilted elements shading adjacent panels. These would have a small reducing effect on reflections but have not been taken into account in the analysis.

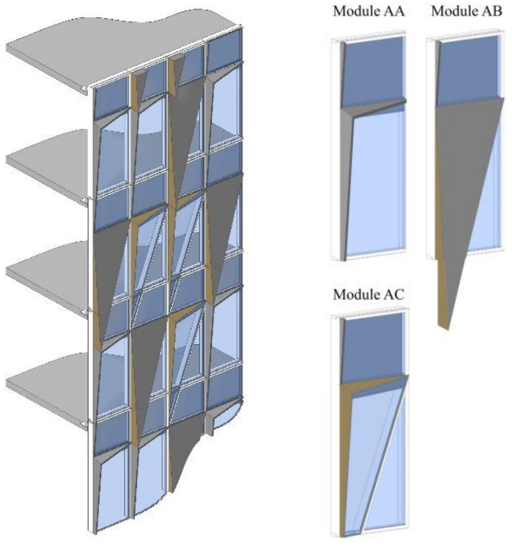

Figure 3: Tower facade with three main panel types

Podium

The podium is articulated in a series of volumes mostly visible from the west of the site, with solid wall towards the Western Distributor passing underneath the site, with a smaller group of buildings with wellness facilities oriented towards Darling Park on the east.

Facades consist of operable facades to retail tenancies mostly set back under overhangs behind external terraces, and fixed facades with glazing supported by expressed mullions and non-specular reflective solid cladding to opaque sections.

5 Methodology

5.1 Controls

This study responds to the Concept approval of Conditions of Consent C2 requiring a reflectivity analysis demonstrating that the external treatments, materials and finishes of the development do not cause adverse or excessive glare, and to the SEARS Requirements Item 7 requiring detail on the reflectivity level of façade materials.

An explicit limit for the reflectivity of glazing and finishes is not provided in the Conditions of Consent or the SEARS; the 20% limit found in the Sydney DCP 2012 and development controls from other Sydney Councils is assumed as a starting point maximum value for this assessment. The assessment seeks to establish whether this reflectivity level can be applied without causing glare, or whether it is required to restrict reflectivity levels further.

5.2 Criteria for Assessment

The method for this study follows that of David N. H. Hassall of the University of New South Wales, which has been widely used to assess reflections off building projects in Sydney. It has been specifically developed for the purpose of reviewing the potential glare impact of solar reflections from facades on traffic in detail, beyond a nominal facade material reflectivity limit.

The term “glare” describes adverse visual effects caused by large ratios of luminance in the visual field. Glare can generally be defined in two ways by its impact on observers (these may coincide):

- Discomfort glare – resulting in psychological annoyance, desire to avert view
- Disability glare –impacting the ability to recognise objects in the visual field and thus ability to carry out visual tasks (such as reading or driving)

It is critical that a driver’s view is unaffected by disability glare as this has the potential to cause road accidents, thus the Hassall methodology focuses on prediction of this aspect of glare.

It further singles out veiling glare as the predominant mode of glare that can occur from façade reflections towards traffic. Veiling glare is defined in this context as glare due to the effect of multiple reflection and scattering within the eye of direct light from a bright source. This produces a perception similar to a thin veil being overlaid on the visual scene, and reduces the contrast in the scene, potentially impairing visual tasks. A prerequisite for veiling glare is thus that reflections of the sun are visible relatively close to the direction of view of an observer.

Veiling glare is a form of perceptive effect of glare; whether it leads to discomfort or disability glare depends on the intensity of the effect.

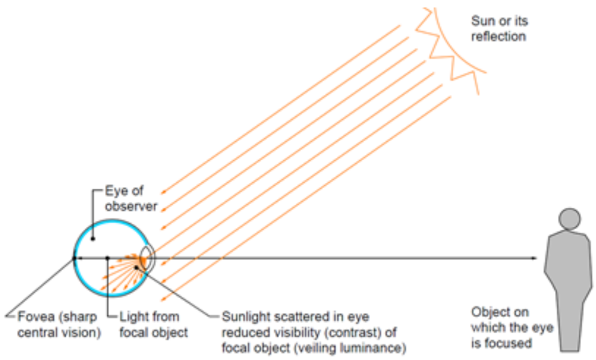

Figure 4: Bright sunlight falling into the eye reduces contrast and visibility of objects. This effect can be quantified by the equivalent veiling luminance measure.

Hassall proposes a workflow to track solar geometry, estimate sun intensity, establish actual façade reflectance, and numerically calculate a measure for the veiling effect. This measure, the equivalent veiling luminance, measured in cd/m² (candela per metre squared), is a representation of apparent brightness to the human eye corrected for the angular distance of the glare source from the focus of vision, which reduces the veiling effect.

The Hassall methodology further proposes a limit of acceptability of equivalent veiling luminance of façade reflections for traffic of **500 cd/m²**. Where this is exceeded, solar reflections are considered as potentially causing disability glare.

5.3 Workflow

Arup use in-house developed software to carry out the Hassall calculation based on 3D models, capable of checking for annual worst-case reflections anywhere off the façade towards locations along a stretch of road. We have applied this software to a simplified model of the glazed surfaces of the proposed development.

This involves several steps, as outlined below:

- The size, orientation and extent of reflective objects on each facade are determined by examination of drawings / 3D models provided by the architect, the site and surrounds, and expected glazing materials.
- Several observer locations are chosen for critical facades, representing locations from which traffic participants may observe the facades.
- Times at which the sun is reflected off the facade are determined, as well as the directions in which it is reflected.
- If the sun is reflected towards any observer, the equivalent veiling luminance in the eye of the observer is calculated and evaluated against the maximum allowed level of 500 cd/m² according to Hassall. This involves calculations of the strength of solar illumination, the position of the sun in front of the facade, the apparent position of the sun reflected in the facade, and the reflected solar illumination received by the observer.
- If the limit is exceeded, further assessment is carried out to evaluate if other factors such as facade shading make the situation acceptable or not. Within his methodology, Hassall discusses situations where an undesirable amount of

veiling glare is experienced but reflections fall outside the cone of sensitive vision and / or can be blocked by sun visor, hand or hat.

- On the multifaceted facades, the sun is only reflected by individual panels at a given time. Observed from a larger distance these do not reflect the full sun disk. In these cases, it is reasonable to assume that the intensity of reflections off a panel is proportionally diminished with the percentage of the sun disk solid angle that is reflected by the same panel.

5.4 Assumptions

- For the purposes of this assessment, all glazed facades are initially assumed to have a reflectivity of 20% (external specular reflectivity at normal incidence) as a maximum assumption based on typical council control limits in the Sydney region. Where glass reflectivity needs to be limited below this level in order to mitigate veiling glare, commentary is provided in the following sections.
- It is assumed that to carry out the visual tasks required for traffic participation, drivers and pedestrians face parallel to their direction of travel and view the road in front of them at 1° down relative to the plane of the road surface, as per view direction assumptions in AS4282:1997 5.4.2 which sets out similar considerations for the purposes of glare from night-time road lighting.

5.5 Modelling and Assessment Approach

This reflectivity study uses a digital 3D model of the proposed building and the surrounding context including buildings and topography. The model has been developed from the architectural 3D model and drawings. Relative road elevation information is taken from available context model 3D topography.

The model is used to interrogate the view of the building and solar reflections originating from it along the paths listed in Table 3.

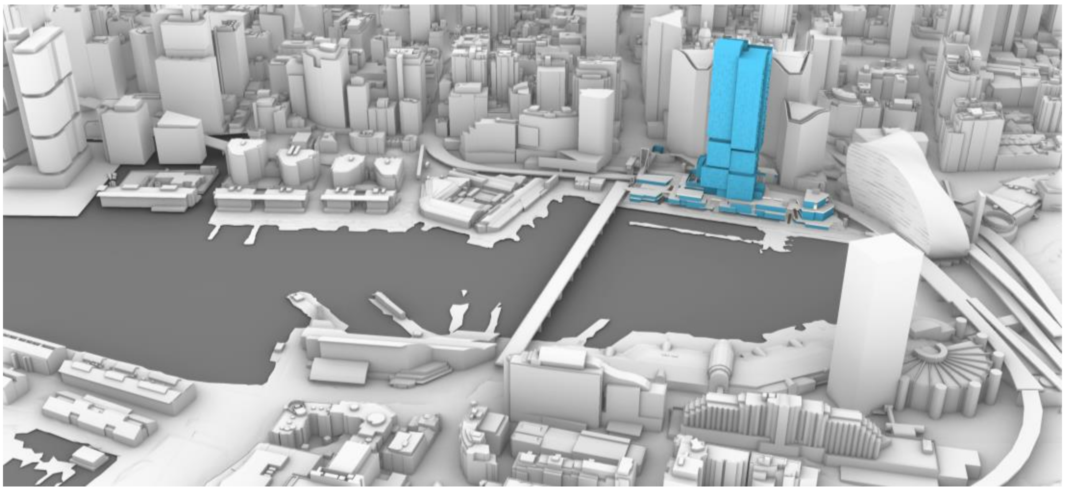

Figure 5: 3D model of proposed building and surrounding context

6 Assessment

6.1 Modelling results

The sections below will comment on the expected impact of reflected glare on traffic, for each observer path reviewed.

Where reflections from the development can exceed the limit of acceptability set out by Hassall (500 cd/m²), indicative perspective views are shown for a single viewpoint on these paths. Note however the modelled paths will be reviewed along their entire lengths.

The equivalent veiling luminance of reflections is colour coded in projected facades in perspective views. Façade areas are shown orange to red where reflections exceed the Hassall limit of 500cd/m² for prevention of disability glare. Reflections off projected façade area shown in blue to cyan are below this limit in intensity.

Calculations per the Hassall methodology are primarily aimed at road traffic but allow by extension reasoning about impact on pedestrians. See section 6.3 for further commentary.

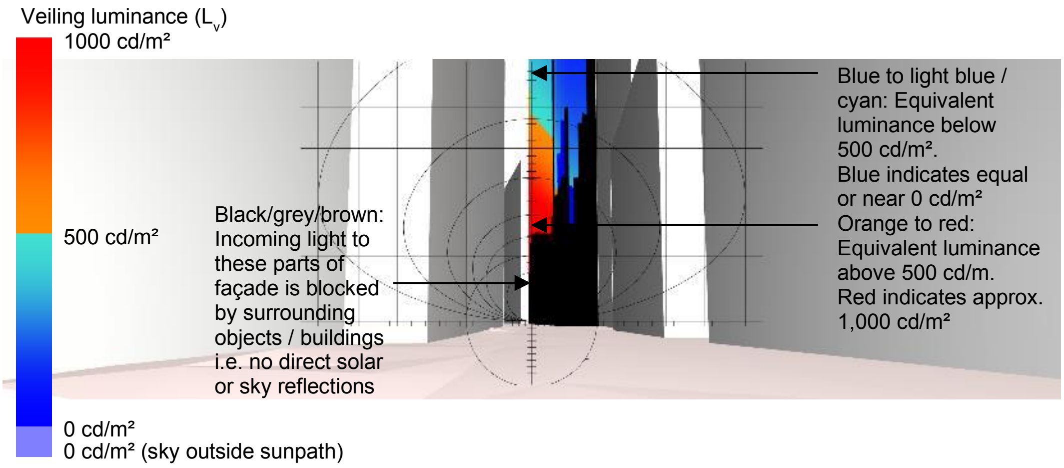

Figure 6: Key of colours indicating reflection intensity per Hassall calculation

6.1.1 Route 1 – Union St / Darling St heading east

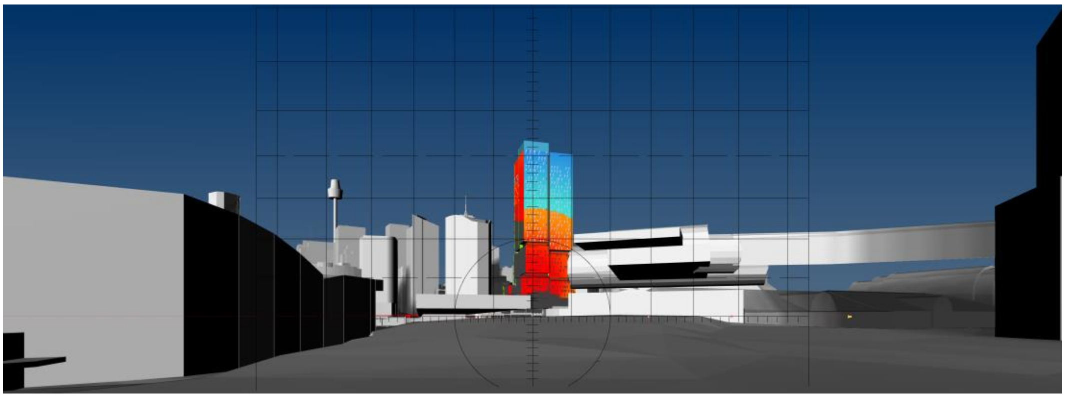

Figure 7: View from Union St / Darling St. Initial analysis assuming 20% reflectivity and full facade area reflecting

The west façades of the podium and tower are visible to drivers approaching from this direction and can reflect sun from the west during winter afternoons at the tower above Level 5.

Initial analysis carried out at 20% reflectivity and assuming fully reflecting flat façade had identified potential for solar reflections above the 500 cd/m² threshold (up to 1,620 cd/m² assuming 20% reflectivity of the glazing) occurring towards drivers on an approximately 20m length of road for the following approximate times:

- Up to 12 min per day between 5.35am and 6.20am in February/March and October

While reflections from the upper levels of the west façade occur above the 5° sun visor cut off angle per Hassall and can be controlled by drivers using the visor, reflections from levels 5-9 are visible below the 5° cut-off angle.

In order to reduce luminance of reflections to below the 500 cd/m² threshold, it is proposed that the nominal glass reflectivity of the tower west façade level 5-9 glazing is limited to <9.5% at normal incidence based on the current façade design.

In addition, the tower west façade has been designed to incorporate at least 37% tilted and non-reflecting elements by area between levels 5-9 which are visible below the 5° sun visor cut off angle. As the sun disk spreads out across several façade panels at this distance, part of the sun disk is not reflected towards drivers at the time that flat glazing reflects, and the resultant equivalent veiling luminance of the partial reflection can be considered proportionally reduced compared to the Hassall calculation value for the full sun disk reflection.

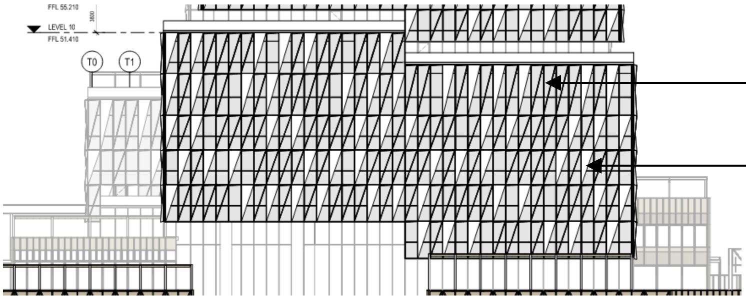

Figure 8: Partial west elevation

When considering the reduction of reflecting area in the proposed design of the tower façade and glazing reflectivity limit to 9.5%, the equivalent veiling luminance of sun reflections from the west façade remains below 495 cd/m², below the limit of acceptability set out by Hassall (500 cd/m²).

Glancing angle reflections (<15º from façade surface) off the upper tower north facades can also occur during mid-season mornings, potentially exceeding the 500 cd/m² threshold (up to 1,600 cd/m² assuming 20% reflectivity of the glazing) for the following approximate times:

- Up to 8 min per day between 6.30am and 7.00am in February/March and October

However, from this viewing direction the excessive reflections on the north façade occur well above the 5° sun visor cut-off angle. Given that Union St / Darling St is not a high-speed road but within a 40km/h speed limit zone, it can be assumed based on Hassall (1991) 5.6 P5 that it is safe for drivers to adjust the sun visor to control glare from these reflections. Reflections would also be significantly reduced by the façade articulation and external shading elements.

With the mitigating effects of the façade articulation in the proposed design, reflections are thus not expected to result in unacceptable glare towards drivers in this location for west façade level 5-9 glazing reflectivity limited to **9.5%.**

An equivalent outcome may be developed with a higher percentage of tilted and solid panels, and glass with reflectivity up to 12%. This would need to demonstrate a similar veiling luminance outcome when developed.

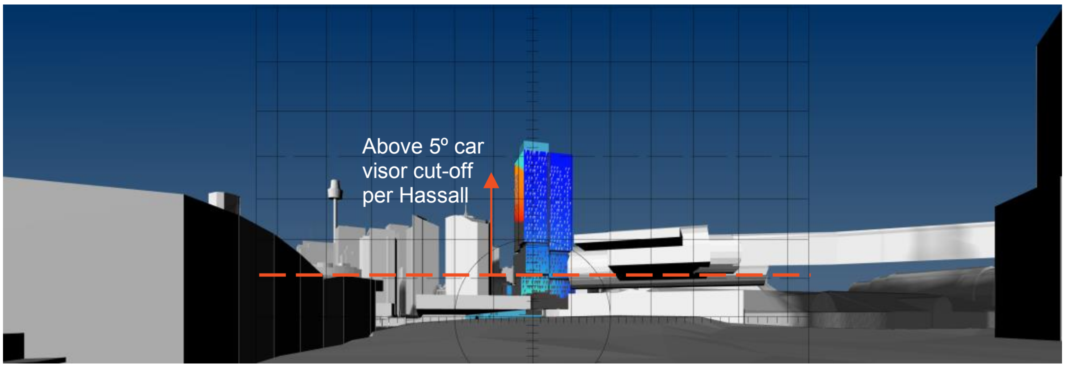

Figure 9: View from Union St / Darling St. Analysis for proposed design (assuming 9.5% reflectivity and factored for 63% facade area reflecting)

6.1.2 Route 2 – Western Distributor heading east / north

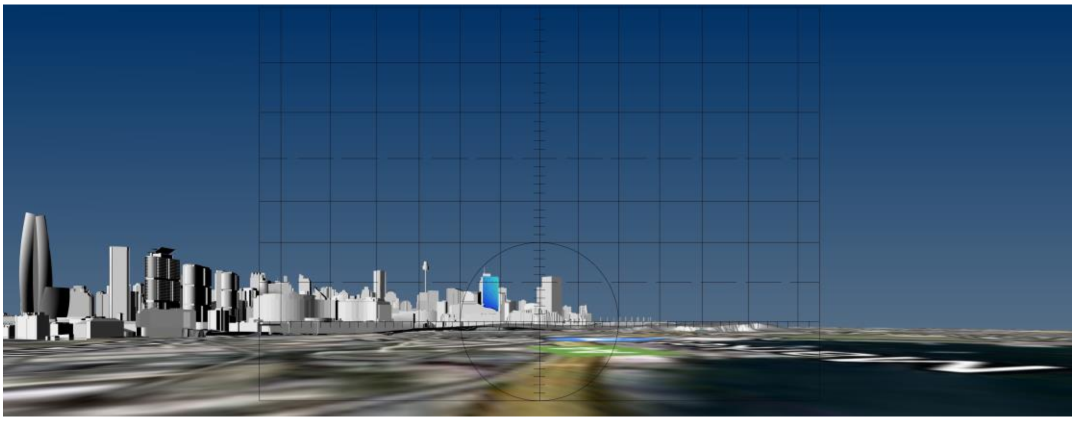

Figure 10: View from Anzac Bridge

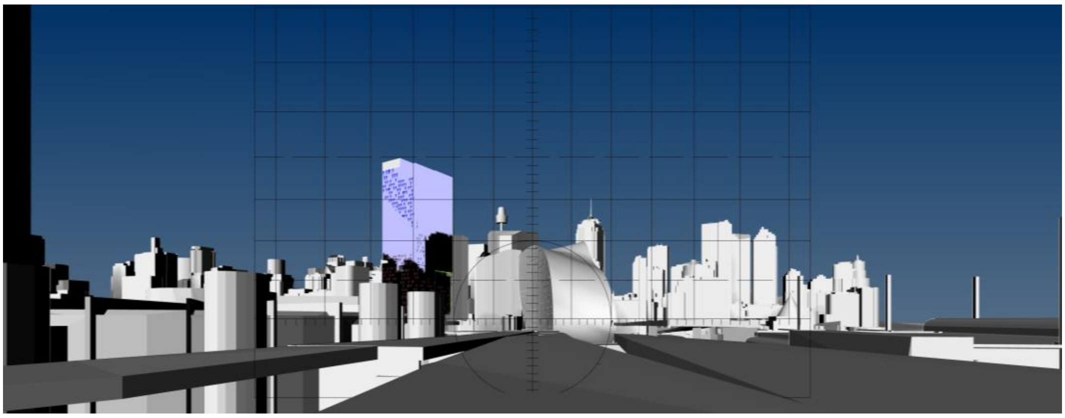

Figure 11: View from Western Distributor at Pymont, close to Darling Harbour

The west and south façades of the proposed tower are visible to drivers approaching from this direction, as well as podium facades once the Western Distributor passes the International Convention Centre close to the site.

The upper west tower facade can reflect sun towards Anzac Bridge at times during winter afternoons. However, the equivalent veiling luminance remains below 380 cd/m², below the limit of acceptability set out by Hassall (500 cd/m²).

Tilted façade triangles on the upper west façade can reflect sun towards the section of the Western Distributor south of Darling Harbour at times during winter afternoons. However, the equivalent veiling luminance remains below 150 cd/m², below the limit of acceptability set out by Hassall (500 cd/m²).

6.1.3 Route 3 – Pier St heading east

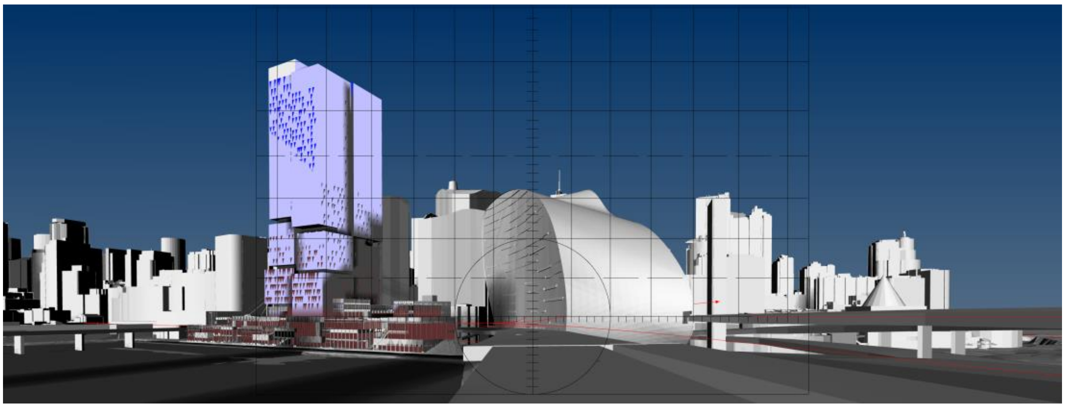

Figure 12: View from Pier St

The west and south façades of the proposed tower and west and south facing podium facades are visible to drivers approaching from this direction.

Tilted façade triangles on the upper west façade can reflect sun towards the section of the Western Distributor south of Darling Harbour at times during winter afternoons. However, the equivalent veiling luminance remains below 150 cd/m², below the limit of acceptability set out by Hassall (500 cd/m²).

6.1.4 Route 4 – Harbour St / Wheat Rd heading north

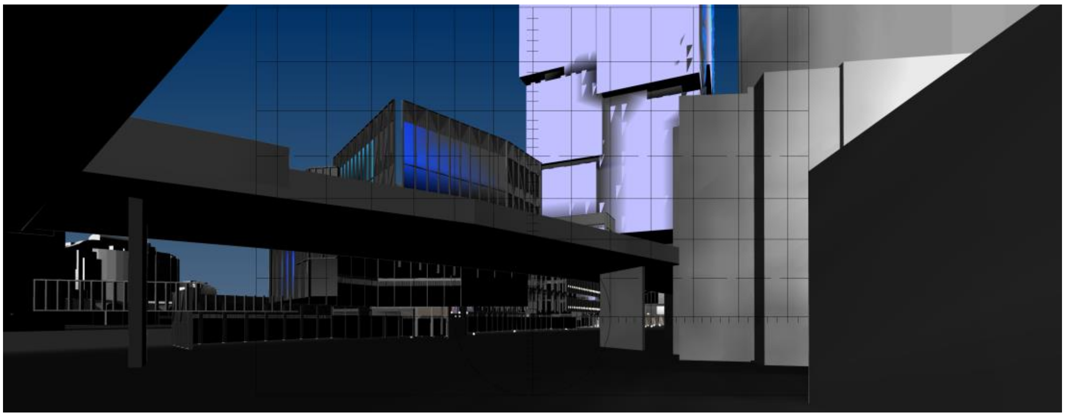

Figure 13: View from Harbour St

The south and east façades of the proposed tower and south west and south east podium facades are visible to drivers approaching from this direction.

The podium south west facades can reflect sun towards the section near the W Hotel building at times during mid-season afternoons, and the podium south east façade can reflect sun at times during mid-season mornings. However, the equivalent veiling luminance remains below 280 cd/m², below the limit of acceptability set out by Hassall (500 cd/m²).

6.1.5 Route 5 – Park St / Druitt St heading west

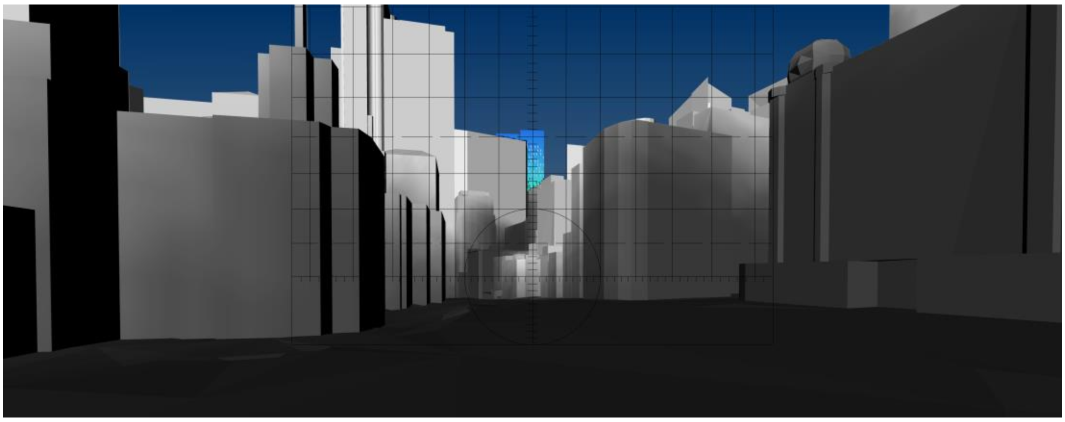

Figure 14: View from Park St leading into Druitt St

The east façades of the proposed tower are visible to drivers approaching from this direction and can at times reflect sun from the east during summer mornings. However, the equivalent veiling luminance remains below 480 cd/m², below the limit of acceptability set out by Hassall (500 cd/m²).

For this reason, reflections are not expected to result in unacceptable glare towards drivers in this location.

6.1.6 Route 6 – Market St heading west

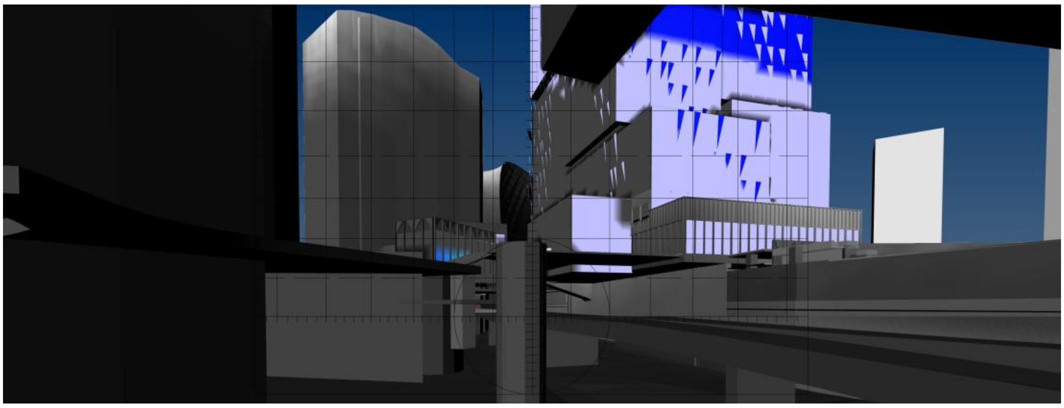

Figure 15: View from Market St

The north and west façades of the proposed building podium and tower become visible to drivers approaching from this direction as they turn onto the ramp towards the Western Distributor. The north facades of the upper tower, some tilted glazing on the tower north façade and part of the podium gym façade can at times reflect sun from the north west during winter afternoons. However, the equivalent veiling luminance remains below 270 cd/m², below the limit of acceptability set out by Hassall (500 cd/m²).

For this reason, reflections are not expected to result in unacceptable glare towards drivers in this location.

6.1.7 Route 7 – Western Distributor heading south

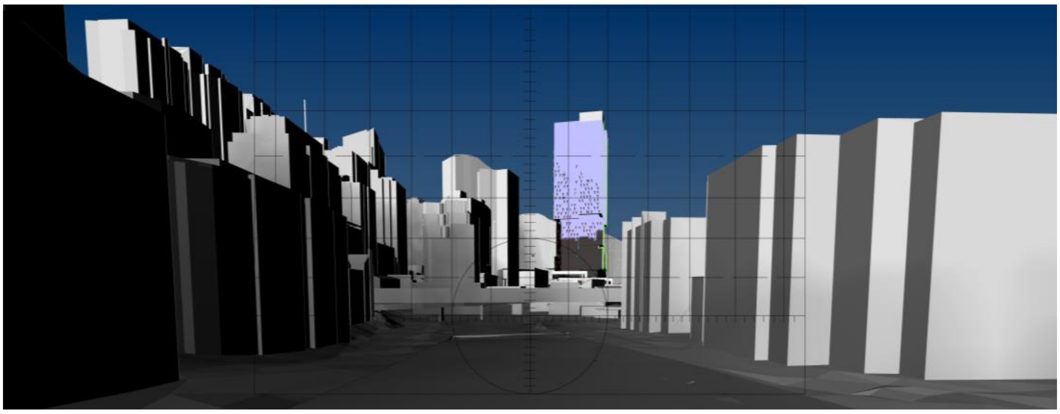

Figure 16: View from Western Distributor heading south

The proposed building facades do not reflect the sun towards drivers approaching from this direction.

6.1.8 Route 8 – Sussex St / Shelley St / Lime St heading south

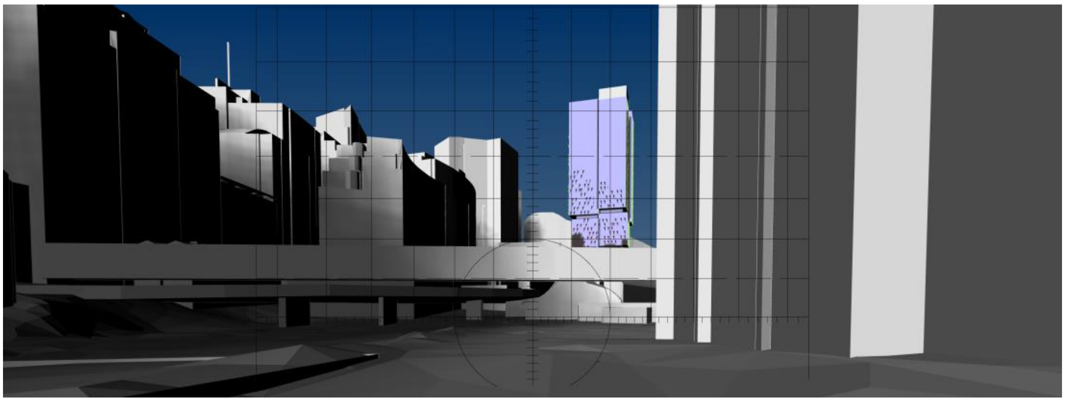

Figure 17: View from Sussex St

The proposed building facades do not reflect the sun towards drivers approaching from this direction in the noted streets.

6.2 Impact on Traffic in Other Locations

From further afield, it may be possible that other locations exist where the building can be seen from road level. These would however be at a distance where typical glazing surfaces of the building would subtend angles significantly smaller than the sun disk, and scattering effects from small misalignments (e.g. due to construction tolerances) would reduce the observable intensity of reflections, so that it is not expected to be high enough to create unacceptable glare.

6.3 Impact on Pedestrians

From the perspective of pedestrians moving along roadways, the incidence of reflections from the building is generally similar to the examined road traffic locations. Glare from reflections is therefore expected in similar locations.

Furthermore, pedestrian observers are easily able to adjust their view and thus reduce the glare impact of reflections. They move at a rate significantly slower than that of a vehicle. For this reason, it can be assumed that it will be safe for pedestrians to divert their vision in order to avoid glare.

6.4 Impact on Surrounding Buildings

Solar reflections off the façade may reach surrounding buildings in the CBD area, as would be expected for any glazed façade in a dense urban context that can be reached by sunlight.

In general, reflections from façades with normal external reflectance below 20% are much less likely to cause discomfort to occupants of surrounding buildings than facades with strongly reflective glazing. The proposed building is targeting a glass reflectance below 20%, which will serve to reduce any potential glare reflections that may occasionally be produced towards pedestrians and other buildings.

7 Conclusion

The following table summarises the outcome of the reflectivity assessment for individual roads reviewed:

Ref.	Road	Dir.	Max Lv identified [cd/m²]	Note
1	Union St / Darling St	East	West façade: 495 (at 9.5%) North façade: 1,600	West façade reflections Within acceptable limit with faceted facade and limiting tower west façade glazing reflectivity to 9.5%. North façade reflections can be controlled using sun visor which is deemed acceptable by Hassall for comparable situations (Hassall, 1991).
2	Western Distributor	East / North	380	Within acceptable limit
3	Pier St	East	150	Within acceptable limit
4	Harbour St	North	280	Within acceptable limit
5	Park St / Druitt St	West	480	Within acceptable limit
6	Market St	West	270	Within acceptable limit
7	Western Distributor	South	0	No sun reflection
8	Sussex St / Shelley St / Lime St	South	0	No sun reflection

Reflected glare risk to traffic participants in all analysed locations could be discounted for all visible facades for either of the following reasons:

- The intensity of any reflections will be below the limit of acceptability set out by Hassall (500 cd/m²);
- Surrounding buildings and topology or other parts of the building itself will be blocking reflections that could cause glare to drivers; or
- The position of reflections within the visual field is not critical and would allow traffic participants blocking with sun visor.

These findings are valid, and Condition of Consent C2 hence satisfied by this report, as long as glazing reflectivity is kept within the following limits:

- **Tower west façade glazing levels 5-9: 9.5%**, with design configuration of solid spandrel and tilted glazing as per SSDA elevations. An equivalent outcome may be developed with a higher percentage of tilted and solid panels, and glass with reflectivity up to 12%; this would need to demonstrate a similar veiling luminance outcome when developed.
- **All other glazed facades: 20%**

These limits set upper bounds for reflectivity relevant to SSDA Requirement 7.

The result is obtained despite conservative assumptions about the extent of reflective facade glazing and does not take into account obscuring effects such as from smaller façade elements (small shading overhangs, joints, local plantroom louvres etc) and surrounding vegetation.

Appendix A

Reference Information

A1 Architectural Drawings

The reflectivity study presented in this report is based on the DA drawings A-DA1000 through A-DA2570 by Henning Larsen Architects and on 3D context model information from the architectural project model.

A2 Glossary and Abbreviations

Reference	Description
AS	Australian Standard
cd/m²	Candela per square meter (equivalent veiling luminance measure)
DA	Development Application

A3 References

Hassall, D. N. H. (1991): Reflectivity. Dealing with Rogue Solar Reflections, Faculty of Architecture, University of New South Wales, ISBN 0 646 07086 X

Appendix E

Air Quality Assessment Report

Cockle Bay Park

Landbridge Internal Air Quality Study

DPT and DPPT Operator Pty Ltd

Reference: 253427

Revision: A

2021-10-08

Document control record

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Client contact		Greg Mannes	**Client reference**			
Rev	**Date**	**Revision details/status**	**Author**	**Reviewer**	**Verifier** (if required)	**Approver**
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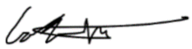
Current revision		**A**				

Approval			
Author signature		Approver signature	
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1 Introduction

This report has been prepared to document the design development that has occurred since the Cockle Bay Park Stage 1 Development Consent (Application no. SSD 7684) was granted in May 2019 as it pertains to the air quality beneath the landbridge. Primarily this relates to an increased landbridge footprint brought about to improve connectivity between Market St and Pyrmont Bridge, and responses to commentary provided during coordination with Transport for NSW.

DPT Operator Pty Ltd and DPPT Operator Pty Ltd (the Proponent) is seeking to secure Stage 2 DA approval for the Cockle Bay Park development.

As part of this development a new landbridge structure over the Western Distributor has been proposed. This landbridge would create a partial enclosure to the elevated northbound Western Distributor and southbound Market St towards Anzac Bridge, the on grade northbound and southbound Harbour St, Western Distributor and northbound Wheat Rd.

This report addresses the internal air quality below the landbridge between the portals it creates.

2 Methodology

This study assesses internal air quality for Carbon monoxide (CO), Nitrogen Dioxide (NO_2) and visibility through a desktop assessment. The visibility parameters examined are $PM_{2.5}$ and PM_{10}, which represent a subset of particulate matter with sizes in the order of 2.5 and 10 microns respectively. Only these pollutants are modelled as they have the most stringent requirements in road tunnels (PIARC - Road tunnels: vehicle emissions and air demand for ventilation, 2019R02EN). The assessment uses one dimensional modelling software IDA Road Tunnel Ventilation to assess pollutant concentrations in steady state.

The assessments will consider the following operations:

- Normal operations: Free flowing traffic at 80 km/hr
- Congested operations: Traffic moving at 40 km/hr
- Congested operations: Traffic moving at 10 km/hr
- Stationary operation: Traffic stopped at 0 km/hr

The study has also accounted for air quality inputs from the adjacent buildings, both existing and proposed.

Desktop assessments consider the condition in the enclosure and at the portals to be averages over the cross-section (as per calculation methodology in PIARC 1995).

3 Model, Inputs and Acceptance Criteria

The following section describes the model and inputs.

3.1 Geometry

The enclosure consists of the northbound and southbound Harbour St, the southbound Western Distributor, the northbound Wheat Rd and elevated northbound Western Distributor and southbound Market St.

Figure 1 displays the approximate extent of the proposed landbridge and the existing underpass southbound of Market Street. For the ventilation model, the geometry has been divided into two connecting sections, the landbridge and the existing Darling Park Underpass. The Darling Park Underpass connection is 50m from the northern portal. Figure 2 shows the cross-sections along the proposed landbridge, and approximate dimensions of the enclosure.

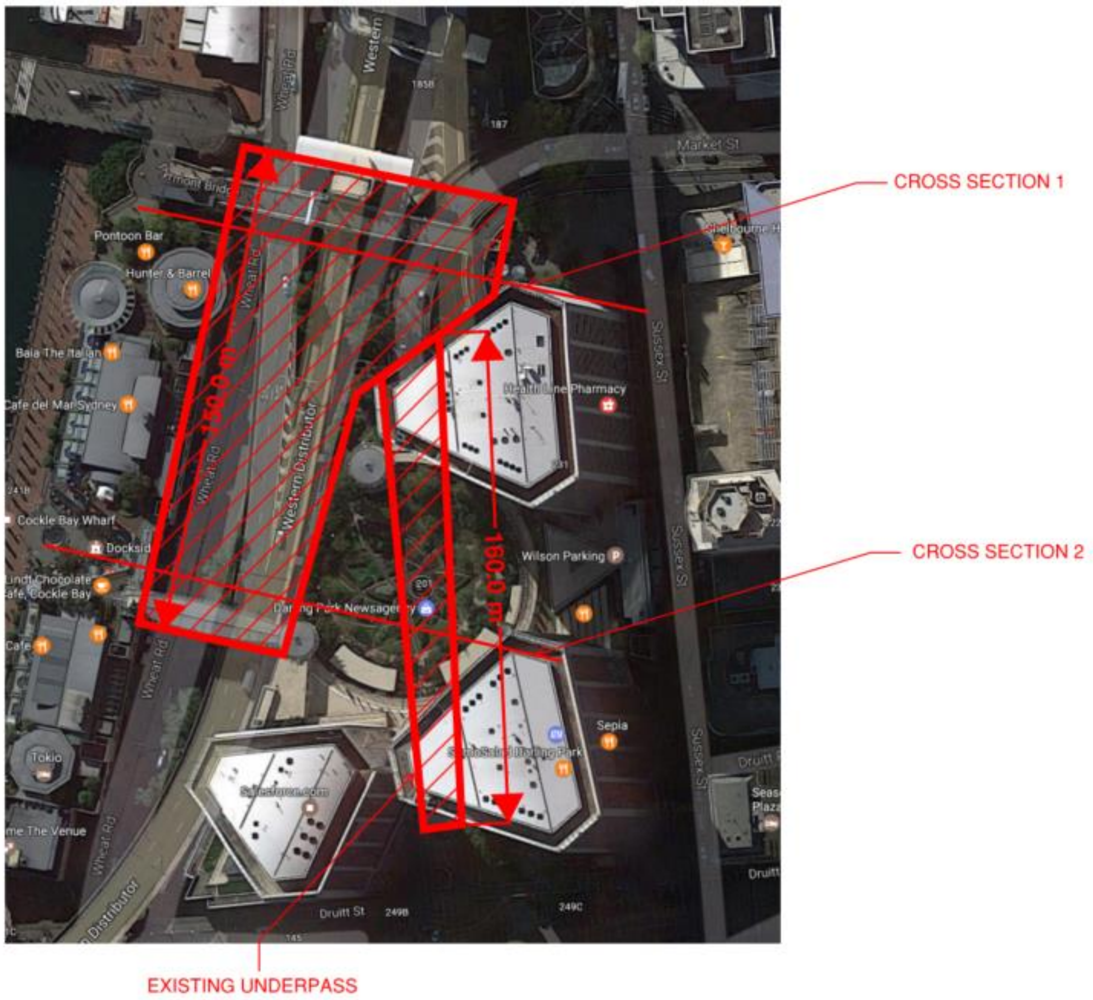

Figure 1: Extent of proposed landbridge and existing underpass – plan

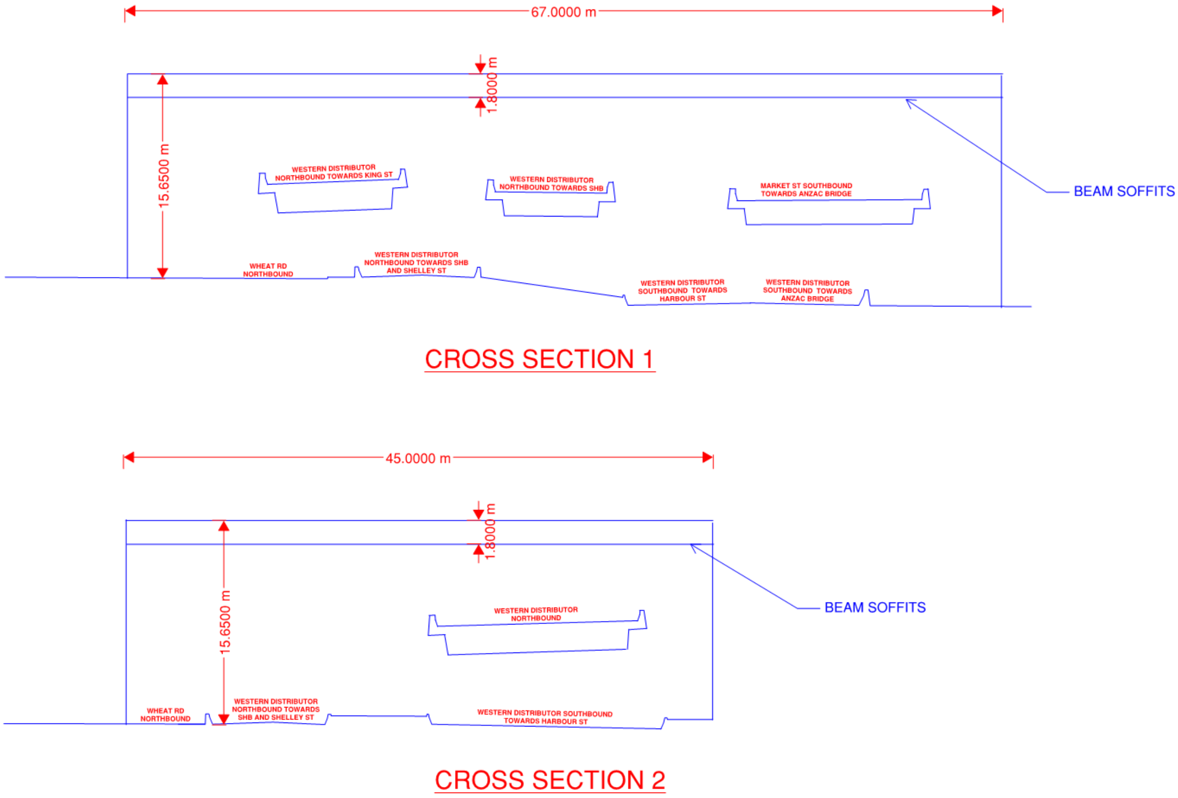

Figure 2: Cross-section of roadways beneath the proposed landbridge (dimensions are approximate only)

The model considers openings only at the portals. It has been assumed that the future tower to the west of the enclosure will feature a solid wall that will not provide any means of ventilation on the western face of the enclosure. However, the air quality inputs along this face are provided to enable the proponent to account for outside air quality inputs to the building drop-off area.

On the eastern wall of the new structure there are openings to an existing car park. This car park features a ventilation system that is activated via CO sensors to exhaust pollutants out of the car park. The exhausting of these pollutants will be directed outside of the landbridge extent. Induced flow from beneath the landbridge into the car park via the openings will be larger than the flow in the other direction. A conservative assumption (for air quality beneath the landbridge) that there is zero flow from beneath the landbridge to the carpark has been taken and a wall is modelled without air exchange. The car park will be reassessed separately by the proponent to account for the induced flow into the car park based on inputs provided from this assessment.

3.2 Inputs

3.2.1 Traffic and vehicle parameters

Traffic and vehicle parameters are not available for the Western Distributor at the location of the underpass and estimates for these parameters were made based on the following data. A permanent vehicle-type classifier on the Sydney Harbour Bridge, approximately 2.5km from the proposed underpass, was used to determine the traffic split. It was determined that in 2016 on average 94% of traffic was classified as passenger cars and 6% as heavy goods vehicles (HGV). To be conservative, for this study, 10% of the total traffic was considered to be composed of HGVs. Additionally, international standard PIARC (Road tunnels: vehicle emissions and air demand for ventilation, 2019R02EN) suggests that where the traffic split for light commercial vehicles (LCV) is not provided, it is suitable to assume that 10% of passenger car vehicles are comprised of LCVs.

PIARC also provides estimates on how many vehicles are expected to be present in a section of road for a given number of lanes, road length and vehicle speed. The number of vehicles per lane over a 15-minute period used for this study are presented in Table 3-1. These values are comparable with those used in the fire engineering study that has been undertaken separately.

Table 3-1: Vehicle type split

Simulation	80 km/h	40 km/h	10 km/h	0 km/h
Vehicle count	Veh/h-lane	Veh/h-lane	Veh/h-lane	Veh/h-lane
Passenger car – petrol	1378	1378	633	95
Passenger car – diesel	243	243	112	17
Light commercial vehicle	193	193	89	14
Heavy goods vehicle	193	193	89	13

For the stationary case with a vehicle speed of 0km/hr, there is no induced velocity in the landbridge from moving vehicles. This will mean that the vehicles will continue producing pollutants with no dilution from outside air and hence the pollutant concentration will continually increase past limits. This result will be nonsensical, and the model will crash. A Computational Fluid Dynamics (CFD) model for stationary vehicles within the landbridge was produced by Aurecon in 2017. The CFD model considered buoyancy and the small velocity induced from each car exhaust to produce a small velocity within the landbridge of 0.4m/s. This velocity from the buoyancy driven flow will be used in the stationary case.

For non-stationary cases, PIARC provides values for the coefficient of drag (C_D) and the cross-sectional area (A) for each of the vehicle types; Passenger cars, light vehicles and heavy goods vehicles. The values are summarised in Table 3-2.

Table 3-2: Standard drag coefficient and cross sectional areas of vehicle types (PIARC, 1995)

Description	C_D (-)	A (m^2)
Passenger \cars	0.4	2
Light Vehicles	1.0	3
Heavy Goods Vehicles	1.0	7

PIARC also provides values for the expected level of emissions per car given a road gradient, travel speed and vehicle type. Given the shallow gradient in the enclosures, the road gradient for the car emissions is taken as 0%. The bidirectional nature of traffic counterbalances any small gradients. A conservative assumption was made that 20% of NO_X is comprised of NO_2. The values found in the emissions tables are then multiplied by a year-factor which accounts for the changes in vehicle emissions over time, to the design year 2020.

Table 3-3 provides a list of average vehicle exhaust parameters based on the data in Table 3-1 and Table 3-2.

Table 3-3: Vehicle exhaust parameters

Description	Value	Unit
Average vehicle exhaust diameter	0.05	m
Average exhaust velocity	1.8	m/s
Average exhaust temperature	100	˚C
Average exhaust density	1.1675	kg/m^3

Description	Value	Unit
CO yield	9.364×10^{-4}	$kg_{CO}/kg_{exhaust}$
NO_2 yield	6.184×10^{-5}	$kg_{NO_2}/kg_{exhaust}$
PM_{10} yield	2.625×10^{-5}	$kg_{PM10}/kg_{exhaust}$
$PM_{2.5}$ yield	3.500×10^{-5}	$kg_{PM2.5}/kg_{exhaust}$

3.2.2 Ambient conditions

The ambient conditions for Sydney were taken from the Bureau of Meteorology (BOM) (Sydney (Observatory Hill) Site No: 066062), where the mean daily high temperature for 2016 of 30˚C was used.

For the base case, wind pressure at the portals is not considered. Wind pressure is considered in a sensitivity analysis. Wind generally induces additional flow and reduces the concentration of vehicle emissions within the enclosure and therefore the base case is conservative.

The background air quality was obtained from 2016 observations at the Rozelle station, an air quality monitoring site located in Rozelle, East Sydney. The air quality data is presented in Table 3-4.

Table 3-4: Ambient air quality (Rozelle Station)

Pollutant	Averaging period	Max	Units
NO_2	1-hour	94	$\mu g/m^3$
CO	8-hour	1.38	mg/m^3
CO (calculated)	1-hour	2.09	mg/m^3
PM_{10}	24-hour	58.8	$\mu g/m^3$
$PM_{2.5}$	24-hour	49.4	$\mu g/m^3$

The CO concentration for an averaging period of 1 hour was not available. However, some guidance for the conversion from an averaging period of 8 hours to 1 hour is available through the regulatory air pollution model AERMOD in Victoria. The conversion is provided by Equation 1.

Equation 1: Conversion of average period concentrations

$$c(t) = c(t_0) \times (\frac{t_0}{t})^{0.2}$$

Where:

t is the averaging period of interest

t_0 is the averaging period available

$c(t_0)$ is the concentration at the available averaging period

3.2.3 Wind sensitivity analysis

A wind sensitivity analysis was completed to understand the effects of various wind conditions. The analysis focuses on wind conditions that would be required to slow the air in the tunnel as these conditions will increase the pollutant concentrations in the tunnel. The wind pressure is applied as a positive pressure on the affected portal. There will be some shielding affect by the surrounding geography which will cause the wind in the landbridge to be less than the prevailing wind condition. This effect is not considered in the study as it requires three-dimensional analysis; this assumption is considered conservative. Wind conditions between 0 and 12 m/s are considered. Wind conditions greater than the largest value used for each case provide more dilution of air and reduced concentrations.

3.2.4 Sources and extract points

Along the alignment for the landbridge, there are various sources and extraction points. These are noted in a mark-up provided by Steensen Varming contained in Appendix B and advice in Appendix C (we confirm that review of the current design does not affect the analysis in this report). The advice provided notes that the kitchen has filtration and minimal pollutants, the generators are a source, and other sources and extract points are minimal discharge. The use of each of the source and extract points in this analysis is described below:

1. Cockle bay podium retail kitchen, toilet and garbage room exhaust – no additional pollution to landbridge, kitchen exhaust filtered with NO2. Negligible exhaust volume.
2. Cockle bay podium sub-station – no additional pollutants to landbridge. Negligible exhaust volume.
3. Cockle bay podium standby generators – outside landbridge. No impact to pollution in landbridge.
4. Darling park car park natural make up air openings – car park exhaust system would remove pollutants from landbridge. It has been not modelled and this is considered conservative.
5. Lift motor room ventilation – just outside landbridge. Negligible exhaust volume.
6. Car park mechanical supply air – supply system would remove pollutants from landbridge. This is not modelled and considered conservative.
7. Vehicle hoist shaft ventilation. No additional pollution to landbridge. Negligible exhaust volume.
8. Circular exhaust stack divided through centre – this is to be rerouted outside landbridge and therefore no impact to landbridge air quality.
9. Darling Park underpass ventilation exhaust system – this system has been modelled and has positive effect for air quality in underpass.
10. Darling Park underpass ventilation exhaust system – this system has been modelled and has positive effect for air quality in underpass.
11. Circular exhaust stack for southern tunnel ventilation system – outlet is outside landbridge.
12. Generators from tower 2 – these are included in air quality model.
13. Generators from tower 1 – these are included in air quality model.

Existing Darling Park Underpass ventilation

The Darling Park Underpass ventilation extraction system has been modelled according to “Area 30 – Vehicle tunnel ventilation system mechanical services” as installed drawings. The drawings are contained in Appendix A. The ventilation extraction system consists of two fans – a 45 m^3/s fan at the southern end of the underpass and a 42.5 m^3/s fan at the northern end. There are 19 openings on the western face of the underpass which have been modelled according to the installation drawings. Extraction of air from the existing underpass will be facilitated outside of the extent of the landbridge.

Existing Darling Park Tower generators

There are two sets of generators that are able to exhaust beneath the landbridge footprint. The generator types and locations have been provided by Steensen Varming on 07/07/20 on “197161 M20 Landbridge Mechanical Drawing.pdf”. The location can be found on the drawing in Appendix B. There are three (two 2250 kVA and one 1538 kVA) generators associated with Darling Park Tower 1, located approximately 90m from the northern portal. These generators become enclosed by the new section of the landbridge. Tower 2 is approximately 40m from the exit portal of the existing Darling Park Underpass and two further generators are contained here (one 2000 kVA and one 1625 kVA). The generators from Tower 2 exist in the covered section already.

3.3 Acceptance Criteria

3.3.1 Emission Limits

External Emission Limits

The concentration limits of CO, NO_2 and visibility are provided by the NSW EPA (Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales, 2016). The limits are shown in Table 3-5.

Table 3-5: Emission and visibility limits

Pollutant	Averaging period	Concentration ppm	Concentration mg/m³	Concentration μg/m³	Reference
CO	1-hour	25	30	-	WHO (2000)
NO_2	1-hour	0.12	-	246	NEPC (1998)
PM_{10}	24-hour	-	-	50	DoE (2016)
$PM_{2.5}$	24-hour	-	-	25	DoE (2016)

Internal emission limits

An approved set of limits for internal emissions does not exist. Hence, pollutant limits were taken from the specification of WestConnex. The limits for 15 min averaging period are summarised in Table 3-6.

PIARC provides a correlation factor between particulate matter 2.5 ($PM_{2.5}$) emissions in visibility (m^{-1}) and concentration ($\mu g/m^3$).

Equation 2: $PM_{2.5}$ convesion from concentration to visibility

$$K = 0.0047\mu$$

Where:

K is in m^{-1}

μ is in $\mu g/m^3$

The Australian Motor Vehicle Emission Inventory (AMVEI) provides a total annual Australian NPI emissions for industry and motor vehicles. Based on this data we are able to determine an average ratio between $PM_{2.5}$ and PM_{10}; this was calculated to be 0.808:1.000. The conversions were considered in Table 3-6.

Table 3-6: Values for internal emission and visibility limits

Pollutant	Averaging period	Concentration ppm	Visibility m^{-1}	Concentration mg/m³	Reference
CO	15-minute	87		100	WHO (2000)
NO_2	15-minute	0.5 (route average)		0.94	WestConnex
NO_2	15-minute	1.0 (point maximum)		1.88	WestConnex
$PM_{2.5}$	15-minute	-	0.005	1.063	WestConnex
PM_{10}	15-minute	-	0.005	1.315	WestConnex

Maintenance and other personnel emission limits

Worksafe Australia provides guidance for workplace exposure standards. These standards can be applied to determine safe working environments for maintenance or other personnel in the underpass. For example, these limits are applied to personnel in adjacent loading docks outside the drop-off area of the new development. Concentrations limits for NO_2 and CO are provided in Table 3-7.

Table 3-7: Values for workplace exposure limits

Pollutant	Averaging period	Concentration ppm	Concentration mg/m^3	Reference
CO	8-hour	30	34	Safe Work Australia, 2018.
NO_2	8-hour	3	5.6	Safe Work Australia, 2018.

4 Results

The internal air quality desktop assessments were conducted for normal and congested operations and the results are contained in the following sections. The assessments are based on the steady-state methods described in PIARC 1995.

Summarising the air quality limits in the previous section, each case can be compared to the limits provided below in Table 4-1. The background air quality is used to calculate the average exposure and the ambient level for each pollutant is also provided in Table 4-1 below. For all the air quality results provided, the results are inclusive of ambient conditions.

Table 4-1: Internal air quality limits

Pollutant	Units	Averaging period	Air quality limit	Ambient
CO	(mg/m^3)	15-minute	100	2.75
NO_2	($\mu g/m^3$)	Point max.	1880	124
NO_2	($\mu g/m^3$)	15-minute	940	124
$PM_{2.5}$	($\mu g/m^3$)	15-minute	1063	123
PM_{10}	($\mu g/m^3$)	15-minute	1315	146

4.1 Normal and congested traffic

The normal and congested scenario results can be found in Table 4-2 below. For these scenarios, the existing Darling Park Underpass ventilation is switched on and the generators at tower 1 and 2 are switched off (refer to commentary below regarding these generators). These are the baseline cases. In each results table, the worst-case average is provided.

Table 4-2: Internal air quality, inclusive of ambient air conditions

Pollutant	Units	Averaging period	Normal - 80 km/hr	Congested - 40 km/hr	Congested - 10 km/hr	Stationary – 0 km/hr traffic, buoyancy driven airflow
CO	(mg/m^3)	Route average	3	3	6	5
NO_2	($\mu g/m^3$)	Route max.	178	258	1027	853
NO_2	($\mu g/m^3$)	Route average	165	223	720	300
$PM_{2.5}$	($\mu g/m^3$)	Route average	158	188	338	225
PM_{10}	($\mu g/m^3$)	Route average	190	227	413	273

For all normal, congested and stationary scenarios at 80, 40, 10 and 0km/hr, the air quality at the landbridge remains below limits. The faster flowing traffic, which generates greater airflow for pollutant dilution produces a lower pollutant concentration. In comparison, the 10km/hr traffic reduces the airflow and causes a higher pollutant concentration, however values remain below limits. The stationary case with the air velocity from the CFD analysis completed previously also produces acceptable air quality.

4.1.1 Underpass ventilation switched off

A check for the impact of the underpass ventilation system on the pollutant levels has been undertaken. The results for the base cases with the ventilation switched off can be seen below in Table 4-3.

Table 4-3: Internal air quality, inclusive of ambient air conditions

Pollutant	Units	Averaging period	Normal - 80 km/hr	Congested - 40 km/hr	Congested - 10 km/hr	Stationary - 0 km/hr
CO	(mg/m³)	Route average	3	3	6	5
NO_2	(μg/m³)	Route max.	177	254	926	762
NO_2	(μg/m³)	Route average	166	224	757	426
$PM_{2.5}$	(μg/m³)	Route average	158	186	314	212
PM_{10}	(μg/m³)	Route average	189	225	383	257

Switching the ventilation off has minimal impact on the pollutant level for 80km/hr and 40km/hr traffic. For 10 and 0 km/hr traffic, switching the ventilation system off improves the pollutant concentration. This is because, for slow moving traffic, the ventilation system has a greater effect on the slower tunnel airflows and slows the air down more. For conservatism, the ventilation system will be switched on for the remaining cases.

4.1.2 Wind sensitivity analysis

The following results provide a wind sensitivity analysis to understand the impact of wind on the baseline results. For reasons described in 4.1.3, the Darling Park building generators are assumed to be turned off for this analysis.

Stationary traffic

Table 4-4 below provides a sensitivity analysis for stationary traffic to wind from the south. For all wind velocities from the south, the air quality within the landbridge remains below limits.

Table 4-4: Internal air quality, inclusive of ambient air conditions – 0km/hr traffic, wind from south

Pollutant	Units	Averaging period	Stationary traffic	0.5 m/s wind	1 m/s wind	2 m/s wind	8 m/s wind
CO	(mg/m³)	Route average	5	4	3	4	3
NO_2	(μg/m³)	Route max.	853	551	253	350	134
NO_2	(μg/m³)	Route average	300	218	178	173	130
$PM_{2.5}$	(μg/m³)	Route average	225	183	141	155	125
PM_{10}	(μg/m³)	Route average	273	220	169	186	148

Table 4-5 below provides a sensitivity analysis for stationary traffic to wind from the north. Whilst for wind velocities of 0.5, 0.8 and 1.3m/s from the north, a static model forecasts air quality in exceedance of the 15minute NO2 target, it can be assumed that the pollutants will be dispersed to acceptable levels by the action of unsteady wind behaviour at portals, wind irregularity, and buoyancy effects.

Table 4-5: Internal air quality, inclusive of ambient air conditions – 0km/hr traffic, wind from north

Pollutant	Units	Averaging period	Stationary traffic	0.3 m/s wind	0.5 m/s wind	0.8 m/s wind	1.3 m/s wind	1.5 m/s wind	8 m/s wind
CO	(mg/m³)	Route average	5	6	12	13	27	8	3
NO_2	(μg/m³)	Route max.	853	1057	2667	2911	6746	1537	141
NO_2	(μg/m³)	Route average	300	414	988	858	997	486	132
$PM_{2.5}$	(μg/m³)	Route average	225	253	478	512	1048	320	125
PM_{10}	(μg/m³)	Route average	273	308	586	628	1291	391	149

Congested traffic – 10 km/hr

Table 4-6 provides a wind sensitivity analysis to 10km/hr traffic, with wind from the south. As there is already portal inflow at both the existing Darling Park Underpass and landbridge from this direction, there are no stagnation points. As the traffic is slow moving, the wind speeds of interest are low; 8m/s was also considered. All wind speeds produce acceptable air quality.

Table 4-6: Internal air quality, inclusive of ambient air conditions – 10km/hr traffic, wind from south

Pollutant	Units	Averaging period	No wind	0.5 m/s wind	1 m/s wind	2 m/s wind	8 m/s wind
CO	(mg/m^3)	Route average	6	4	6	3	3
NO_2	(µg/m^3)	Route max.	926	594	994	195	130
NO_2	(µg/m^3)	Route average	757	300	319	154	127
$PM_{2.5}$	(µg/m^3)	Route average	314	236	331	140	124
PM_{10}	(µg/m^3)	Route average	383	286	404	168	148

Table 4-7 provides a wind sensitivity analysis to 10km/hr traffic, with wind from the north. There is a theoretical stagnation point found in the numerical modelling, however, if the wind increases or decreases by 0.1 m/s, the air returns to an acceptable quality. This theoretical point will not occur in reality due to the transient nature of traffic and wind and therefore is not considered as a design case.

Table 4-7: Internal air quality, inclusive of ambient air conditions – 10km/hr traffic, wind from north

Pollutant	Units	Averaging period	No wind	0.13 m/s wind (theoretical stagnation point)	0.2 m/s wind	0.5m/s wind	8 m/s wind
CO	(mg/m^3)	Route average	6	290	7	7	3
NO_2	(µg/m^3)	Route max.	926	82689	1438	1337	132
NO_2	(µg/m^3)	Route average	757	22269	580	621	128
$PM_{2.5}$	(µg/m^3)	Route average	314	19898	438	414	125
PM_{10}	(µg/m^3)	Route average	383	24620	536	506	149

Congested traffic – 80 km/hr

Table 4-8 provides a wind sensitivity analysis to 80km/hr traffic, with wind from the south. As the traffic speed is higher, the wind speed of interest is higher to slow the air. There are no stagnation points and air quality remain below limits for all wind speeds.

Table 4-8: Internal air quality, inclusive of ambient air conditions – 80km/hr traffic, wind from south

Pollutant	Units	Averaging period	No wind	5 m/s wind	8 m/s wind	10 m/s wind	12 m/s wind
CO	(mg/m^3)	Route average	3	3	3	4	5
NO_2	(µg/m^3)	Route max.	178	171	224	399	159
NO_2	(µg/m^3)	Route average	165	153	167	206	140
$PM_{2.5}$	(µg/m^3)	Route average	158	154	188	302	146
PM_{10}	(µg/m^3)	Route average	190	184	227	368	175

Table 4-9 provides a wind sensitivity analysis to 80km/hr traffic, with wind from the north. Again, there is a theoretical stagnation point at 3.2 m/s however 0.1 m/s winds provide acceptable air quality.

Table 4-9: Internal air quality, inclusive of ambient air conditions – 80km/hr traffic, wind from north

Pollutant	Units	Averaging period	No wind	3.1 m/s wind	3.2 m/s wind (theoretical stagnation point)	3.3 m/s wind	5 m/s wind
CO	(mg/m^3)	Route average	3	4	543	5	3
NO_2	(µg/m^3)	Route max.	178	443	113427	669	192
NO_2	(µg/m^3)	Route average	165	230	22870	297	158
$PM_{2.5}$	(µg/m^3)	Route average	158	331	74017	478	168
PM_{10}	(µg/m^3)	Route average	190	404	91600	586	202

4.1.3 Generator Darling Park Tower 1

The 80 km/hr normal case was run with the three generators from Tower 1 switched on at 100% load. The full generator load is conservative, no information about the load percentage or frequency has been provided. The results are below in Table 4-10.

Table 4-10: Internal air quality with generators from tower 1, inclusive of ambient air conditions

Pollutant	Units	Averaging period	Normal - 80 km/hr
CO	(mg/m^3)	Route average	5
NO_2	$(\mu g/m^3)$	Route max.	5181
NO_2	$(\mu g/m^3)$	Route average	2932
$PM_{2.5}$	$(\mu g/m^3)$	Route average	158
PM_{10}	$(\mu g/m^3)$	Route average	190

The Tower 1 generators switched on provide an air quality inside the existing Darling Park Underpass that exceeds both the NO_2 point maximum and 15-minute average limits. The values are 2-3 times higher than the limits. This scenario is modelled with 80km/hr traffic. The results will be worse for slower moving traffic.

Figure 3 below shows the NO_2 concentration in the underpass where the generators from Tower 1 are exhausted to. The traffic direction in the underpass is from 160m to 0m chainage on the graph shown. Tower 1 is located at 120m chainage.

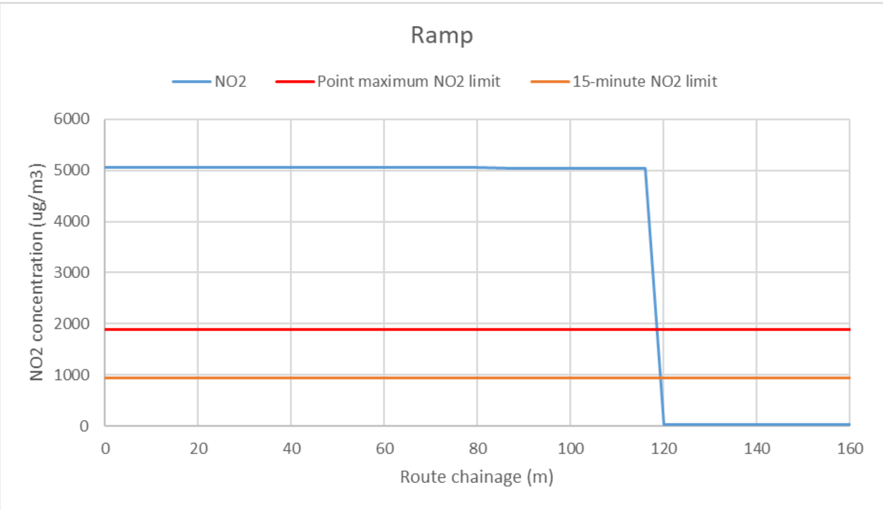

Figure 3 Ramp NO2 levels with generators from Tower 1 running – 80km/hr traffic

From the figure above, the generators from Tower 1 exceed both point maximum and 15-minute NO_2 limits and provide an unacceptable air quality inside the landbridge section.

Given the above findings, exhausts from Darling Park Tower 1 generators will be re-routed so as to not be exhausted beneath the landbridge. As a result, the design scenario described in section 4.1 which assumes that the generators are switched off remains valid. Re-routing these exhausts will also provide an improvement to the current scenario where the exhaust location is directly beneath existing publicly used footbridges.

4.1.4 Generator Darling Park Tower 2

Exhaust from the existing diesel generators in Darling Park Tower 2 vent into the Darling Park underpass at a location 40 m from the southern exit portal. In the event that these generators switch on, pollutants in the underpass are typically pulled towards the exit portal in the direction of traffic, venting away from the landbridge and therefore have no impact on the air quality in the space under the future landbridge.

Under certain wind conditions, it is possible that the pollutants from the Tower 2 diesel generators will be forced northwards, against the direction of traffic, and into the air space under the future development. For the purposes of this landbridge air quality study, this report details the event where this occurs.

The full generator load considered for this study is conservative since no information about the load percentage or frequency has been provided at this stage of design. The following scenarios present an analysis of the wind conditions applied to the existing underpass portal that reverse the airflow within the ramp and push the pollutants from the generator in the opposite direction to traffic flow. The results are contained in Table 4-11 below.

Table 4-11: Internal air quality with generators from Tower 2, inclusive of ambient air conditions – 80km/hr traffic, south wind (opposing exit portal)

Pollutant	Units	Averaging period	No wind	Wind 9.1 m/s	Wind 10 m/s
CO	(mg/m^3)	Route average	4	30	14
NO_2	(µg/m^3)	Route max.	3492	80925	35929
NO_2	(µg/m^3)	Route average	861	13095	15410
$PM_{2.5}$	(µg/m^3)	Route average	158	599	303
PM_{10}	(µg/m^3)	Route average	190	736	369

For 80km/hr traffic, a wind velocity of 9.1m/s causes the air to stagnate within the ramp. A velocity above this pushes the air back along the ramp against the 80km/hr traffic.

The concentration along the ramp can be seen graphically for 9.1m/s wind and 10m/s wind in Figure 4 and Figure 5 below respectively.

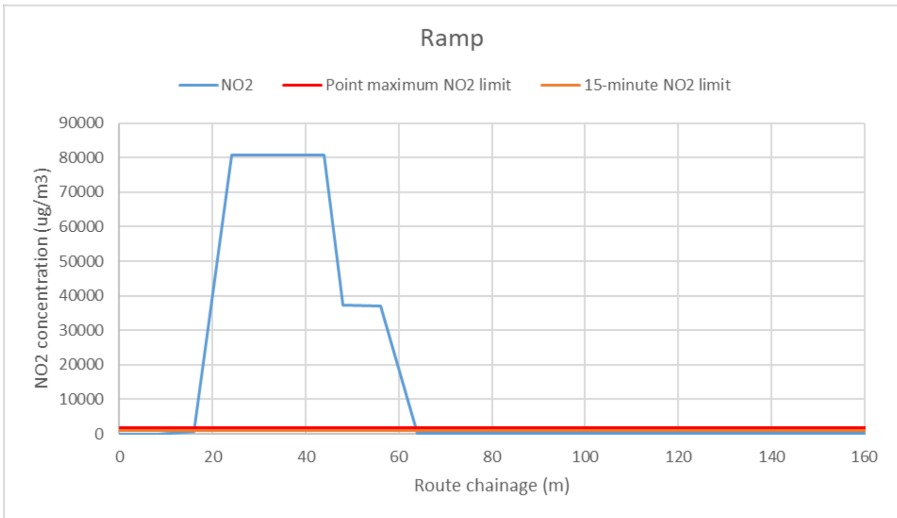

Figure 4 Ramp NO2 levels with generators from Tower 2 running – 80km/hr traffic, 9.1m/s wind at south portal

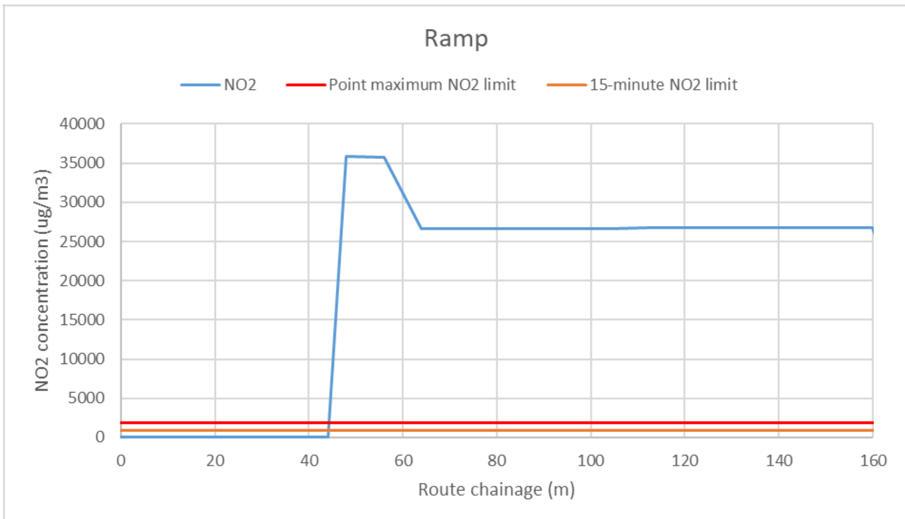

Figure 5 Ramp NO2 levels with generators from Tower 2 running – 80km/hr traffic, 10m/s wind at south portal

For 10m/s wind, the pollutants from the generator reach the connection to the main line. The main line NO_2 concentration can be seen in Figure 6 where the NO_2 levels rise at 100m due to the small 8m^3/s inflow from the ramp.

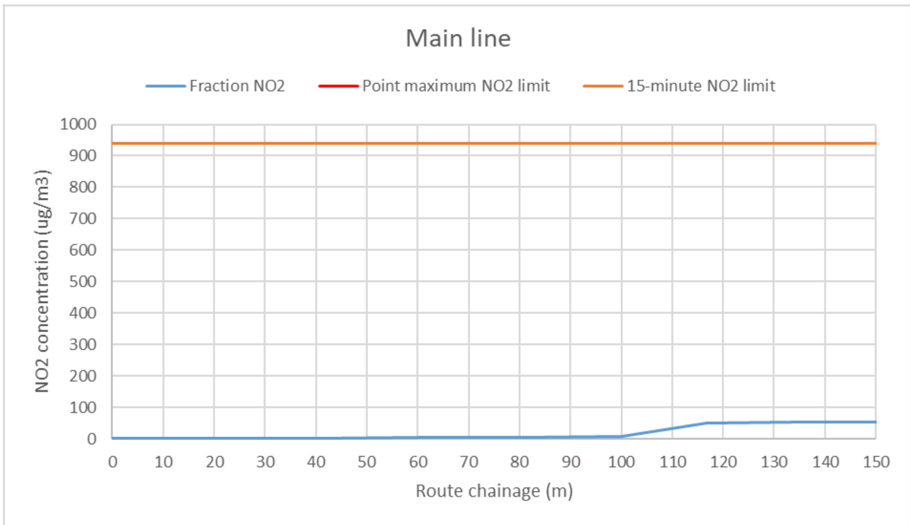

Figure 6 Main line NO2 levels with generators from Tower 2 running – 80km/hr traffic, 10m/s wind at south portal

The results demonstrate that, in the case where wind conditions force the Tower 2 generator pollutants against the traffic flow in the Darling Park underpass, and hence into the airspace under the future landbridge, the air quality under the landbridge is acceptable and pollutant levels are below the exposure limits.

4.1.5 Car park pollutants from Tower 2

Table 4-12 provides the air quality within the landbridge for normal 80km/hr traffic and congested 10km/hr traffic with the pollutants from the car park at tower 1 being exhausted into the landbridge. For both cases, the air quality remains within limits.

Table 4-12: Internal air quality, inclusive of ambient air conditions

Pollutant	Units	Averaging period	Normal - 80 km/hr	Congested - 10 km/hr
CO	(mg/m^3)	Route average	3	8
NO_2	(µg/m^3)	Route max.	227	1357
NO_2	(µg/m^3)	Route average	176	830
$PM_{2.5}$	(µg/m^3)	Route average	176	484
PM_{10}	(µg/m^3)	Route average	212	593

Table 4-13 provides a wind sensitivity analysis to congested 10km/hr traffic with wind from the south.

Table 4-13: Internal air quality, inclusive of ambient air conditions – 10km/hr traffic, wind from south

Pollutant	Units	Averaging period	No wind	1 m/s wind	2 m/s wind	3 m/s wind	4 m/s wind
CO	(mg/m^3)	Route average	8	9	23	10	5
NO_2	(µg/m^3)	Route max.	1357	1385	4215	1562	641
NO_2	(µg/m^3)	Route average	830	611	924	752	380
$PM_{2.5}$	(µg/m^3)	Route average	484	508	1408	574	286
PM_{10}	(µg/m^3)	Route average	593	623	1737	704	348

A wind of 2m/s from the south produces unacceptable air quality within the landbridge. The results show that winds of 1m/s above and below 2m/s produce acceptable air quality. Therefore, this point is a stagnation point and will not occur in reality due to the transient nature of traffic and wind.

4.2 Maintenance access air quality assessment

The internal air quality assessment values are converted to 8-hour rolling averages and presented in Table 4-14. These can now be directly compared with the workplace exposure limits shown in Table 4-14.

Table 4-14: Workplace air quality limits and ambient air quality (8-hour averaging period)

Pollutant	Units	Averaging period	Workplace air quality limit	Ambient
CO	(mg/m^3)	8-hour	34	1.38
NO_2	(µg/m^3)	8-hour	5600	62

Table 4-15: Internal air quality inclusive of ambient air conditions (8-hr averaging period)

Pollutant	Units	Averaging period	Normal - 80 km/hr	Congested - 40 km/hr	Congested - 10 km/hr
CO	(mg/m^3)	8-hour	2	2	3
NO_2	(µg/m^3)	8-hour	83	111	360

The concentration of pollutants is within the required workplace exposure limits; however, it is recommended that maintenance activities are carried out during off-peak hours to reduce exposure. The results consider peak traffic volumes and are considered conservative. The values provided can also be used for non-maintenance workers such as people in the Darling Park Tower 1 loading dock or the ground floor entry to the new development.

4.3 Potential impacts on nearby locations

There are three nearby locations where air quality is of interest. These are the existing Darling Park Underpass intake vents, the car park openings next to the southbound Harbour Street and the ground level drop-off area for the new Cockle Bay Park development. The air quality at each of these points is provided in the sections below. This is used by the proponent to design the mechanical ventilation systems within the adjacent buildings.

4.3.1 Existing Darling Park Underpass intake vents

The Darling Park Underpass intake vents extract air from the western face of the underpass. There are two exhaust fans with capacity 45m^3/s and 42.5m^3/s at the south and north end respectively.

The pollutant levels in the air at each location are shown in Table 4-16 and Table 4-17 below for both normal 80km/hr traffic and congested 10km/hr traffic.

Table 4-16: Darling Park Underpass ventilation extraction stack – south (45 m3/s)

Pollutant	Units	Normal - 80 km/hr	Congested - 10 km/hr
CO	(mg/m^3)	3	5
NO_2	(µg/m^3)	173	837
$PM_{2.5}$	(µg/m^3)	178	316
PM_{10}	(µg/m^3)	162	333

Table 4-17: Darling Park Underpass ventilation extraction stack – north (42.5 m3/s)

Pollutant	Units	Normal - 80 km/hr	Congested - 10 km/hr
CO	(mg/m^3)	3	4
NO_2	(µg/m^3)	157	554
$PM_{2.5}$	(µg/m^3)	168	249
PM_{10}	(µg/m^3)	149	250

4.3.2 Car park openings next to the southbound Harbour Street

The car park next to the southbound Harbour Street can be seen in in Figure 7 below. The opening is a 70m long section shown in green.

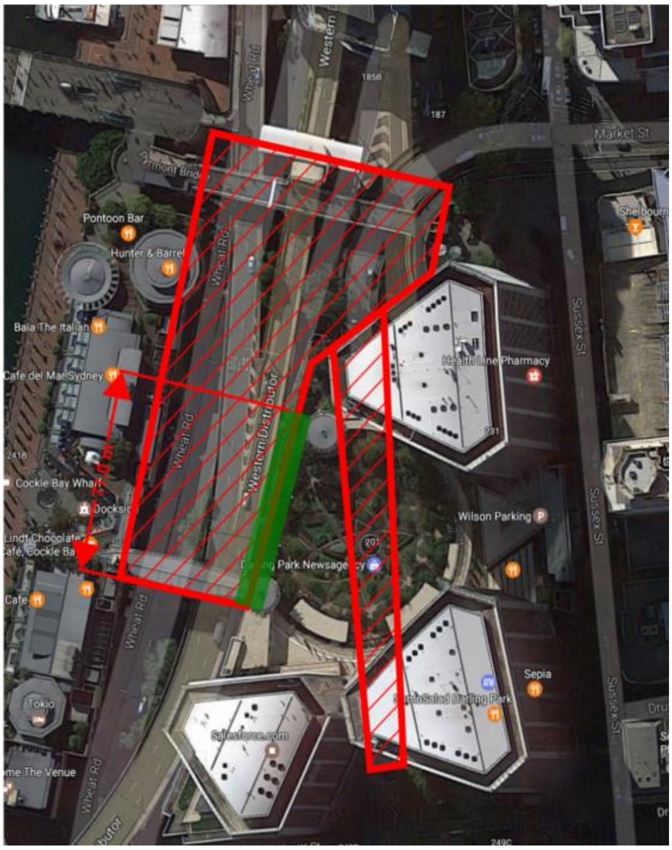

Figure 7 Carpark next to Southbound Harbour Street

The air quality averaged along this 70m open section from the main line can be seen in Table 4-18 below.

Table 4-18: Car park openings next to southbound Harbour St

Pollutant	Units	Normal - 80 km/hr	Congested - 10 km/hr
CO	(mg/m^3)	3	3
NO_2	$(\mu g/m^3)$	134	185
$PM_{2.5}$	$(\mu g/m^3)$	130	157
PM_{10}	$(\mu g/m^3)$	155	189

4.3.3 Open vehicle drop-off of new development

Approximately 50m from the north portal there is an open vehicle drop-off for a new development. The location is shown on Figure 8.

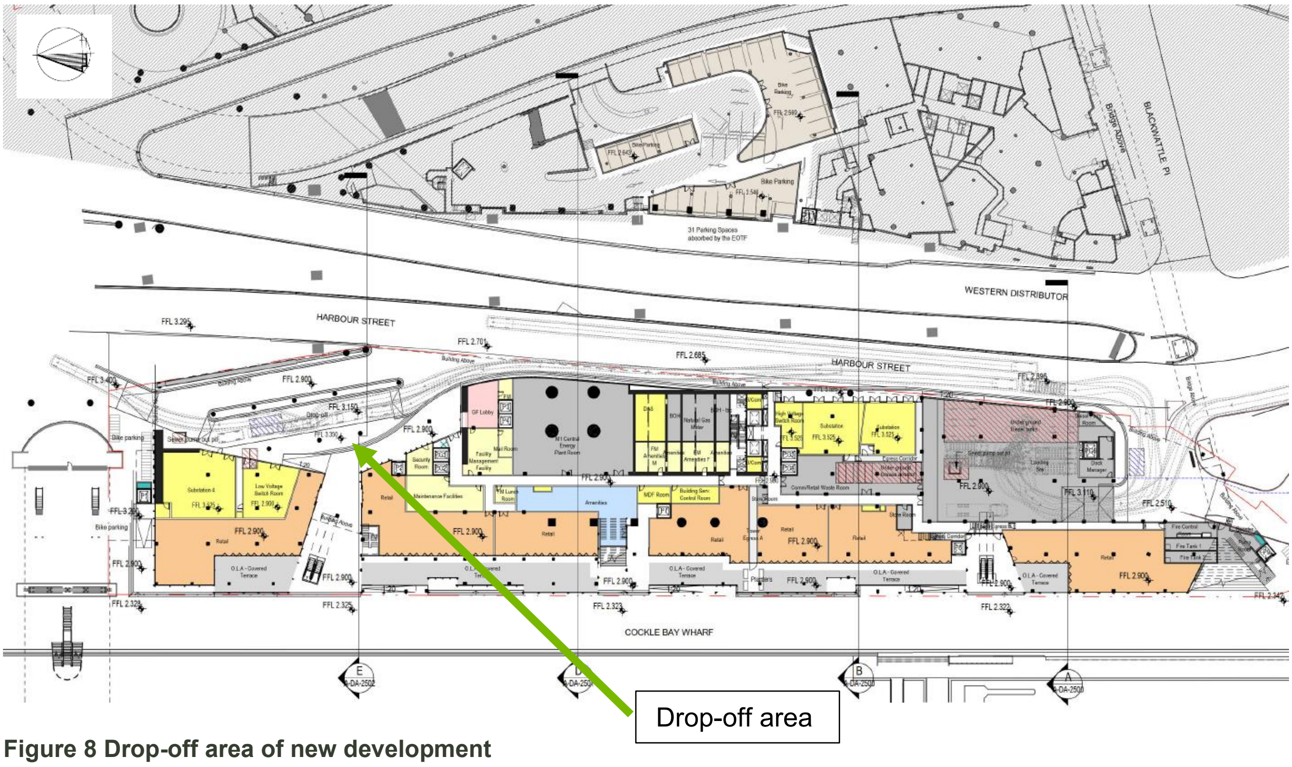

Figure 8 Drop-off area of new development

The air quality of the air at this location can be seen in Table 4-19 below.

Table 4-19: Internal air quality, inclusive of ambient air conditions – drop-off area of new development

Pollutant	Units	Normal - 80 km/hr	Congested - 10 km/hr
CO	(mg/m^3)	3	4
NO_2	(μg/m^3)	153	534
$PM_{2.5}$	(μg/m^3)	165	246
PM_{10}	(μg/m^3)	147	247

4.3.4 Tower 1 loading dock at street level

Approximately 90m from the north portal there is a loading dock for Tower 1 at street level. The location is shown on Figure 9.

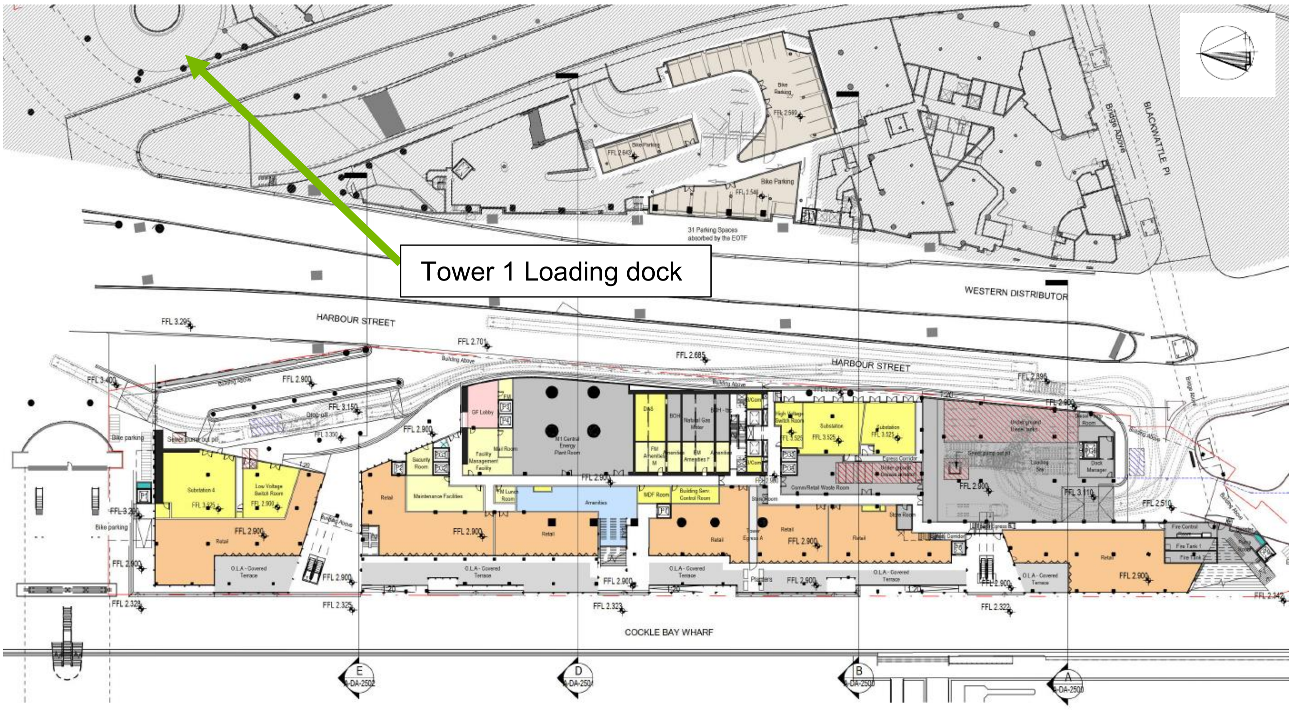

Figure 9 Tower 1 loading dock

The air quality of the air at this location can be seen in Table 4-20 below.

Table 4-20: Internal air quality, inclusive of ambient air conditions – Tower 1 loading dock

Pollutant	Units	Normal - 80 km/hr	Congested - 10 km/hr
CO	(mg/m^3)	3	4
NO_2	(µg/m^3)	159	612
$PM_{2.5}$	(µg/m^3)	169	263
PM_{10}	(µg/m^3)	151	267

5 Conclusions and recommendations

This desktop study has investigated the internal air quality below the landbridge for the proposed development at Cockle Bay Park. The internal air quality assessment shows that the limits are satisfied under normal, congested and stationary traffic conditions when there are no building generators switched on.

The analysis has shown that the presence of the existing Darling Park Tower 1 generator exhausts produce an unacceptable air quality beneath the landbridge. As a result, the Tower 1 generator exhausts shall be re-routed outside the landbridge extent.

Under certain wind conditions the pollutants from the Tower 2 generators are forced northwards in the Darling Park underpass against the flow of traffic and into the airspace under the future landbridge. These pollutants are sufficiently diluted and are within the acceptable criteria for air quality under the landbridge.

A check for the pollutants from the car park from Tower 2 has been conducted. The air quality is acceptable under all realistic wind scenarios.

A sensitivity analysis for wind has been conducted for both north and south portals. The analysis shows that there are certain wind conditions that produce air quality above the limits. These conditions are for small bands of wind velocities which have been shown to be very unlikely to be sustained for a length of time to produce unacceptable air quality under the landbridge. For these theoretical cases, a small change in wind or traffic flow produces acceptable air quality conditions. All other wind and traffic scenarios produce acceptable air quality within the landbridge area.

Acceptable air quality levels are also demonstrated for workplace exposure for both maintenance non-maintenance access scenarios.

6 References

WHO 2000, WHO Air Quality Guidelines for Europe, 2nd Edition, World Health Organization, Geneva.

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DoE 2016, National Environment Protection (Ambient Air Quality) Measure – as amended, Federal Register of Legislative Instruments F2016C00215, Department of the Environment, Canberra.

EPA 2016, Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales, Environmental Protection Authority NSW

PIARC, Road tunnels: Vehicle Emissions and Air Demand for Ventilation, 2019R02EN

PIARC, Vehicle Emissions, Air Demand, Environment Longitudinal ventilation, 1995

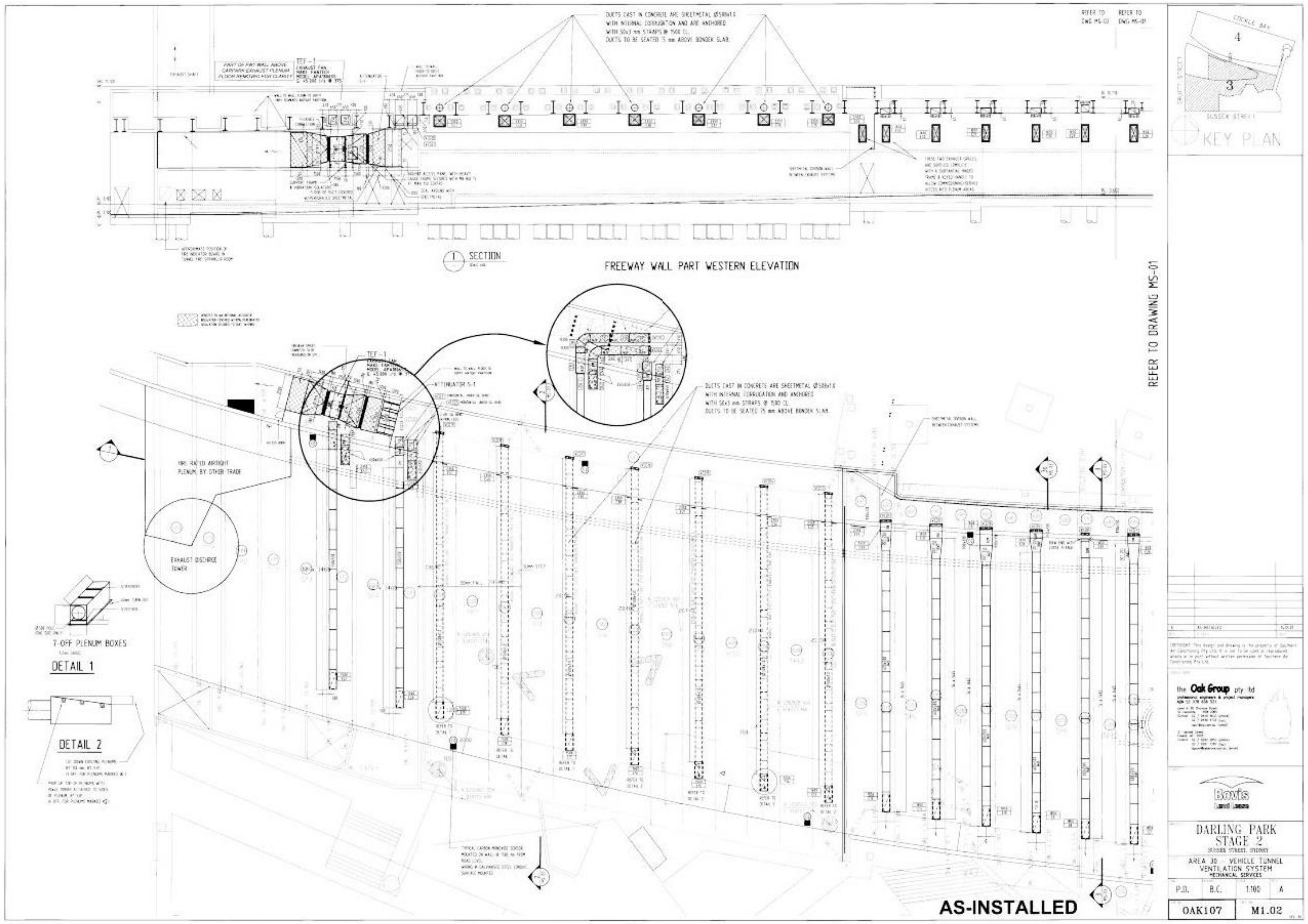
Australian Motor Vehicle Emission Inventory for the National Pollutant Inventory (NPI), 2014

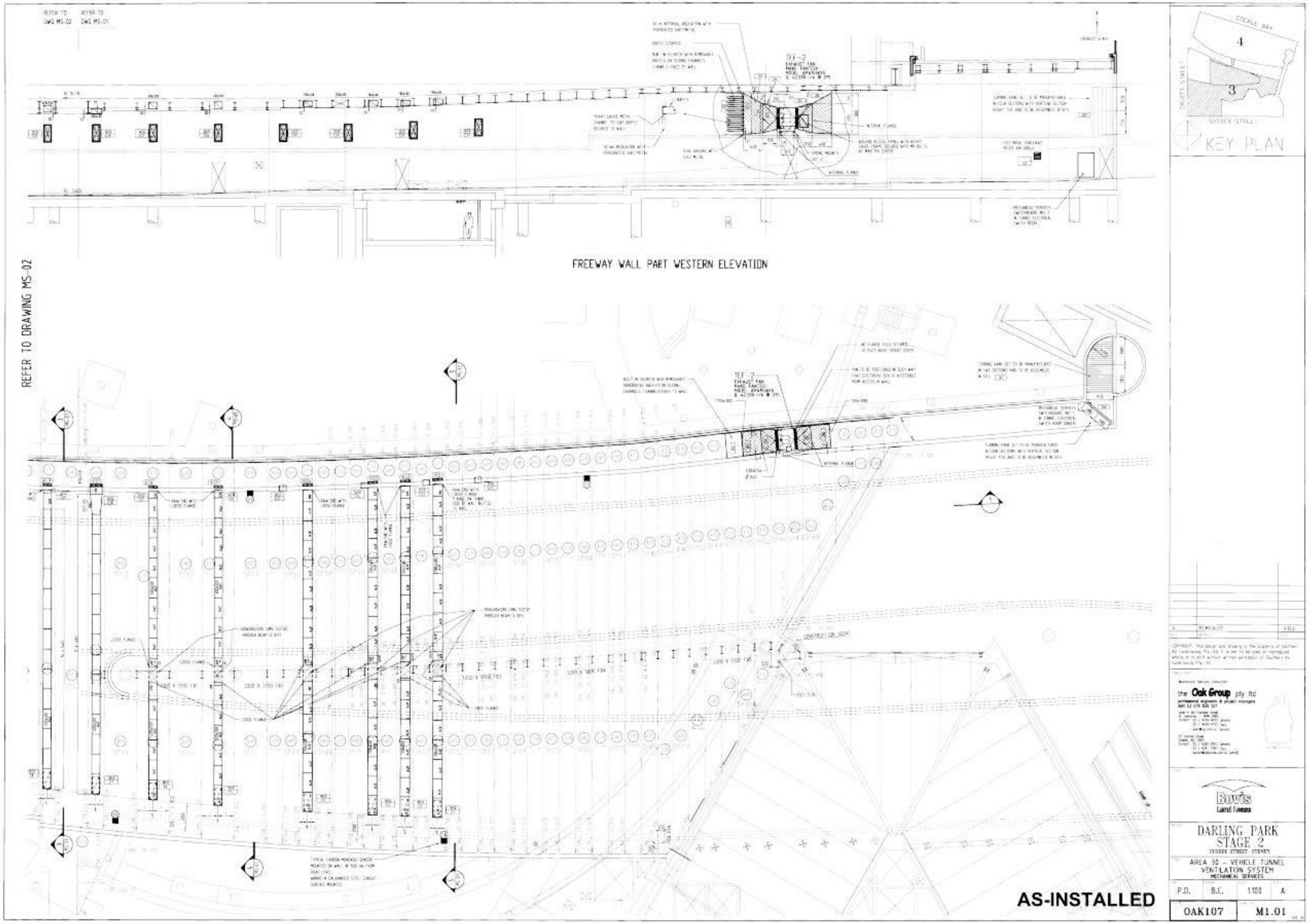
Pacific Environment, AQ-NW-001-21532, Environmental Impact Statement – State Significant Development Application 241-249 Wheat Road, Cockle Bay (SSD 784) Cockle Bay Wharf Redevelopment, December 2016.

Safe Work Australia, Workplace Exposure Standards for Airborne Contaminants, 2018.

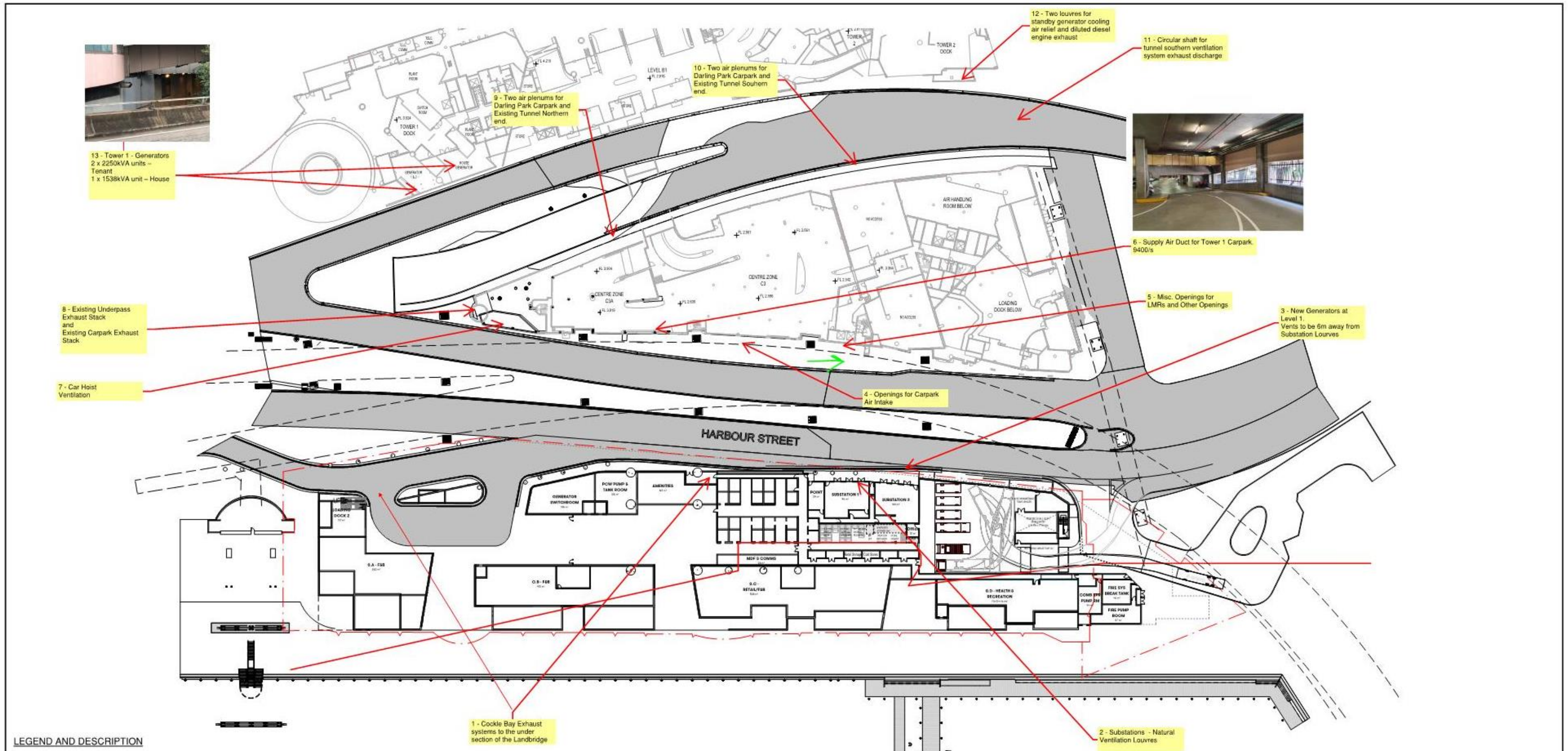
Appendix

Appendix A – Existing Darling Park Underpass ventilation drawing




FREEWAY WALL PART WESTERN ELEVATION
REFER TO DRAWING MS-02
KEY PLAN
the Oak Group pty ltd
DARLING PARK
STAGE 2
SUSSEX STREET, SYDNEY
AREA 30 - VEHICLE TUNNEL
VENTILATION SYSTEM
MECHANICAL SERVICES
OAK107
M1.01
AS-INSTALLED

Appendix B – Steensen Varming ventilation and exhaust discharges mark-up



LEGEND AND DESCRIPTION

1 - COCKLE BAY PODIUM RETAIL KITCHEN, TOILET AND GARBAGE ROOM EXHAUST. KITCHEN EXHAUST FILTERED WITH NO2 AND ODOUR ALSO REMOVED.

2- COCKLE BAY PODIUM SUB-STATION. NATURALLY VENTILATED TO REMOVE HEAT BUILD UP WITHIN THE SUB-STATION.

3- COCKLE BAY PODIUM STANDBY GENERATORS. DIESEL ENGINE EXHAUST AND EXHAUST VENTILATION TO REMOVE HEAT FROM THE GENERATOR.

4 - DARLING PARK CAR PARK NATURAL MAKE UP AIR OPENINGS. OPENINGS WITHIN THE WESTERN WALL OF THE CAR PARK TO ALLOW VENTILATION AIR TO ENTER THE CAR PARK.

5. LIFT MOTOR ROOM VENTILATION. OPENINGS WITHIN THE WESTERN WALL WITH LOUVRES TO ALLOW THE LIFT MOTOR ROOMS TO BE VENTILATED.

6. CAR PARK MECHANICAL SUPPLY AIR. LOUVRE IN THE WESTERN WALL OF THE CAR PARK CONNECTED TO A SUPPLY AIR FAN AND DUCTWORK SUPPLYING AIR INTO THE CAR PARK TUNNEL, SUPPLY AIR RATE 9400 l/s.

7 - EXHAUST LOUVRE IN THE WESTERN WALL OF THE CAR PARK. EXHAUSTS AIR FROM THE VEHICLE HOIST SHAFT.

8 - CIRCULAR EXHAUST STACK DIVIDED THROUGH THE CENTRE. SERVES AS AN EXHAUST DISCHARGE FOR BOTH THE ADJACENT CAR PARK AND THE NORTHERN END OF THE TUNNEL VENTILATION SYSTEM.

9 - TWO SEPARTE EXHAUST PLENUMS, ONE FOR THE NORTHERN END OF THE TUNNEL VENTILATION SYSTEM 42,500 l/s AND THE OTHER FOR THE CAR PARK NORTHERN EXHAUST SYSTEM 48,820 l/s. BOTH SYSTEMS CO CONTROLLED AND DISCHARGING INTO THE CIRCULAR STACK (8).

10 - TWO SEPARATE EXHAUST PLENUMS, ONE FOR THE SOUTHERN END OF THE TUNNEL VENTILATION SYSTEM 45,000 l/s AND THE OTHER FOR THE CAR PARK SOUTHERN EXHAUST 19,000 l/s. BOTH SYSTEMS CO CONTROLLED, TUNNEL EXHAUST DISCARGING INTO THE CIRCULAR STACK (11).

11 - CIRCULAR EXHAUST STACK SERVING AS THE DISCHARGE FOR THE SOUTHERN TUNNEL VENTILATION SYSTEM

12 - TWO LOUVRES WITHIN THE EASTERN WALL OF THE TUNNEL. STANDBY GENBERATOR COOLING AIR EXHAUST LOUVRES.

13 - TWO STANDBY GENERATOR DIESEL EXHAUST DISCHARGES. DIESEL ENGINE EXHAUST FUMES.

VENTILATION AND EXHAUST DISCHARGES IN AND AROUND THE EXISTING TUNNEL AND PROPOSED UNDERPASS - PREPARED BY STEENSEN VARMING 07/07/2020

DESIGNED UNDER QUALITY SYSTEM CERTIFIED AS COMPLYING WITH ISO 9001 BY AN ACCREDITED CERTIFICATION BODY

STAGE 3A

AMENDMENTS

REV	DESCRIPTION	DATE
A	CONCEPT VALIDATION STAGE	07/07/20

Copenhagen, London, Sydney, Hong Kong, New York

8, 9 Castlereagh St.
Sydney, NSW, 2000, Australia
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STEENSEN VARMING

PROJECT
COCKLE BAY PARK DEVELOPMENT
SYDNEY, NSW

DRAWING TITLE
MECHANICAL SERVICES
SITE VENTILATION LAYOUT

A3

CREATED	DRAWN	DESIGN	CHECKED	APPROVED	SCALE
JUN'20	MH	MH	BAJ	MH	NTS

PROJECT No.	DRAWING No.	REVISION
197161	CBP-SK-STE-ELE-DRW-10-115-0	A

Appendix C – Steensen Varming various openings to existing tunnel and proposed landbridge

RE: 197161 - Landbridge - various HVAC openings to the existing tunnel and proposed landbridge

MH Michael Harrold <michael.harrold@steensenvarming.com>

Reply | Reply All | Forward | ...

To Michael O'Brien

Wed 8/07/2020 5:55 PM

Cc Roland Towning; Ben Jones; Justin Woodcock; Doug Southwell (dougs@scottcarver.com.au); Viggo Haremst; Chris Arkins; Cristian Biotto; David Moore

You forwarded this message on 8/07/2020 9:28 PM.

- 197161 - generators
  Outlook item
- 197161 - CBP Darling Park Tunnel Ventilation
  Outlook item
- 197161 CAN M05 rev 0 Impact of the new Landbridge on the Darling Park Tower 2.pdf

Michael

Just making sure you have this information attached and below.

For Carbon Monoxide (CO) and Nitrogen Dioxide (NO2)

Kitchen
Generally air quality from kitchens are not normally assessed in detail however we have made an assessment regards to the kitchen exhaust system based on advice received from Airepure Australia that their filtration media will remove Nitrogen Dioxide from the gases being exhausted.

Generally :
Elect cooking – has nil CO
Gas cooking - has minimal CO (only if not maintained)

Existing - Generators
See attached email. We assume you can use this info. The impact of these would be much greater than the kitchen.

Existing - Others
We believe the others to be vented air and minimal discharge.

If exact data is required it can be measured.
Let me know.

Regards

Michael Harrold
Associate Director
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STEENSEN VARMING

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aurecon

Bringing ideas to life

Appendix F

Falling Objects Report

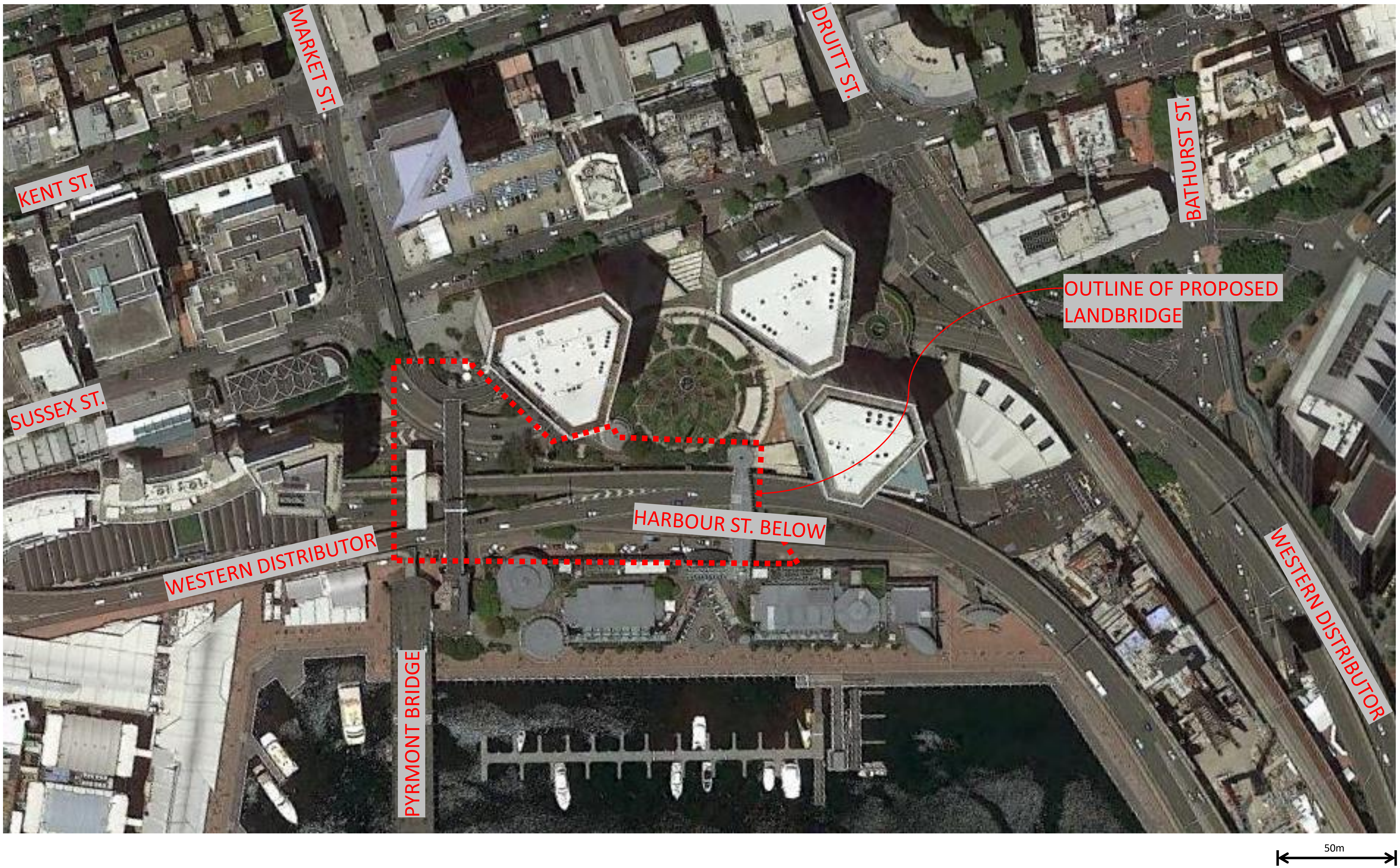
COCKLE BAY PARK
SYDNEY

Landbridge Edge Protection

TfNSW 2020.09.17

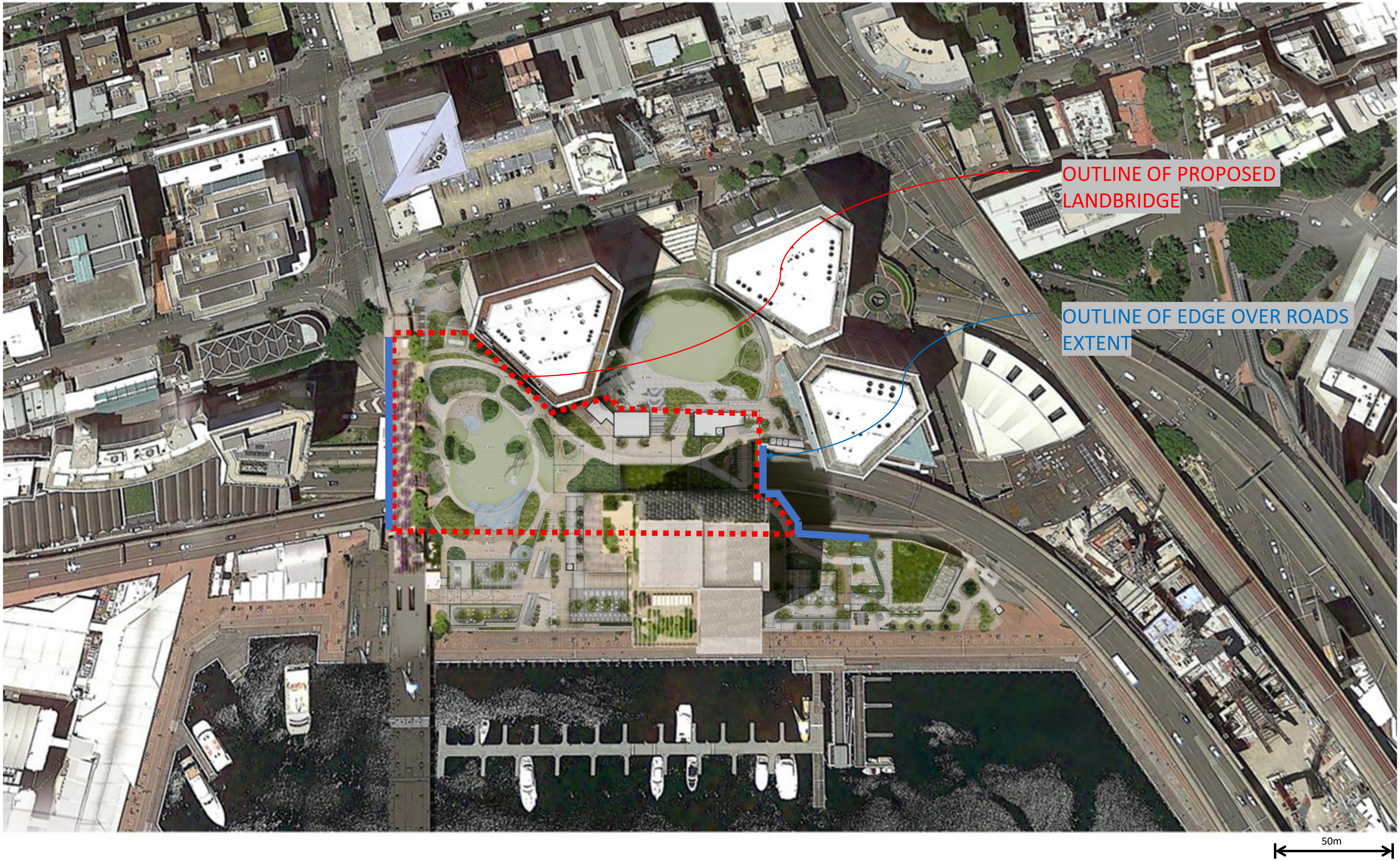
GPT The GPT Group
AMP CAPITAL
Henning Larsen
geoffreything.studio
MCGREGOR COXALL
architectus
ARUP
enstruct

Cockle Bay – Existing Aerial View



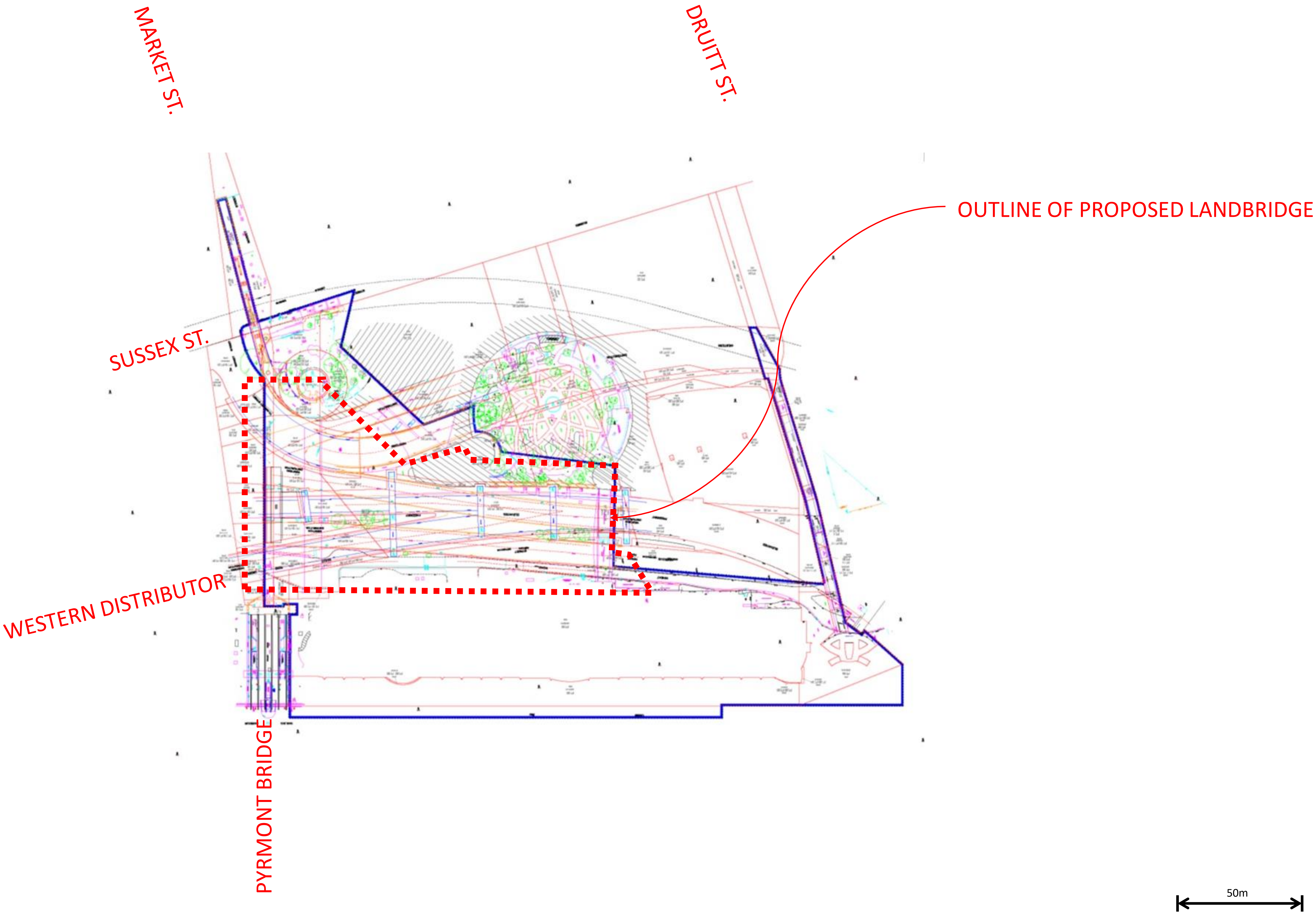
Henning Larsen geoffreything.studio MCGREGOR COXALL architectus enstruct ARUP

Cockle Bay Park Public Domain - Proposal



Henning Larsen geoffreything.studio MCGREGOR COXALL architectus enstruct ARUP

Cockle Bay – Existing Survey



Cockle Bay Park – Risk Assessment Matrix

Assessment Factor No	Description	W	S	WxS
1	Type of road/speed	2	8	16
2	Pedestrian Bridge	10	10	100
3	Distance from school	9	8	72
4	Distance from hotel or club	8	4	32
5	Distance from youth attraction	6	8	48
6	Other pedestrian generators	1	10	10
7	Lightning	3	0	0
8	Exposure from adjacent buildings	7	0	0
9	Exposure from passing traffic	7	0	0
10	History of graffiti	10	0	0
11	Any loose objects	4	0	0
Sum of WS				278
Risk Rating Score = WS/11		25.2727		
If rating > 30 warrants action				

Assessment Matrix for Sussex St. / Harbour St.

Assessment Factor No	Description	W	S	WxS
1	Type of road/speed	8	8	64
2	Pedestrian Bridge	10	10	100
3	Distance from school	9	8	72
4	Distance from hotel or club	8	4	32
5	Distance from youth attraction	6	8	48
6	Other pedestrian generators	1	10	10
7	Lightning	3	0	0
8	Exposure from adjacent buildings	7	0	0
9	Exposure from passing traffic	7	0	0
10	History of graffiti	10	0	0
11	Any loose objects	4	4	16
Sum of WS				342
Risk Rating Score = WS/11		31.0909		
If rating > 30 warrants action				

Assessment Matrix for Western Distributor

Assessment Criteria

Assessment for the need for safety screens on bridges over roads shall be carried out using the formal risk assessment process set out in Appendix 2.

The risk assessment factors to be considered and scored are as follows:

- Previous history of incidents and/or signs of graffiti in the vicinity of the bridge
- Ease of pedestrian access
- Type of road underneath
- Posted speed of the road underneath
- Proximity to pedestrian traffic generators such as schools, hotels, clubs, sporting venues etc
- Lighting
- Visibility of pedestrians on the bridge to traffic on the bridge and to traffic passing under the bridge
- Amount of loose material nearby

Source: TfNSW Bridge Technical Direction btd2012_01

Cockle Bay Park – Design of Safety Screens on Bridges

Geometric Requirements

Safety screens shall have the following geometrical properties:

(a) A minimum height of 3.0 m above the roadway or footway surface or 2.0 m above the top rail or top surface of any adjacent pedestrian or traffic barrier, whichever is the greater.

(b) The safety screen shall extend at least 6 m beyond the edge lane line of the roadway below or, if this is not possible, to within 1 m of the end of the Abutment wing walls or on pedestrian and shared path bridges to the landings at the end of the main bridge spans.
The safety screen shall be at or above the minimum height for a distance of at least 2 m past the outer edge lane line of the roadway below, and may then taper down in height.

(c) Where the safety screen is adjacent to the traffic carriageway, the screen shall have a minimum setback from the inside face of the traffic barrier of 350 mm.

(d) For pedestrian footways on road bridges and on pedestrian bridges the safety screens shall have a minimum head clearance of 2.20 m at the inside face of the railing and 2.40 m at 150 mm from the inside face of the railing or handrail.

(e) On shared path bridges and cycleways the safety screens shall have a minimum head clearance of 2.5 m at 300 mm from the inside face of the adjacent railing or handrail.

(f) A minimum clear width of 80 mm shall be provided between the safety screen and the railing or handrail.

(g) Post spacing shall not exceed 3 m. However, as the standard size of a mesh panel is 2.4 x 3.0 m, post spacing based on an infill panel width of 2.4 m will eliminate the need for a 2 mesh panels vertically.

(h) Pedestrian and shared path bridges with a clear width between railings or handrails of up to 3.0 m may be fully enclosed, but measures shall be taken to restrict unauthorised access onto the top of the screen. On shared path bridges the minimum head clearance over the central 2.0 m of the bridge carriageway shall be 3.0 m.

(i) For safety screens that are not fully enclosed, the maximum effective outward slope measured to a straight line drawn through the top of the infill panel and the bottom of the infill panel at the top of the parapet or kerb shall not exceed 1 in 10.

(j) Posts for safety screens that are located on a bridge where the longitudinal grade of the bridge exceeds 6% at any point, shall be detailed to be truly vertical for the full extent of the screens. Where the longitudinal grade does not exceed 6% at any point, the posts should normally be perpendicular to the top of the concrete parapet or footway surface.

Source: TfNSW Bridge Technical Direction btd2012_01

Advice Received from TfNSW following presentation on 28 May 21

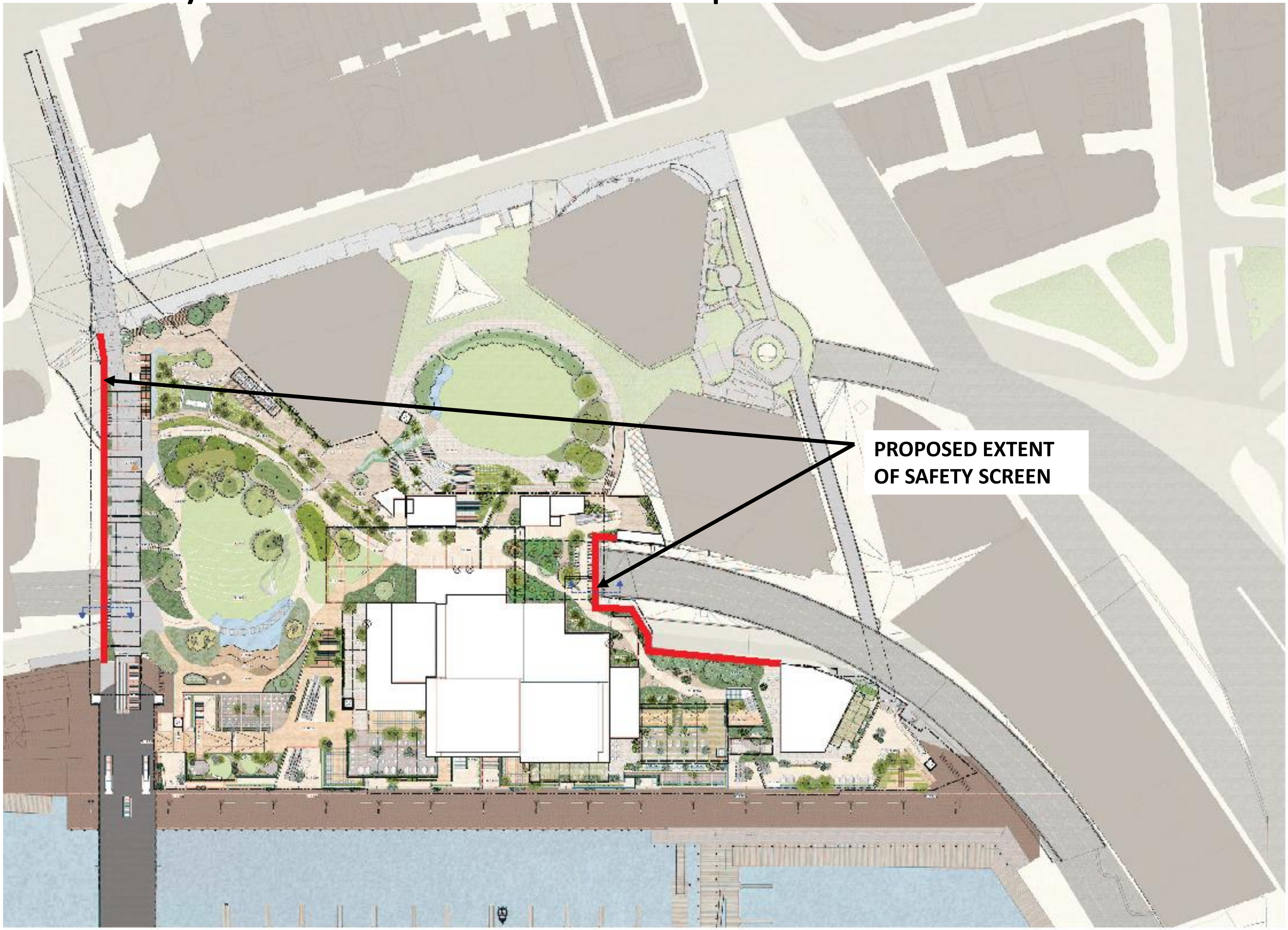
Western Distributor edge

- The risk assessment is over 30 risk rating so will need to follow the BTD geometric requirements
- material choice for the infill panels may be flexible, such as safety glass/Perspex as long as the design still qualifies the geometric requirements

The Sussex St. / Harbour St edge

- The risk assessment is under 30 and doesn't need an exemption from the technical direction
- but will still need to follow the usual design process and be approved by bridge branch
- from an urban design perspective there should be some design continuity between the design of the two edge treatments

Cockle Bay Park – Screen Extent Proposal



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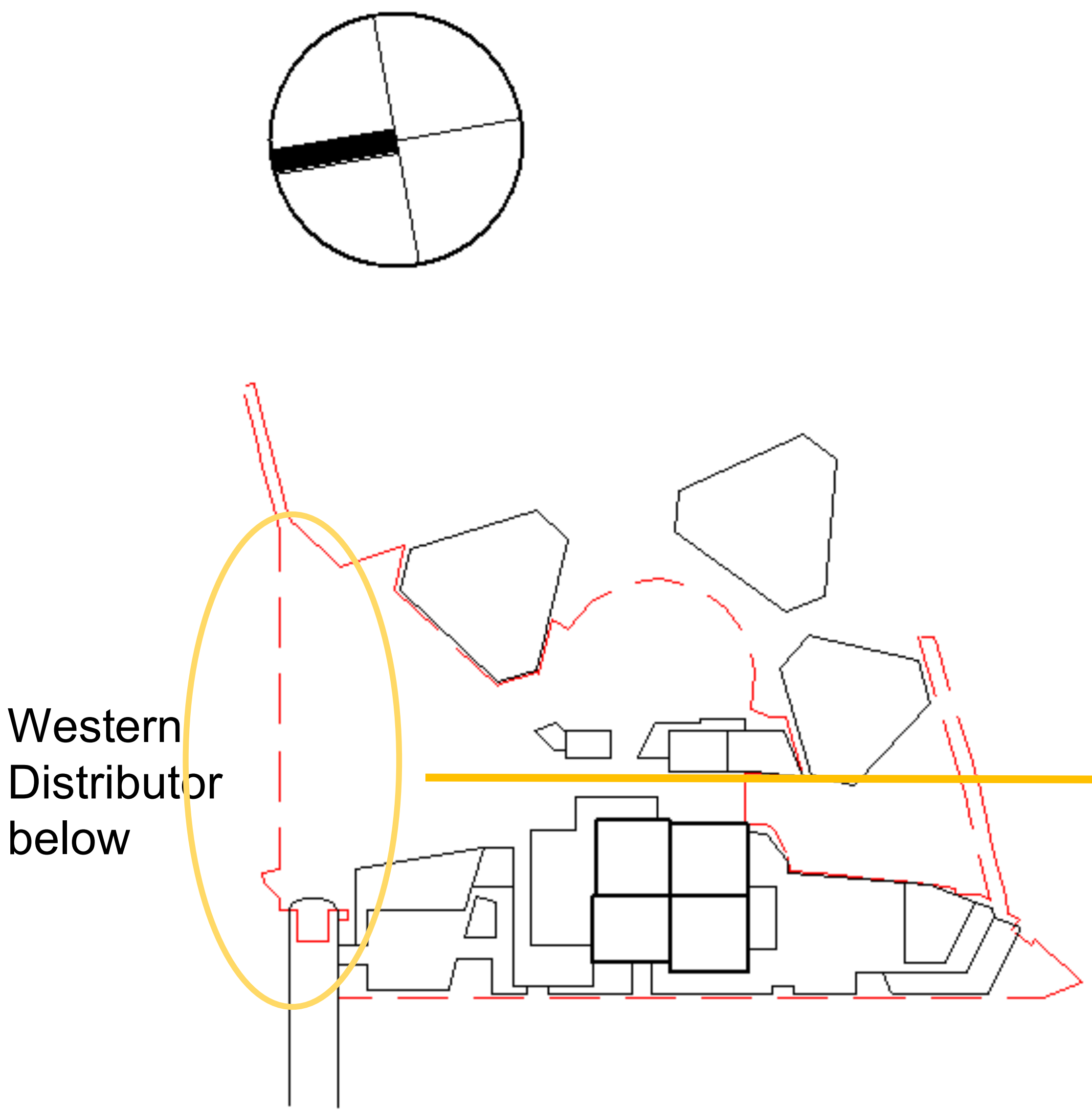
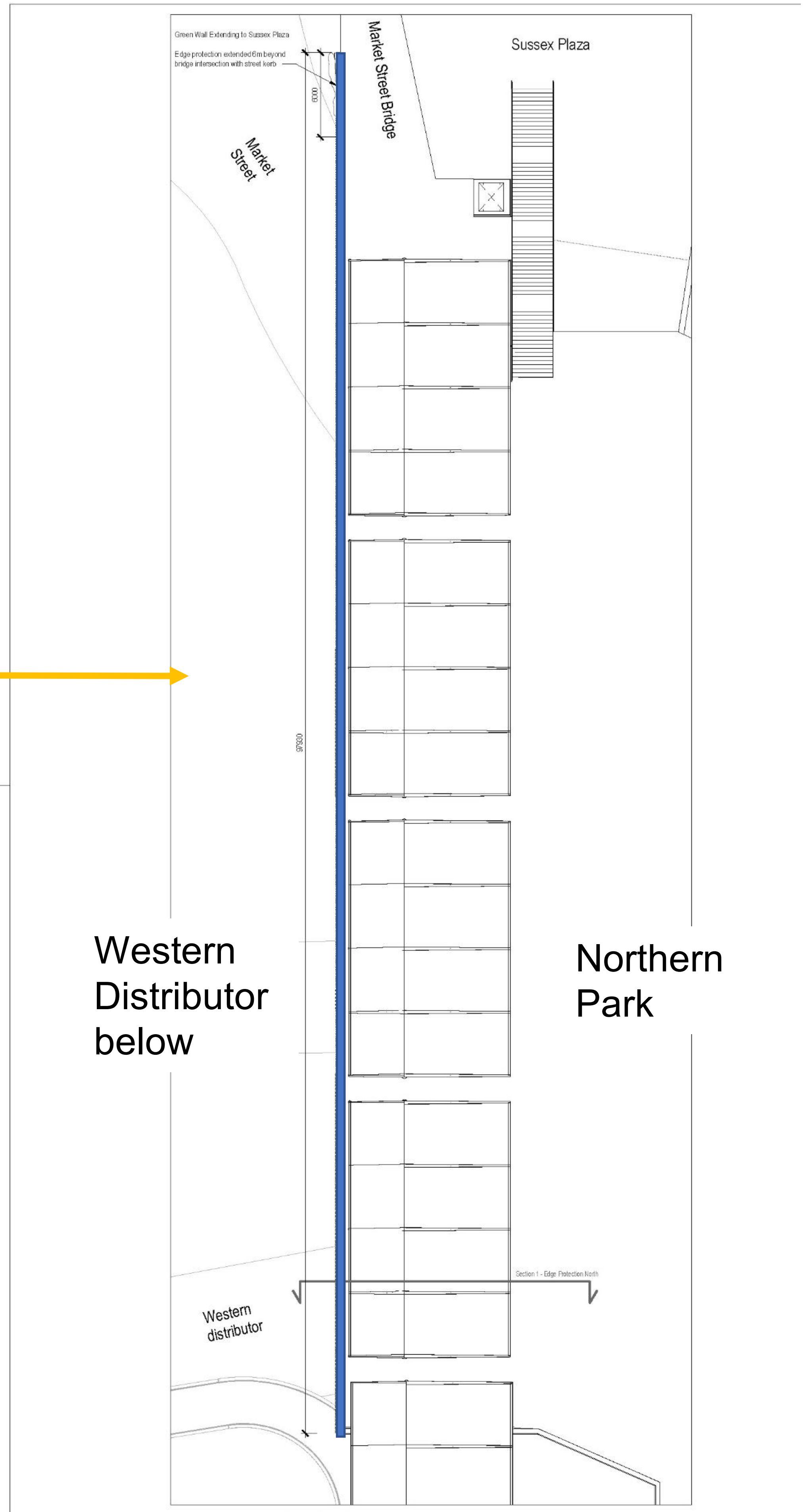
North Arrival

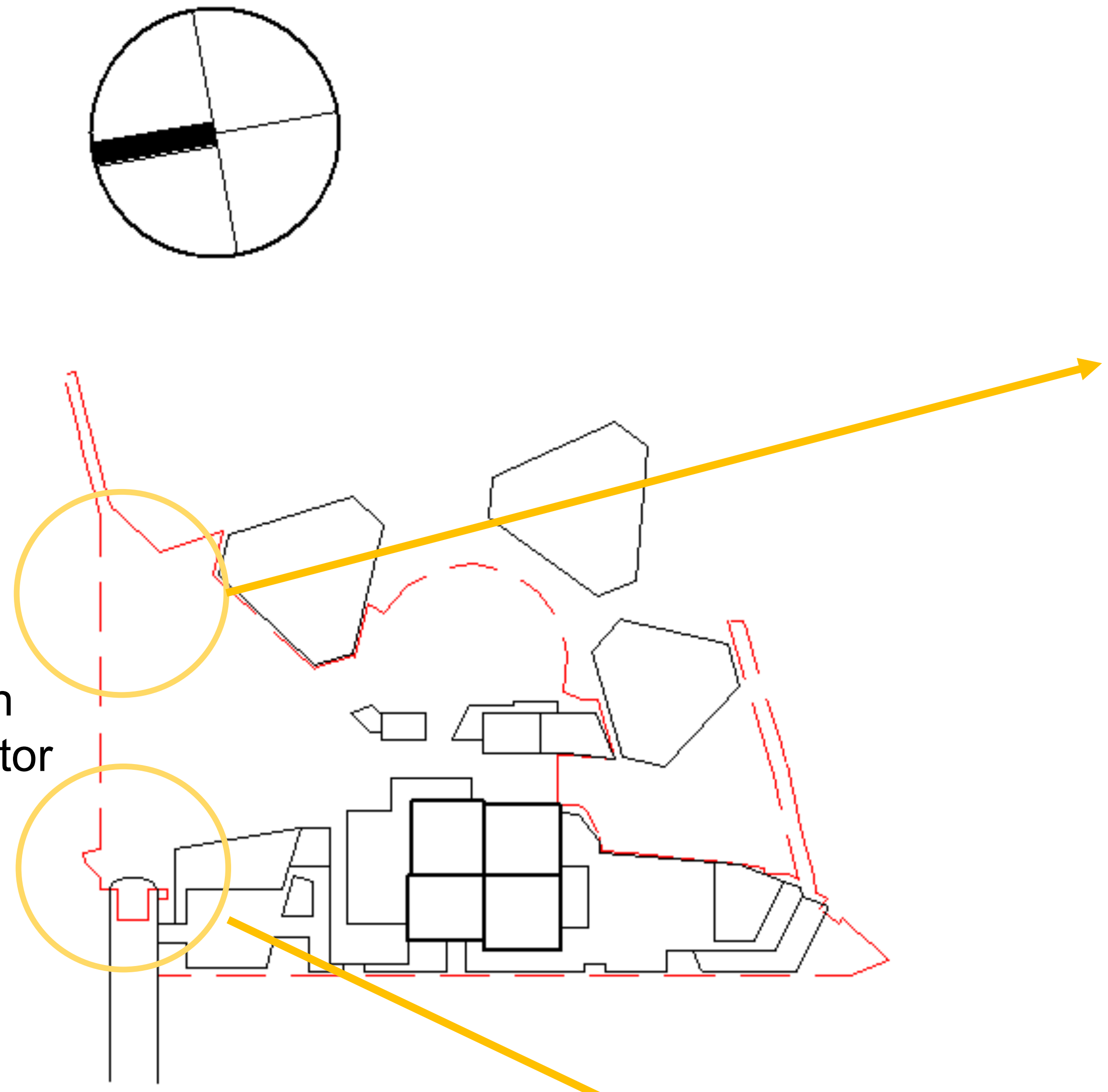
Cockle Bay Park – Screen Extent Proposal - North



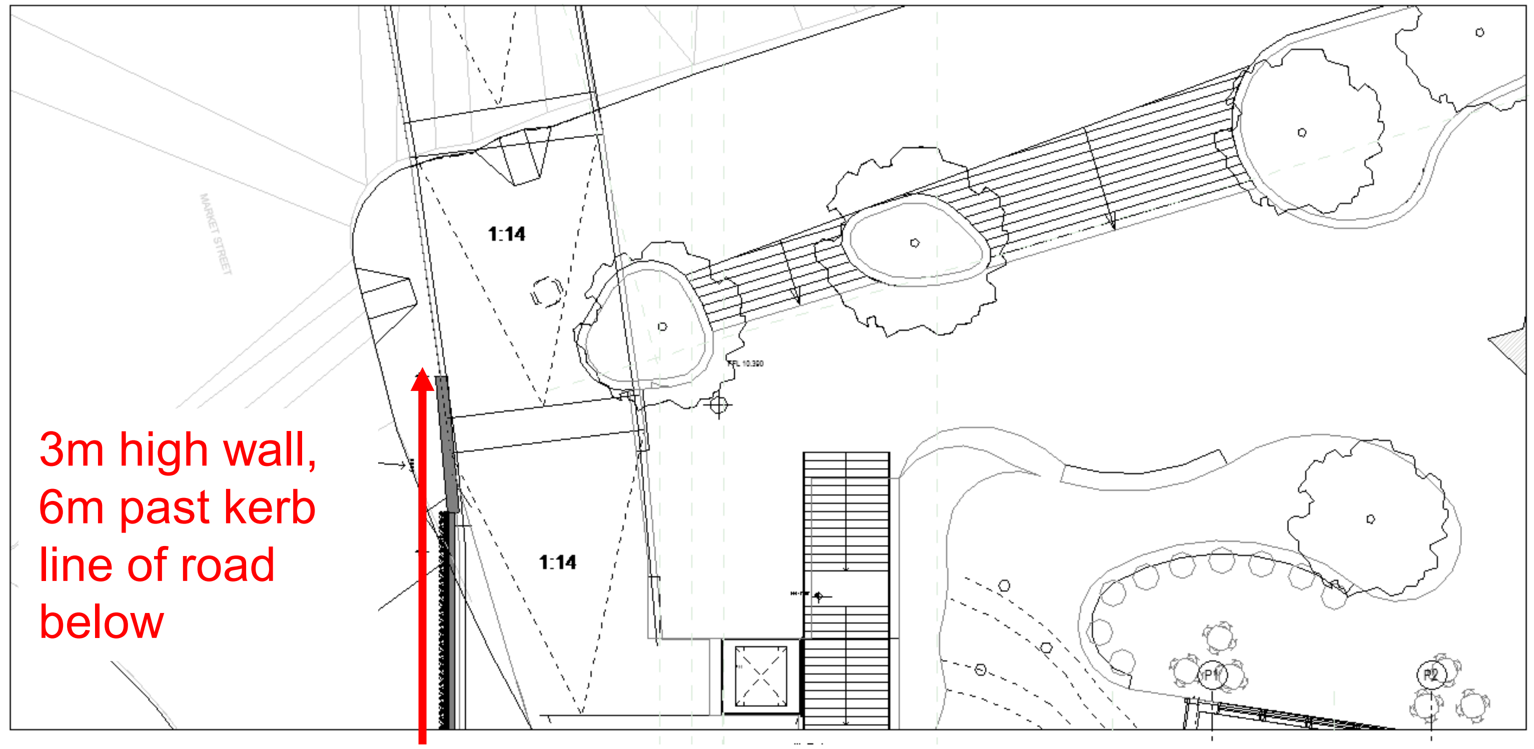


Level 3 - North Landbridge edge protection
1:200

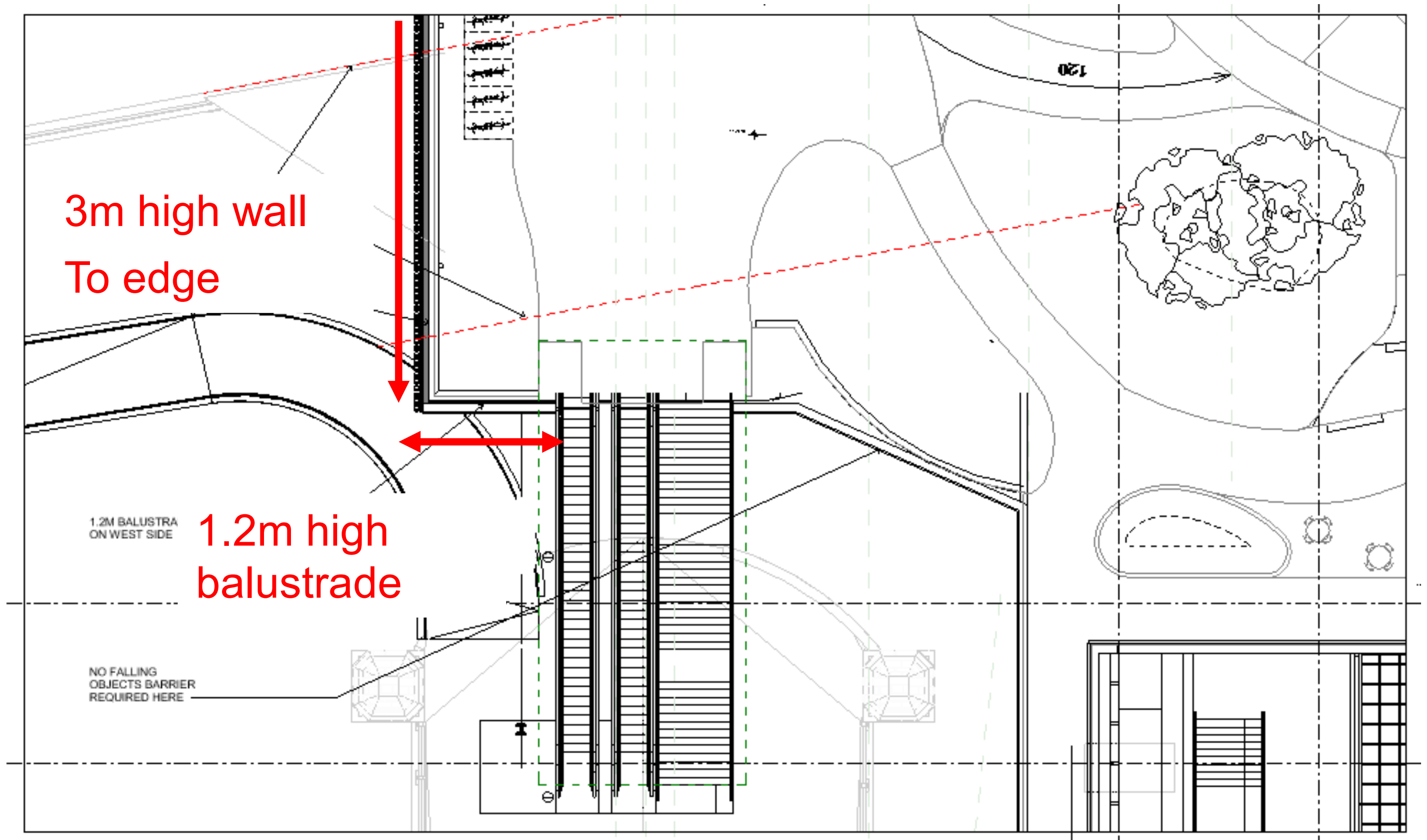
Cockle Bay Park – Screen Extent Proposal – North (cont.)



Western Distributor below

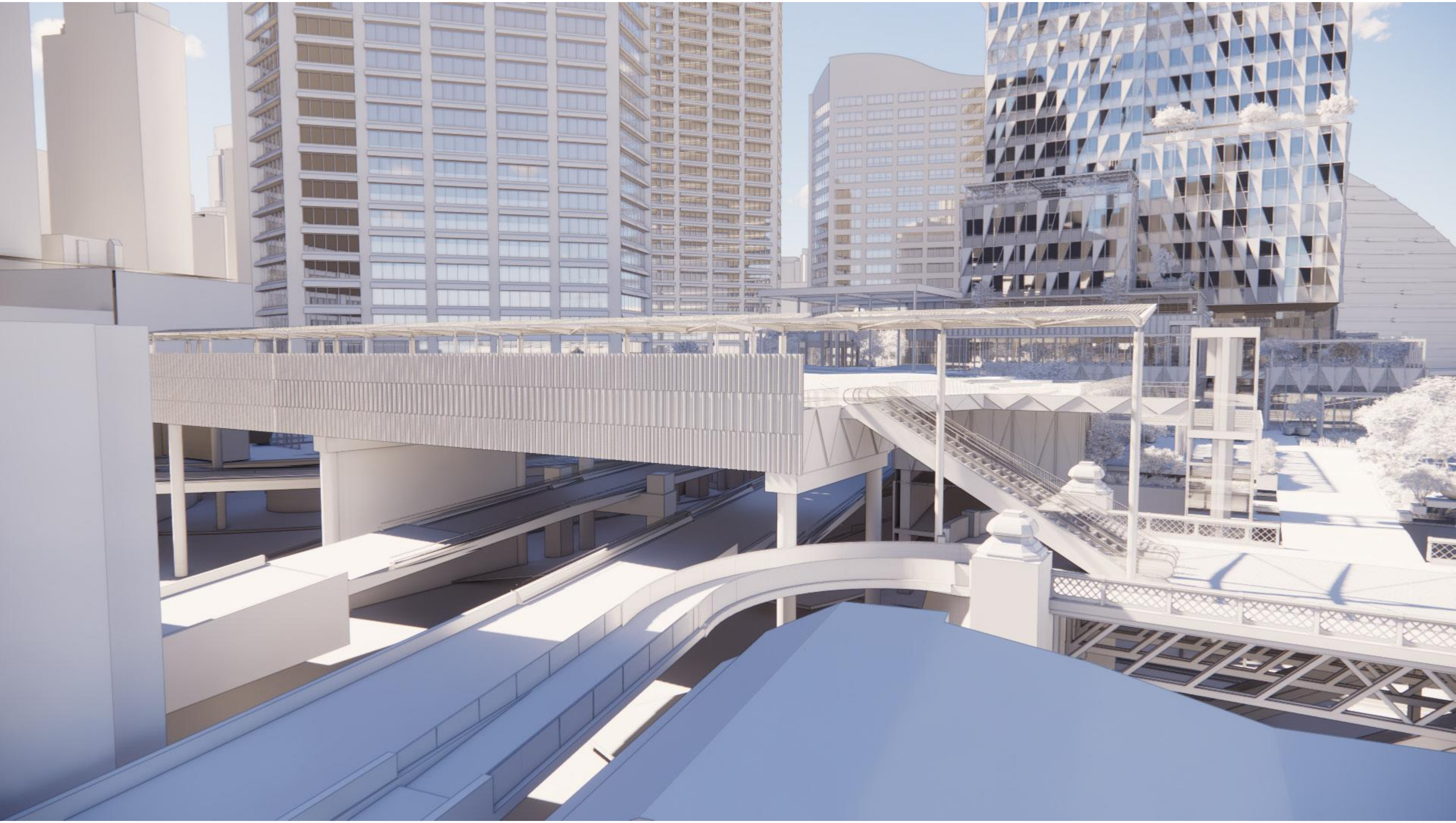


NE Detail Plan

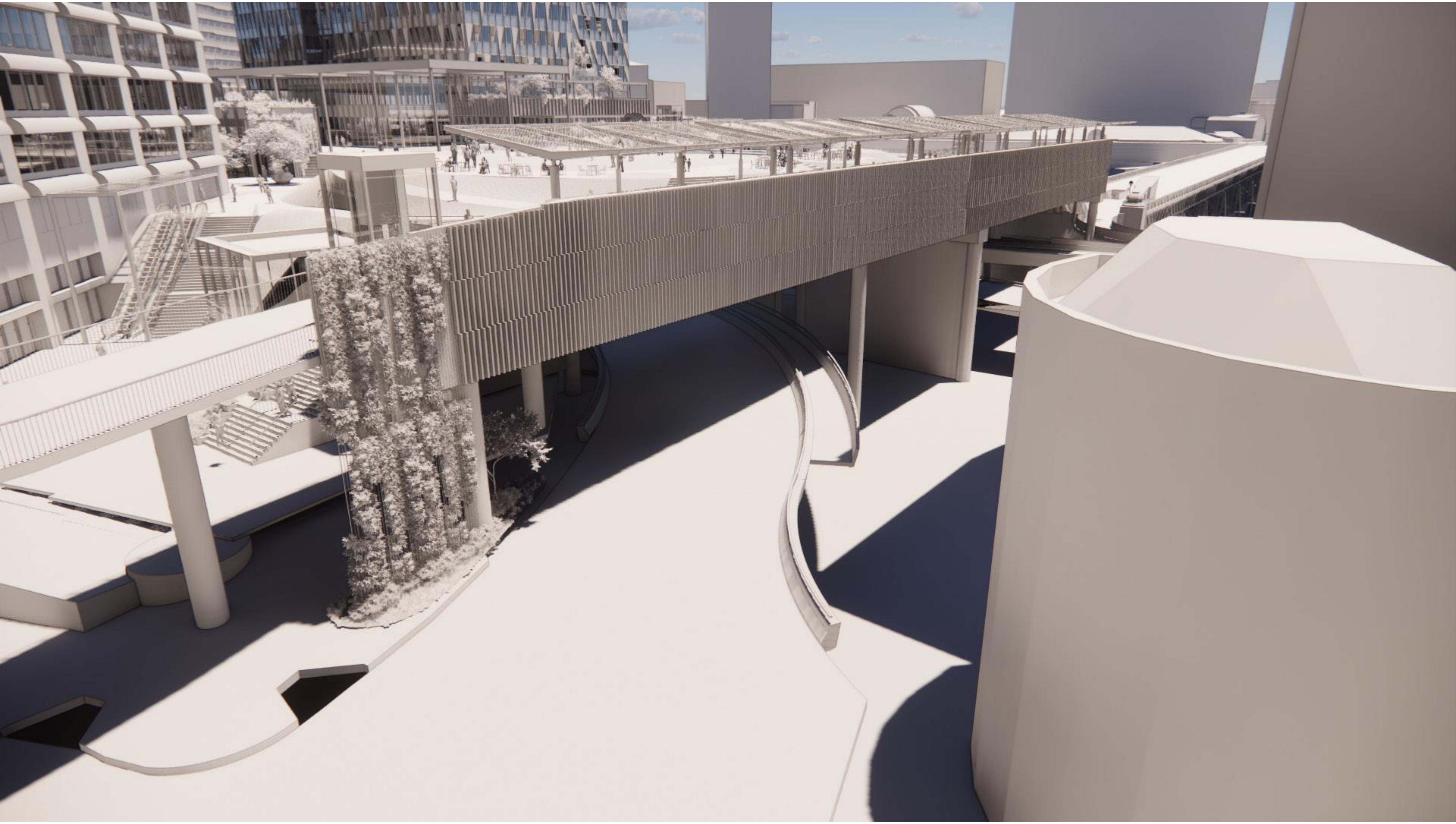


NW Detail Plan

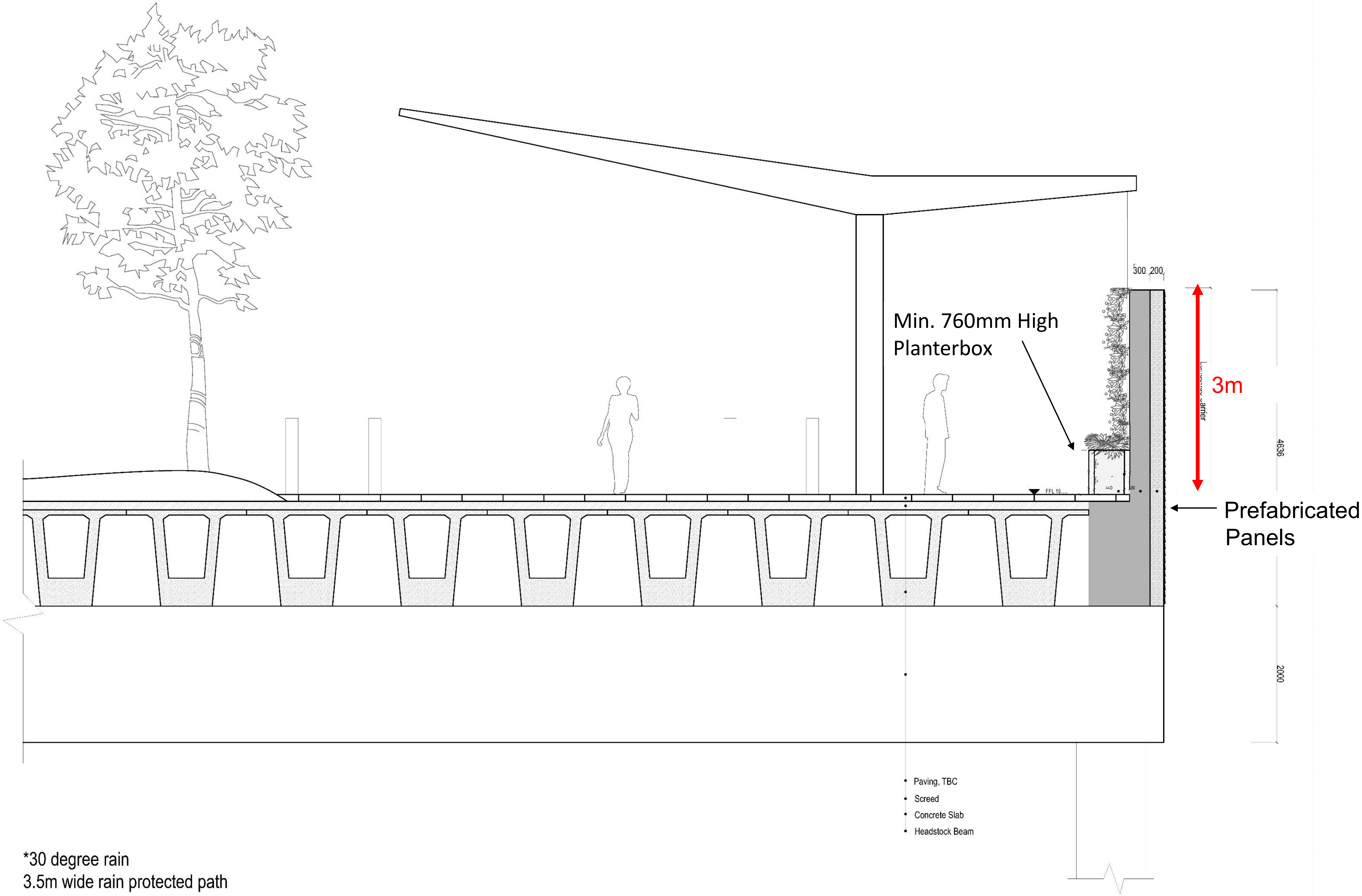
Cockle Bay Park – North Screen



Cockle Bay Park – North Screen



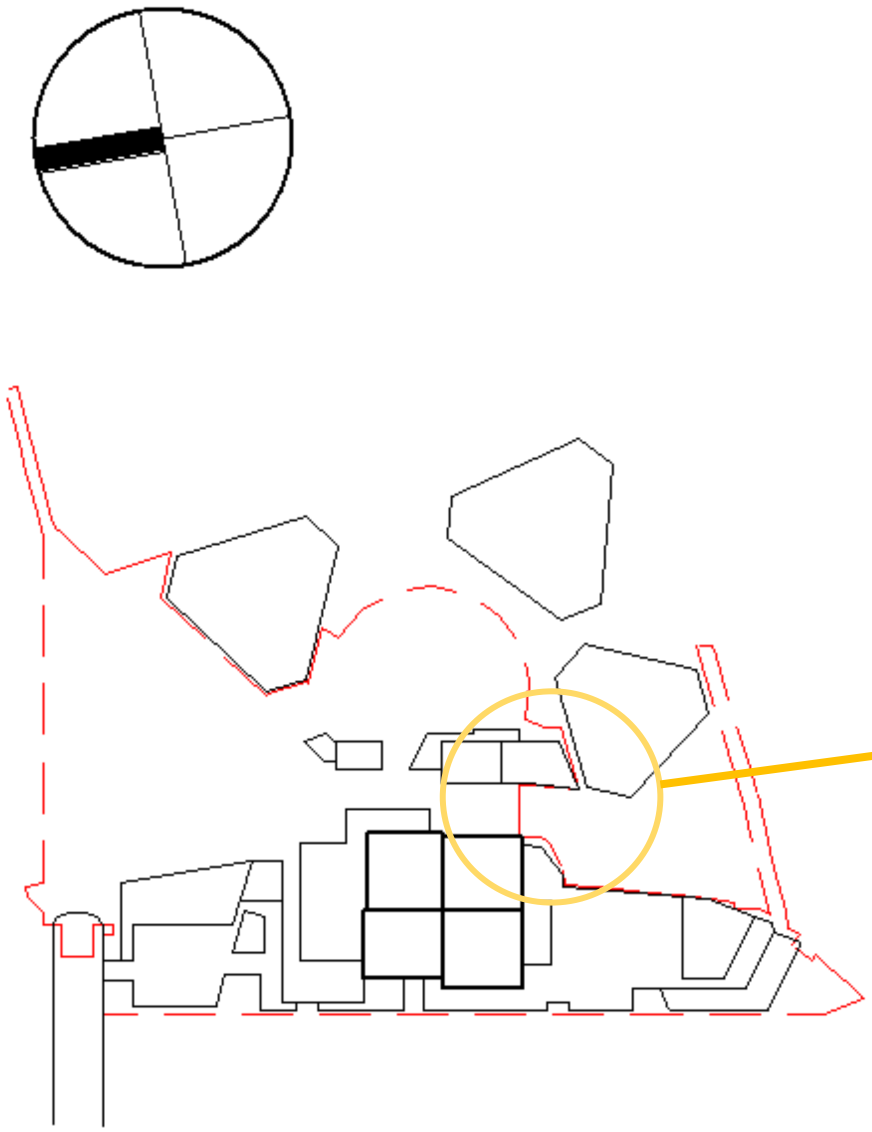
Cockle Bay Park – North Screen Detail



*30 degree rain
3.5m wide rain protected path

Cockle Bay Park – Landbridge View

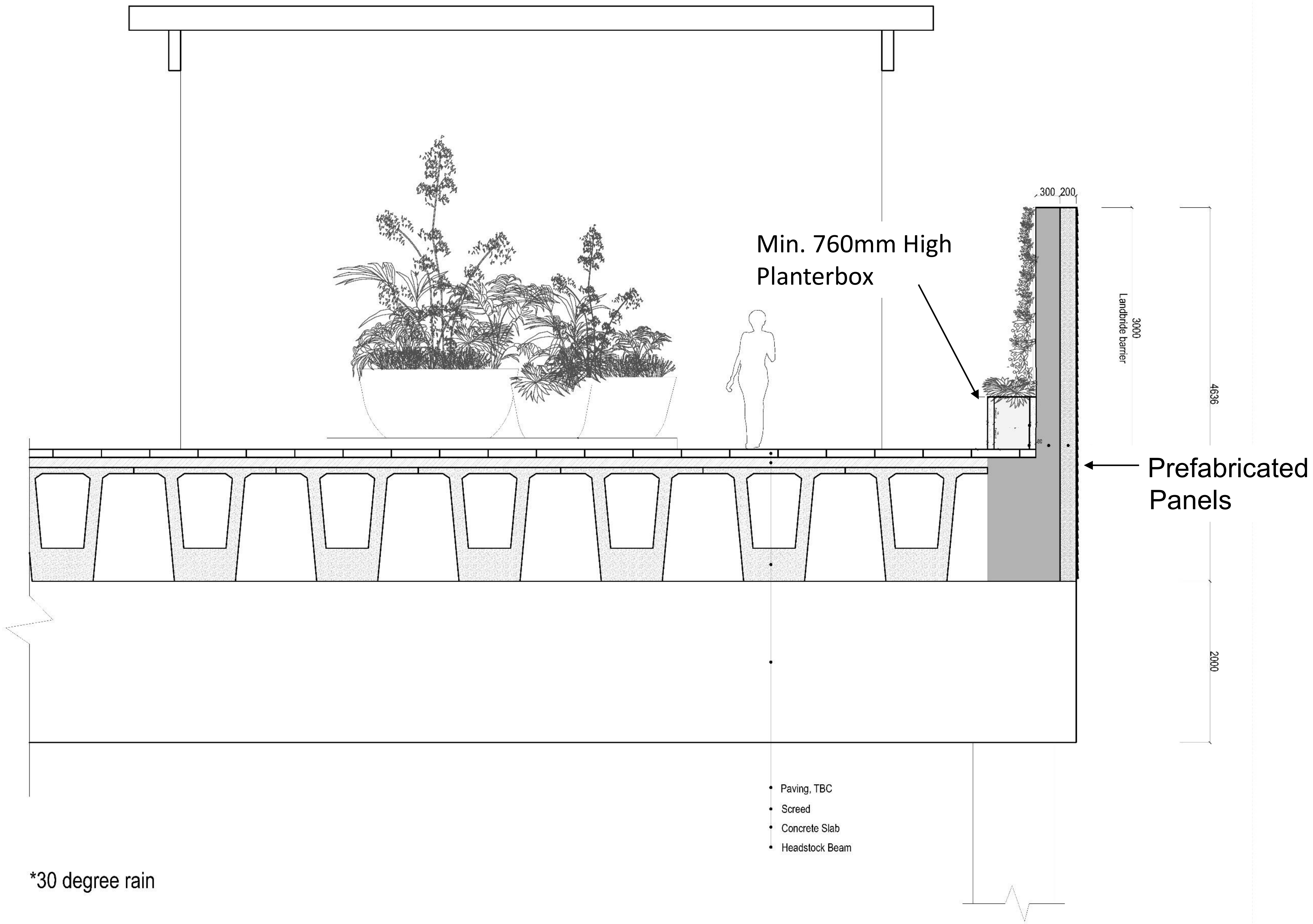
Cockle Bay Park – Screen Extent Proposal - South



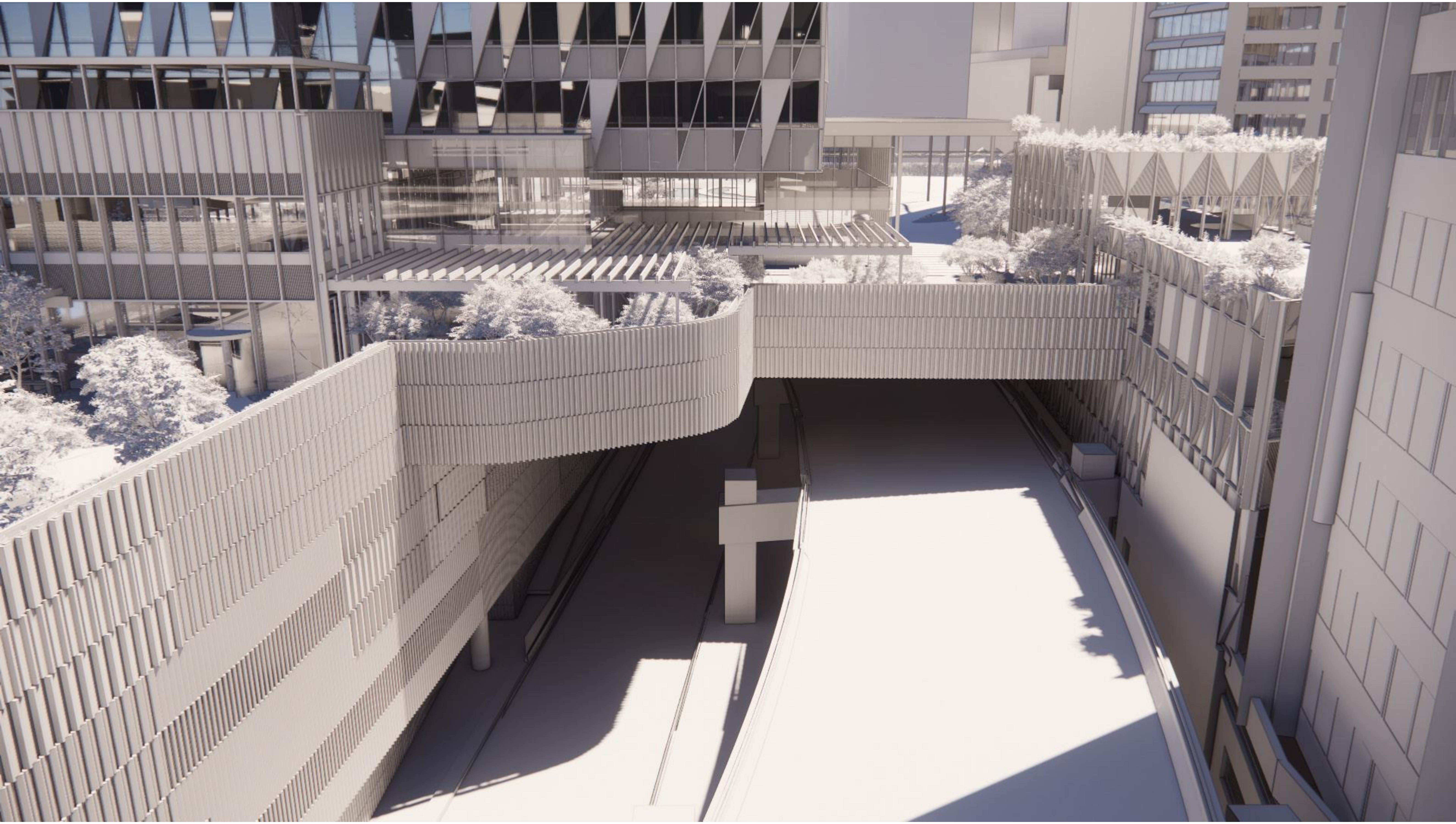
Western Distributor below

Level 3 - Landbridge South edge
1:200

Cockle Bay Park – South Screen Detail

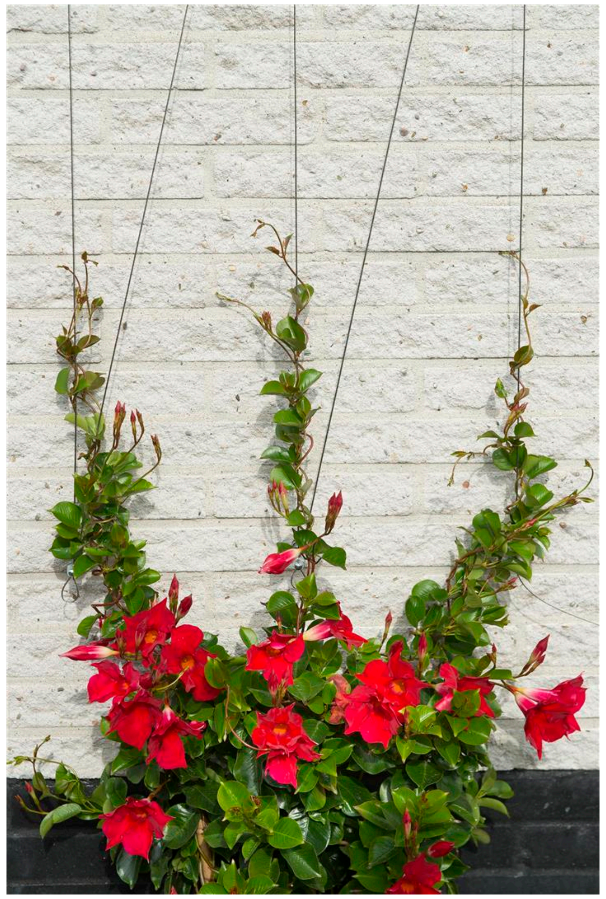


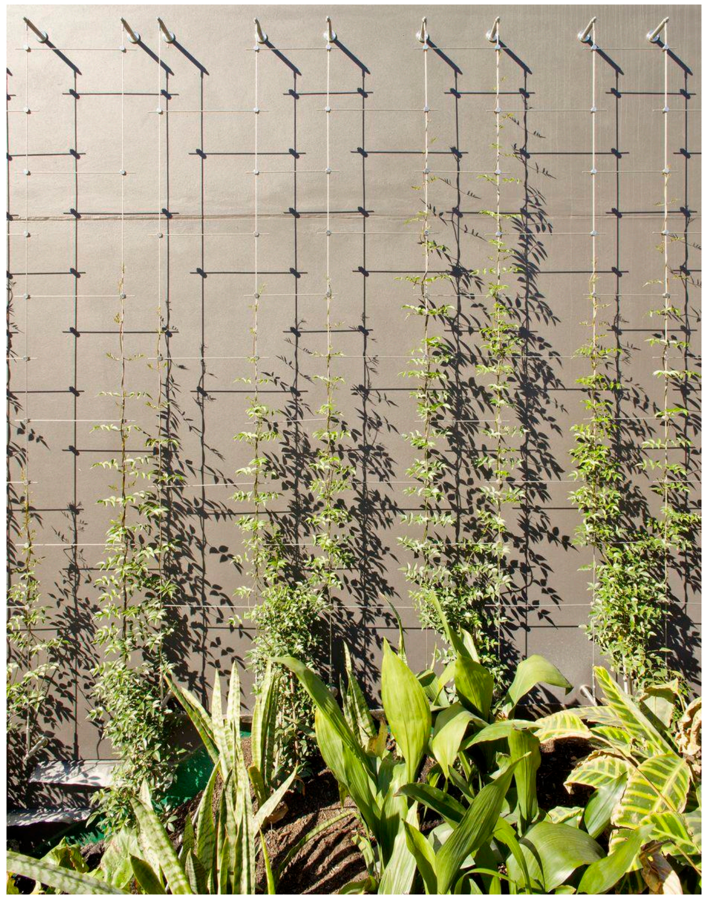
Cockle Bay Park – South Screen



Southern Garden

Cockle Bay Park – Green Wall (reference images)





Suitable plant species:

- Star Jasmine (Trachelospermum jasminoides)
- Banksia Rose (Rosa banksiae)
- Bauhinia (Bauhinia corymbose)


icare
MACQUARIE
Thank you.

Appendix G

Landbridge Structural Drawings

ISSUE AUTHORISATION

Rev	Date	Purpose of Issue / Nature of Revision	Prepared by	Reviewed by	Issue Authorised by
A	03/09/21	Issued for SSD DA	JGR	TBB	TBB
B	10/09/21	Issued for SSD DA	JGR	TBB	TBB

ISO 9001 Quality Management
ISO 14001 Environmental Management
ISO 45001 Occupational Health & Safety Management

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Table of Contents

1. Introduction

This report has been prepared to accompany a detailed State Significant Development (SSD) Development Application (DA) (Stage 2) for a commercial mixed use development, Cockle Bay Park, which is submitted to the Minister for Planning and Public Spaces pursuant to Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act). The development is being conducted in stages comprising the following planning applications:

- Stage 1 – Concept Proposal setting the overall 'vision' for the redevelopment of the site including the building envelope and land uses, as well as development consent for the carrying out of early works including demolition of the existing buildings and structures. This stage was determined on 13 May 2019, and is proposed to be modified to align with the Stage 2 SSD DA.
- Stage 2 – detailed design, construction, and operation of Cockle Bay Park pursuant to the Concept Proposal.

The Site

The site is located at 241-249 Wheat Road, Sydney to the immediate south of Pyrmont Bridge, within the Sydney CBD, on the eastern side of the Darling Harbour precinct. The site encompasses the Cockle Bay Wharf development, parts of the Western Distributor and Wheat Road, Darling Park and Pyrmont Bridge.

The Darling Harbour Precinct is undergoing significant redevelopment as part of the Sydney International Convention, Exhibition and Entertainment Precinct (SICEEP) including Darling Square and the IMAX renewal (The Ribbon) projects. More broadly, the western edge of the Sydney CBD has been subject to significant change following the development of the Barangaroo precinct.

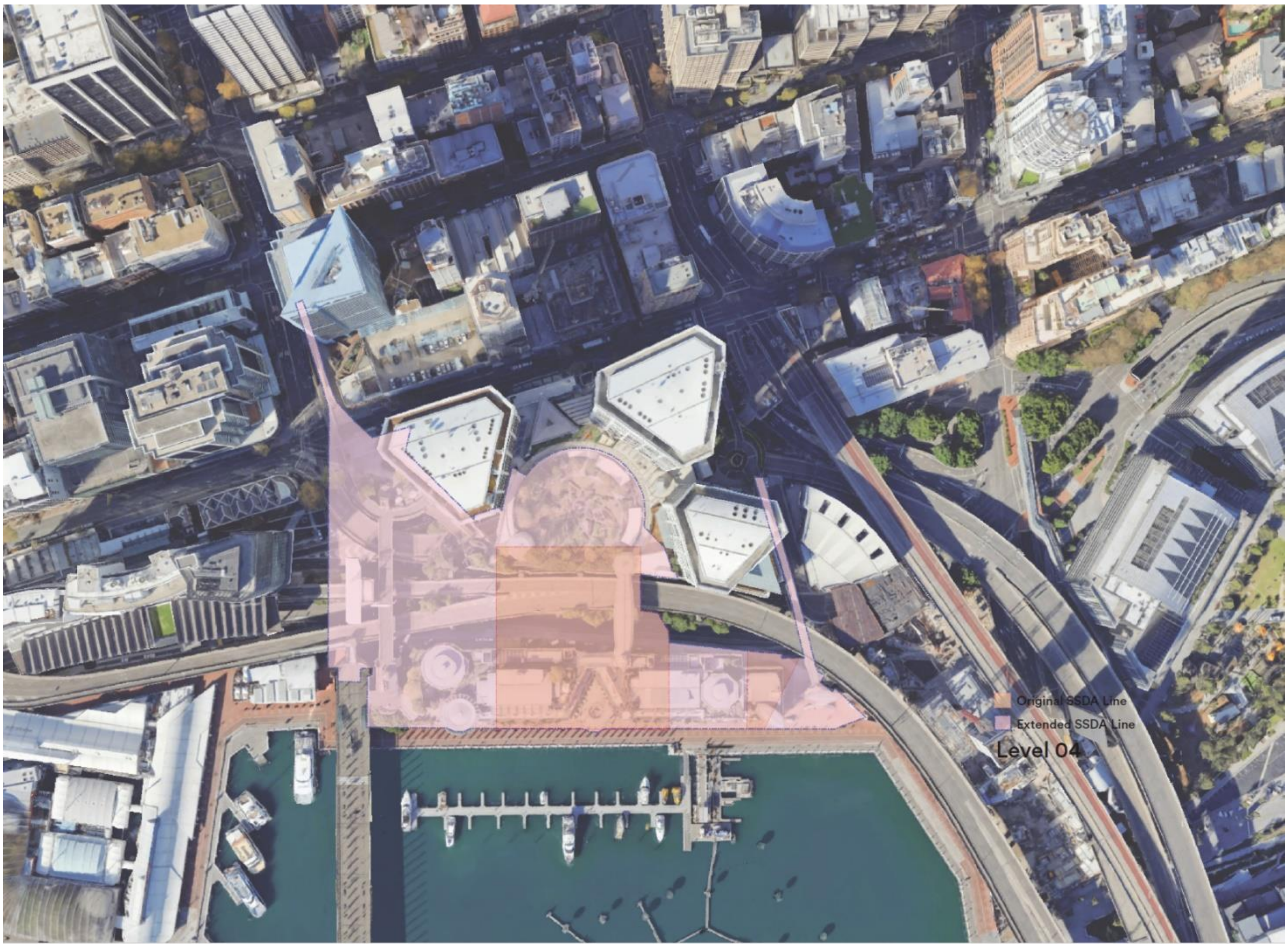


Figure 1 – Location Plan

This report has been prepared in response to the Secretary's Environmental Assessment Requirements (SEARS) dated 12 November 2020 for SSD-9978934. Specifically, this report has been prepared to respond to those SEARS summarised in Table 1.

TABLE 1 - SEARs requirements		
Item	**Description of Requirement**	**Section Reference (this report)**
C24	Western Distributor Future Development Application(s) shall demonstrate compliance with RMS Technical Direction (GTD 2012/001) - Excavation Adjacent to Roads and Maritime Infrastructure.	Section 8
C25	Western Distributor Future Development Application(s) shall include a Geotechnical and Structural Investigation Report considering design and construction methodology	All Sections
C31	CBD Rail Link Future Development Application(s) shall consider the impact of the design and construction of the development on the CBD Rail Link (CBDRL), in consultation with TfNSW and Sydney Trains, and shall address the following matters: a) all buildings and structures and any basement levels, foundations and ground anchors for the development which have a potential impact on the CBDRL, must be designed in accordance with design criteria specified by TfNSW b) allowances for the future construction of railway tunnels in the vicinity of the development c) allowances for future operation of railway tunnels in the in the vicinity of the development especially in relation to noise, vibration, stray currents, electromagnetic fields and fire safety d) consultation with TfNSW and provision to TfNSW of drawings, reports and other information related to the design development e) such other matters which TfNSW consider appropriate or as the Applicant and TfNSW may agree.	Section 9

Landbridge

A significant feature of the Cockle Bay Park redevelopment is the planned landbridge connecting the city on the East to the Harbour on the West. The landbridge will restore a direct link between Pyrmont Bridge and Market St across the Western Distributor and Harbour Street, providing large public plaza and park spaces.

Constructability of the landbridge structure is a key element for design consideration to ensure an efficient and buildable arrangement is provided. The structural system developed for the landbridge predominantly utilises precast concrete elements to minimise onsite construction time and allow the structure to be built through night possessions of the Western Distributor. The precast structure also has the benefit of good inherent fire resistance and durability requiring minimal maintenance over the design life of the structure.

Due to the structure being constructed over the road corridor, the landbridge structure is to be designed and constructed in accordance with Transport for NSW (TfNSW) requirements. Regular consultation with TfNSW has occurred throughout the EIS process to progress the approval of the landbridge design. The consultation process with TfNSW has been positive and collaborative and is working towards execution of a Works Authorisation Deed (WAD) with TfNSW.

The Landbridge structure abuts the existing Darling Park development which will require integration of vertical structure to support the landbridge. Construction of new structure supported off the existing structure at Crescent Garden will facilitate connection to the Landbridge and provide a single contiguous space.

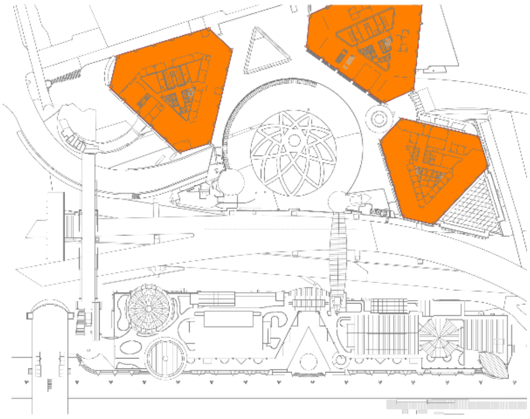
Figure 2 – Existing Site Context

Figure 3 – Proposed Landbridge Footprint with Beam Outlines

2. Landbridge Context

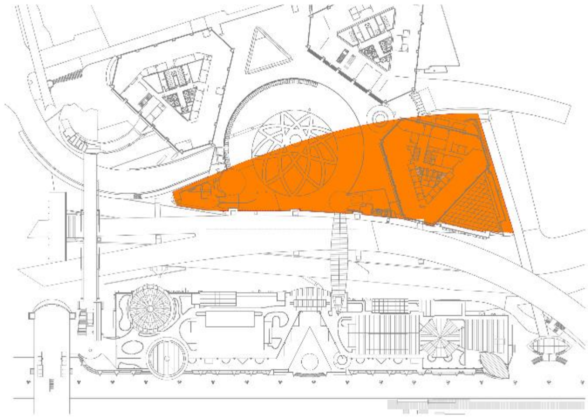
Darling Park Towers

Commercial towers DP1, DP2 & DP3 situated to the East



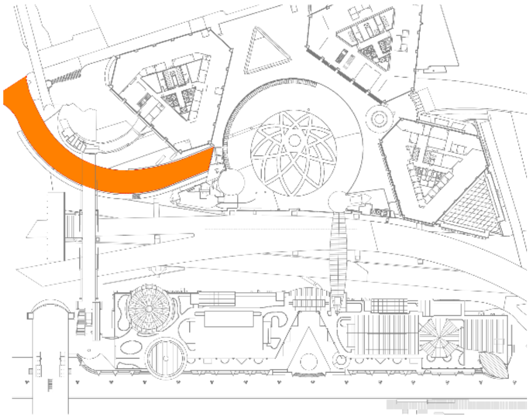
Darling Park Car Park

Existing three level carpark. New landbridge columns placed to minimise impact to operation.



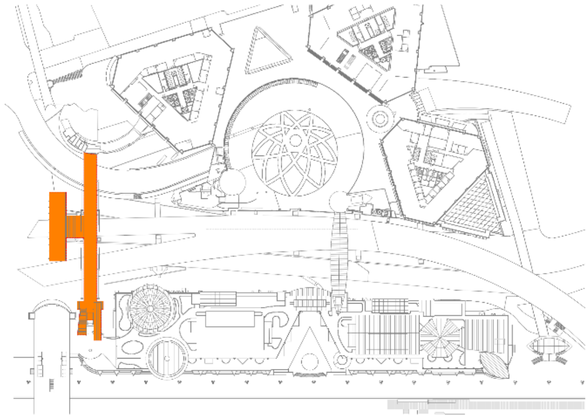
Market St Ramp

Vehicle clearance heights above ramp influence landbridge SSL



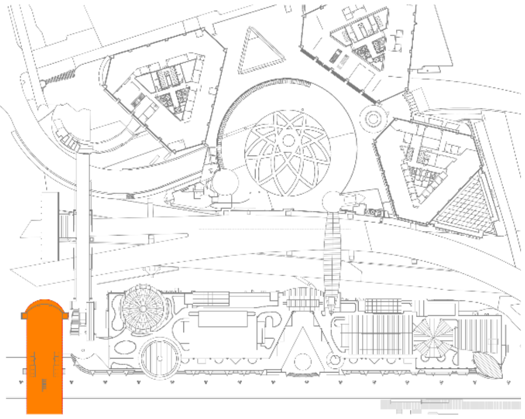
Monorail Station & Pedestrian Bridge

To be demolished. Existing foundation beams and pads to be demolished. Landbridge foundations placed to avoid existing piles.



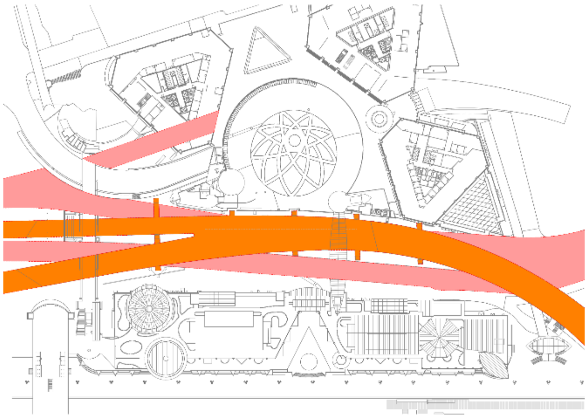
Pyrmont Bridge

Heritage structure situated to the Northwest. New stairs and escalator support structure to be integrated with existing structure.



Western Distributor Network

Elevated viaduct (WD) and on grade road (Harbour St) network



In-Ground Services

Detailed survey of existing in ground services on-going. All proposed structure and foundations located to minimise excavation and relocation works.

3. Structural Design Criteria

Standards

Design standards applicable to the proposed structure are outlined below.

Structures within TfNSW Portion:

- AS/NZS 3845.1:2015 - Road Safety Barrier Systems and Devices - Road safety barrier systems
- AS 5100.1:2017 - Bridge design - Scope and general principles
- AS 5100.2:2017 - Bridge design - Design loads
- AS 5100.3:2017 - Bridge design - Foundation and soil-supporting structures
- AS 5100.4:2017 - Bridge design - Bearings and deck joints
- AS 5100.5:2017 - Bridge design – Concrete
- AS 5100.6:2017 - Bridge design – Steel and composite construction
- BTD 2008/07 – Design of bridge supports for collision load from road traffic
- GTD 2020/001 - Excavation adjacent to Transport for NSW Infrastructure

Structures outside of TfNSW Portion:

- AS/NZS 1170.0:2002 - Structural design actions - General principles
- AS/NZS 1170.1:2002 (R2016) - Structural design actions - Permanent, imposed and other actions
- AS/NZS 1170.2:2021 - Structural design actions - Wind actions
- AS 1170.4:2007 (R2018) - Structural design actions - Earthquake actions in Australia
- AS 2159:2009 - Piling - Design and installation
- AS 3600:2018 - Concrete structures
- AS 3700: 2018 - Masonry Structure
- AS 4100:2020 – Steel structure
- AS 4678:2002 - Earth Retaining Structures

Design Life

- 100-year design life for landbridge superstructure, substructure and foundations immediately adjacent over the Western Distributor (AS5100:2017)
- 50-year design life for all other structures (AS 3600:2018, AS 3700:2018, AS 4100:1998 (R2016))

Importance Level

- All structural elements to be designed for Importance Level 3 (NCC Volume 1 Table B1.2a)

Durability

- All structural elements to be designed for the following exposure conditions for the appropriate design life nominated above:
    - External areas – B1
    - In Ground – B2

Fire

The fire engineering requirement for protection of the landbridge structure was informed by a risk assessment process which addressed the transport of dangerous goods on the Western Distributer roadway underneath.

The landbridge structure must achieve a minimum Fire Resistance Level of 4 hours to the ISO fire curve or 2 hours to the Modified Hydrocarbon curve (HCinc), whichever is the worst.

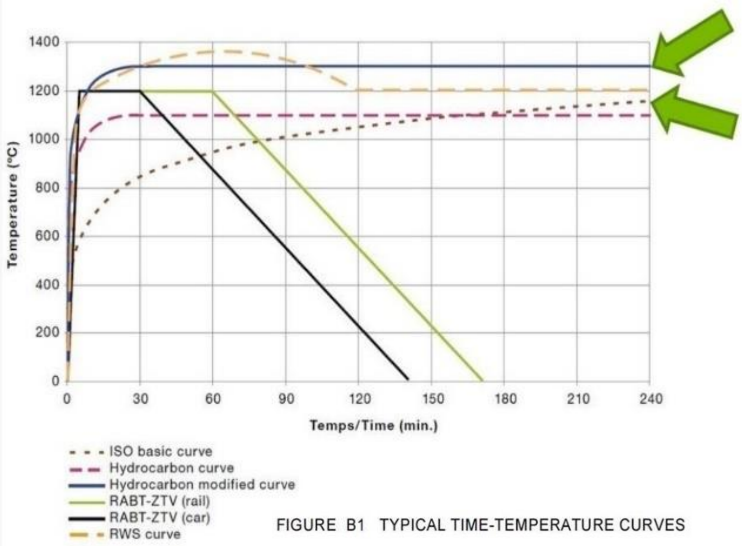


Figure 4 – Time Temperature Curves for Fire Analysis

Earthquake

The analysis and design of all structural elements will be in accordance with AS/NZS 1170.0 (2002) – General Principles, AS 1170.4 (2007) – Earthquake Actions in Australia, AS5100 (2017) – Bridge Design, and AS3600 (2018) – Concrete Structures.

Design Life [AS5100]	100-years[1]
Importance Level [BCA Table B1.2a]	3
Probability Factor (kp) [AS1170.4]	1.3
Hazard Factor (Z) [AS1170.4]	0.08
Site sub-soil Class [AS1170.4]	De[2]
Earthquake Design Category (EDC) [AS1170.4]	h_n < 50m: EDC II h_n > 50m: EDC III

Note:

1) Applies to landbridge superstructure, substructure and foundations immediately adjacent and over the Western Distributor only.
2) Geotechnical advice on site sub-soil classification is from a partially completed geotechnical investigation and is subject to further refinement with a detailed site investigation for the project, and may be improved based on findings of these investigations.

Impact

All columns and supporting elements for the Landbridge designed in accordance with AS 5100 – Bridge Design and BTD2008/07 – Design of bridge supports for collision load from road traffic. Design considers vehicular collision requirements for those columns within the road corridor.

General Loading

OCCUPANCY	OCCUPANCY TYPE TO AS1170.1	DEAD LOAD (kPa / kN)	LIVE LOAD (kPa / kN)
Lobby	C3	3.5 / -	4.0 / 4.5
Paving	C3	5.0 / -	5.0 / 4.5
Light Planting (300mm Soil)	C3	8.0 / -	5.0 / 4.5
Medium Planting (600mm Soil)	C3	15.0 / -	5.0 / 4.5
Heavy Planting (1200mm Soil)	C3	27.0 / -	5.0 / 4.5
Trees	-	- / 40	-
Podium Transfer Columns	-	VARIES	VARIES

The landscape design loading applied to the landbridge structure is shown below.

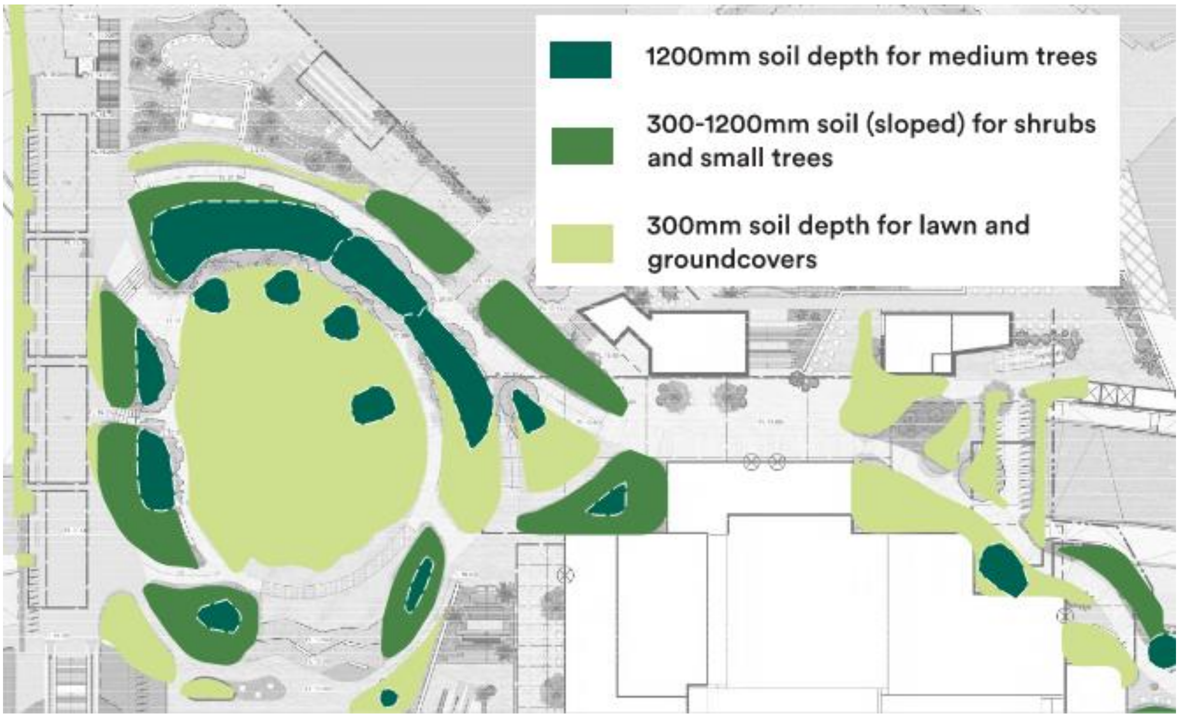


Figure 5 – Landscape Loading Diagram

Deflection Criteria

Element	DEAD	LIVE	INCREMENTAL	TOTAL
Precast Floors over Western Distributor	Span/360	Span/500		Span/300
Transfer Beams over Western Distributor			Span/1000	Span/500

4. Structural Surface

The direct load carrying structure consists of precast beams with a modified Super-T shape which span the roadway onto headstock supports. An in-situ topping slab is proposed to be cast over the precast beam elements, creating a continuous structural surface onto which waterproofing and finishes can be applied.

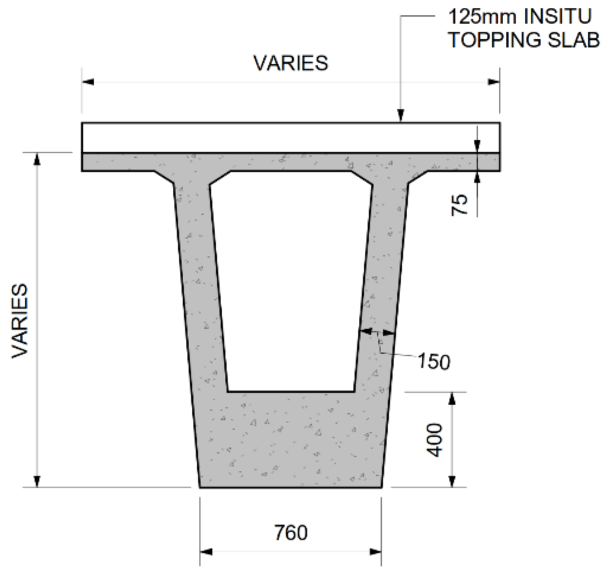


Figure 6 – Precast Beam Section

Precast Beams

Beams spanning the roadway have spans ranging from 5m to 40m with the majority spanning 35m whilst maintaining a minimum clearance to the road below. Off-site fabrication of the beam elements within the road corridor is a hard design constraint since formwork cannot be installed off the road surfaces under, which must remain operational during construction.

The proposed beam type is a modified closed Super-T profile precast with prestressing in the bottom flange and a flat top surface. The sections typically have a constant cross section with a central void and solid shear blocks at each end.

- Typical beams have a large bottom flange to fit the required number of pre-stressing strands and a 75mm thickness top surface.
- High road levels to the South require a zone of tapered beams, with the beam bottom surface inclined to provide the required clearance at critical pinch points.
- A cantilevered zone at the South-West requires beams with an enhanced top flange to accommodate large amounts of top stressing

The void in the middle of the beam has an inherent efficiency in reducing the overall concrete volume in the non-critical region of the cross-section, therefore reducing mass requiring support and enabling installation using fixed cranes. The flat top surface will provide a working surface immediately after beam installation, increasing site safety and productivity.

The beam depths and spacing have been optimised for the load applied to each one, since there is no load path for sharing to adjacent planks. The typical arrangement of beams is 1.75m centre-to-centre spacing using a 1400mm deep precast section.

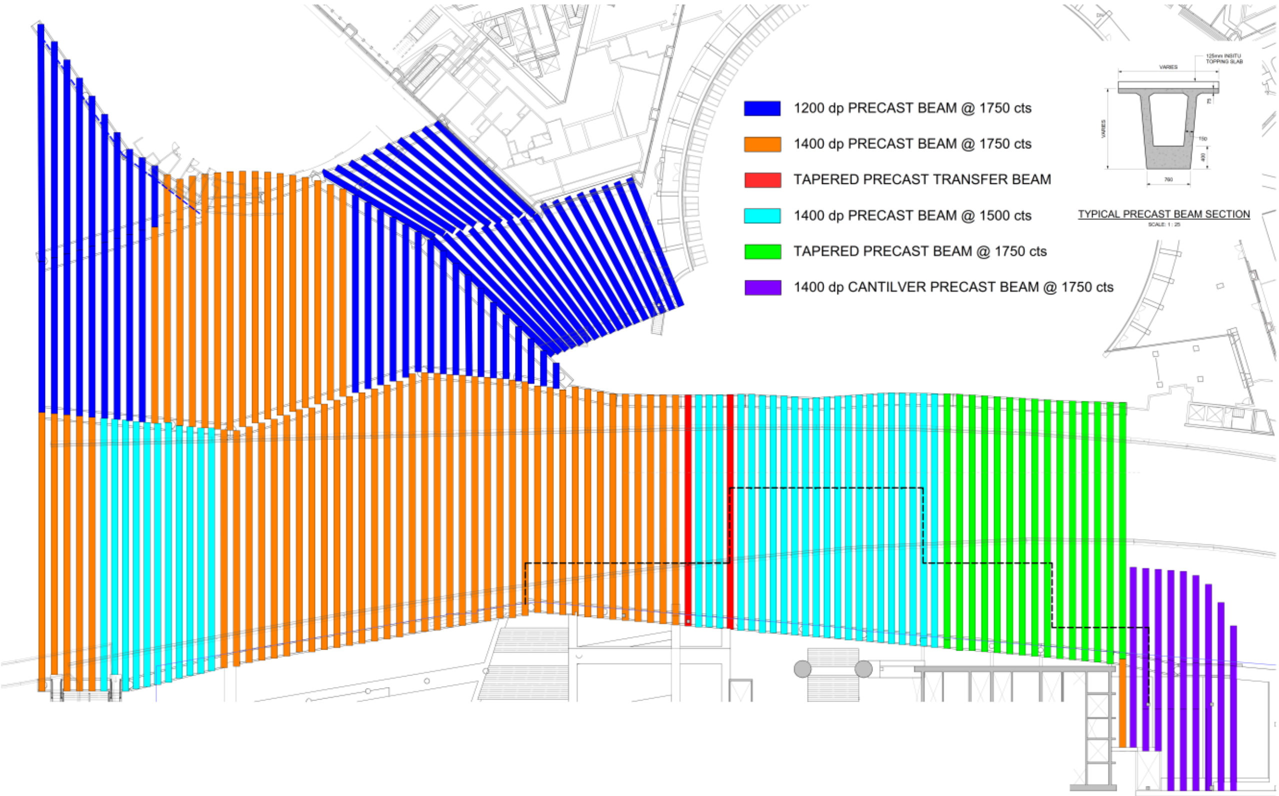


Figure 7 – Precast Beam Plan

Topping Slab

A 125mm thick cast in-situ topping slab is proposed over the entire top surface of the beams, creating a continuous structural surface. The beams themselves will be laid to falls, with a minimum 1% to suit the drainage design and ensure the topping slab can remain a constant thickness.

The combined topping slab and precast beam top surface will form an essential part of the diaphragm system which distributes horizontal loading to the lateral support walls.

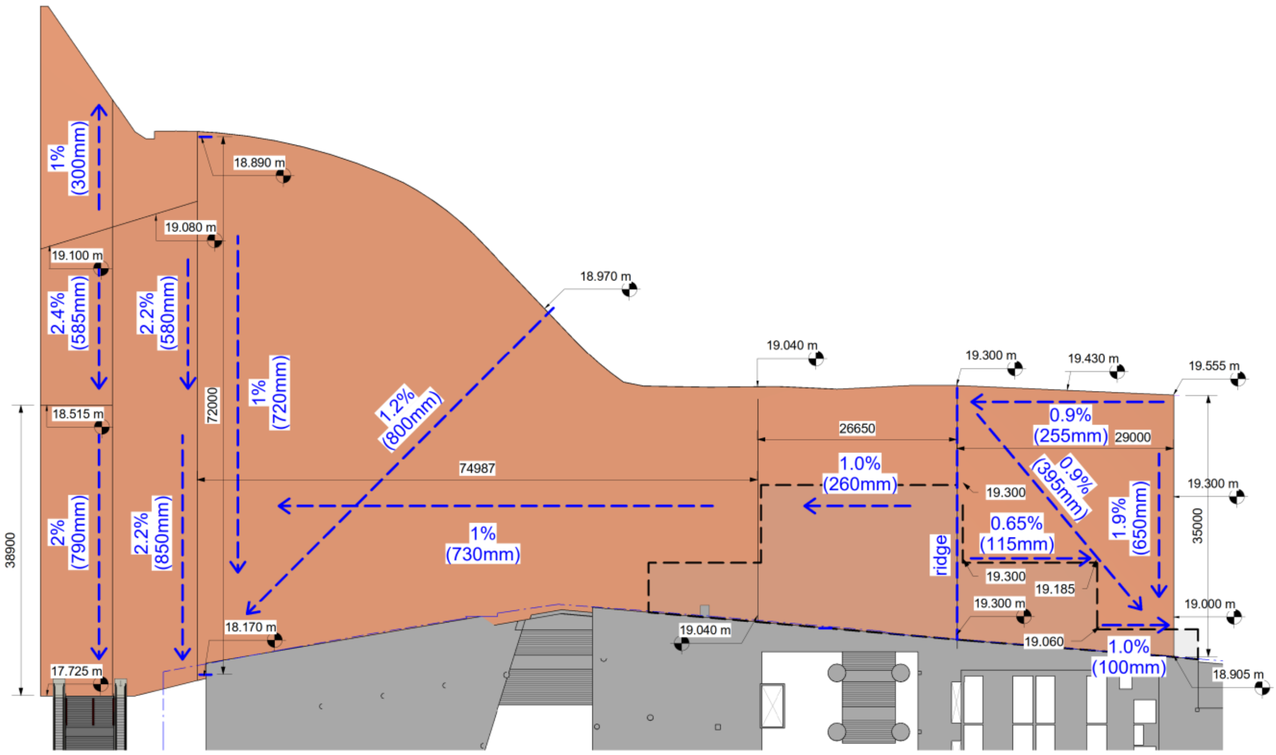


Figure 8 – Indicative Surface Falls for Drainage

Fire treatment

Requirements for protection of concrete with respect to the ISO fire curve are included in AS3600, with an appropriate level of cover to reinforcement provided in design calculations and additional heat analysis of the structure not required.

Assessment methods for concrete with respect to the HCinc curve are as outlined in AS5100. A time temperature analysis of the unprotected beam cross section was carried out and highlighted the need for additional mitigation of heat effects, with the proposed solution being application of a cementitious protection layer, such as CAFCO Fendolite, or similar. Adopting a fire protection solution will also limit damage to the structure during a fire and is recommended over increased cover, which will require significant structural remediation post-fire.

Noting these fire events are ultimate design criteria, it is expected that the concrete immediately exposed to the fire will undergo significant damage if unprotected and require structural remediation to remove and re-instate the damaged concrete.

Movement Joints and Bearings

The structural system has been planned to allow movement of the existing Darling Park Buildings supporting the landbridge to occur independently of each other, with no lateral load path created by tying adjacent buildings together.

Movement joints are located on the Eastern edge of the Northern Park and Park Plaza, on the Darling Park interface. Columns and headstocks will be cast into the existing structure and will gain restraint from these. Bearings will be installed under the precast beams on the support headstocks and will be designed as free-floating bearings to allow movement in both directions.

Due to the size of the landbridge in the North-South direction a permanent movement joint has been introduced and carried through the podium structure. Completely independent vertical and lateral support structure has been planned for the two halves.

TfNSW have nominated that access to all elements associated with the Landbridge which require maintenance should be designed to allow this maintenance to be undertaken from outside of the road corridor wherever possible. For this reason, the location of all bearings supporting the Landbridge along its eastern edge will allow access to be obtained from within the existing Darling Park structure.

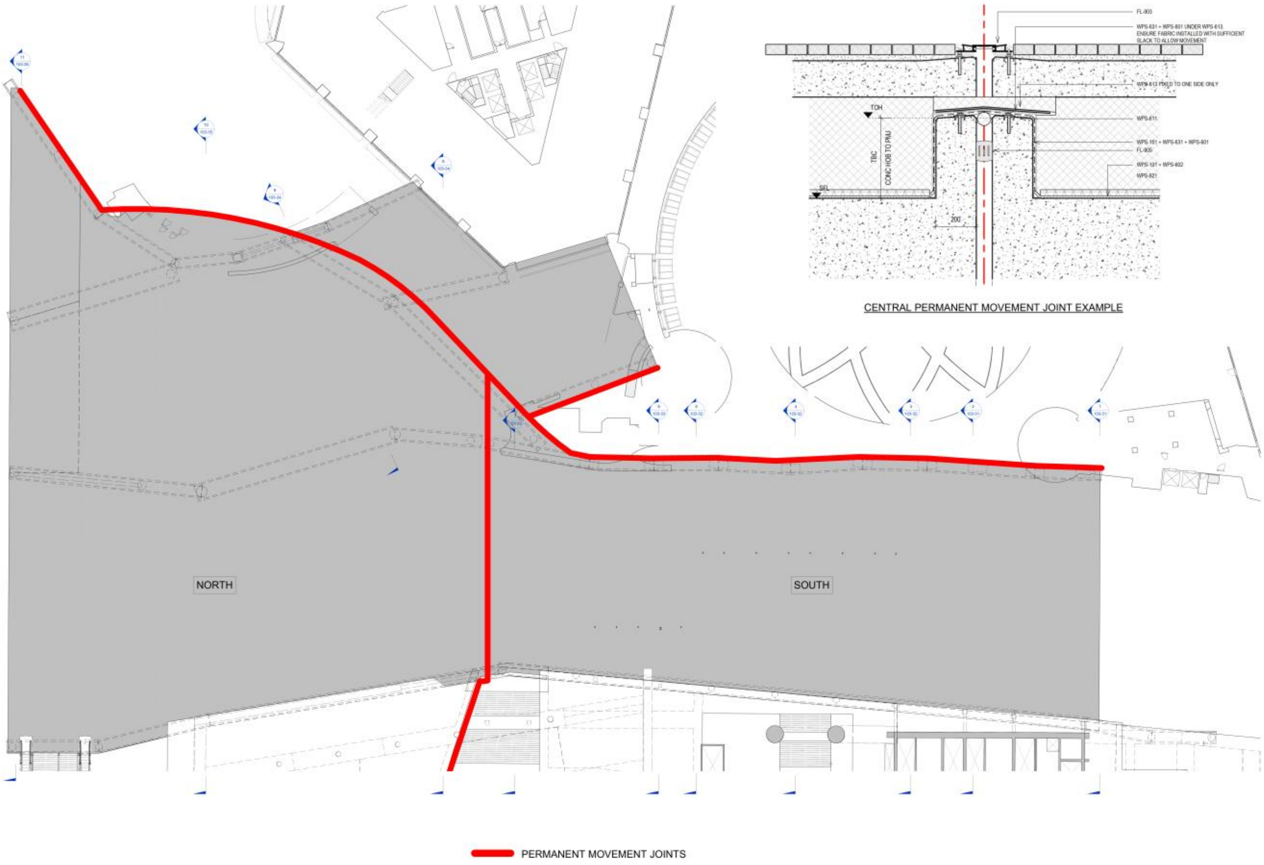


Figure 9 – Movement Joint Plan

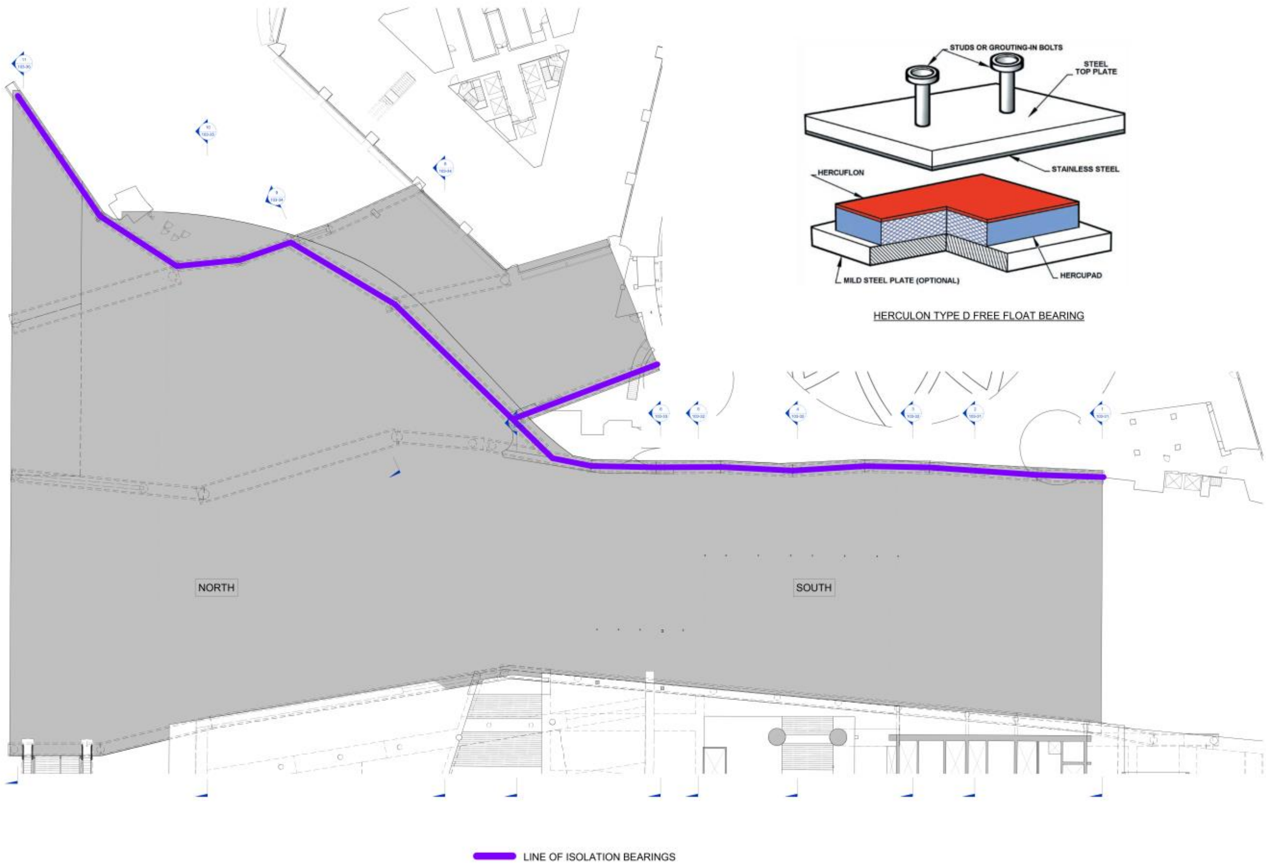


Figure 10 – Bearing Plan

5. Headstock Beams

The precast beams/planks for the Landbridge are detailed with support at either end provided by post-tensioned headstock beams spanning onto columns and walls. Many of the headstocks also span the roads below and will require precast formwork shells to support the cast in-situ concrete within. Where headstocks are located over the existing Darling Park or proposed podium structure, formwork can be provided for cast in-situ construction.

Precast Shells

The magnitude of load carried by the headstock beams is very large and the required cross-sections are too heavy to pre-cast and transported or lift on site. Therefore, a formwork solution using precast concrete U-beam shells that are filled with concrete in-situ and post-tensioned has been developed.

The shells are designed to carry their own weight and the wet weight of concrete inside. On completion of curing and post-tensioning, this combined section is designed to carry the precast beams and topping slab weight. Many of the beams then gain additional stiffness after pouring the topping due to an increase in cross-sectional depth between the precast beams, which are intentionally installed with a gap for this purpose. A staged stress analysis has been carried out to consider the stress state of the concrete and prestressing given the changing cross-section and loading.

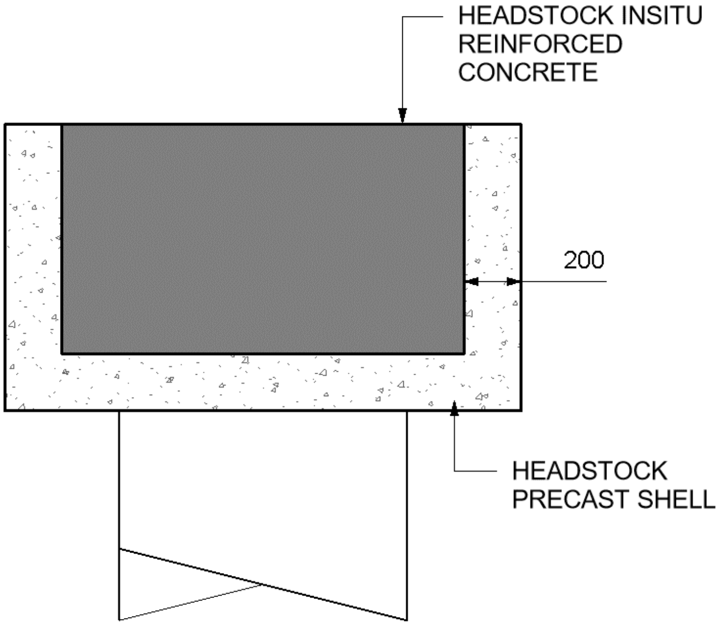


Figure 11 – Precast Shell Headstock Section

Column Corbels

Support for the precast headstock shells will be provided by corbels at the column head with sufficient width to pick up the shear force in each of the vertical legs. Openings in the shell base will enable a direct connection of the cast in-situ headstock to the column.

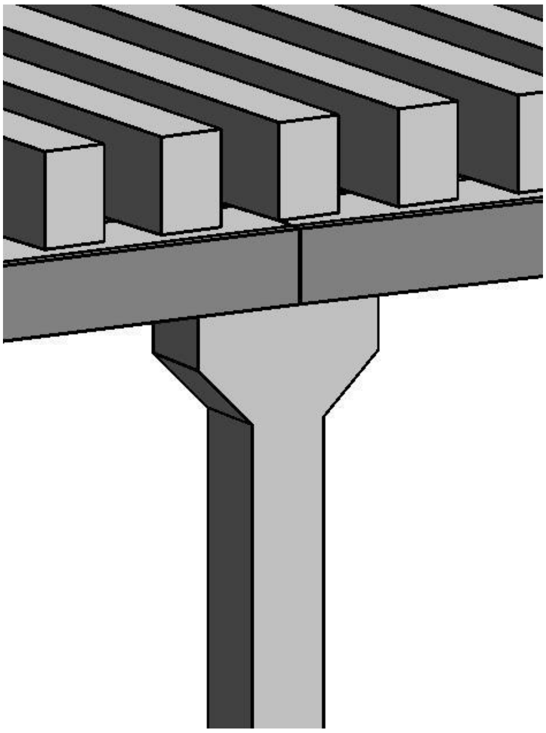


Figure 12 – Column Corbel and Headstock Isometric

6. Columns and Transfers

Columns/vertical structure to support the Landbridge can be split into three groups:

1) Structure within the Cockle Bay Park podium:
   - Podium columns, walls and tower core are used to provide vertical support to the Landbridge along its western edge
2) Structure within the existing Darling Park buildings:
   - New columns will be constructed within the existing Darling Park structure to provide vertical support to the Landbridge along its eastern edge
3) Structure within the road corridor:
   - New columns will be constructed within the road corridor to provide intermediate support to the Landbridge structure to limit the span lengths for the precast planks used for the Landbridge deck structure

1) Cockle Bay Park Podium

Vertical support within the Cockle Bay Park development has been incorporated into the podium structure with support along the western edge of the Landbridge provided by:

- Columns and shear wall at the northern end of the Landbridge
- Columns and transfer structure through the central zone
- Tower core at the southern end of the Landbridge

The columns directly below the headstock beams have been sized to minimise the impacts spatially throughout the podium floorplates. These columns are supported either by shear walls located throughout the Eastern edge of the podium or wing walls cantilevering off the East side of the core. Landbridge column sizes vary from 750mm to 1050mm in diameter and will extend to the underside of the head stock beams. These columns can be formed and constructed using standard formwork and general construction principles.

Transfer Structure

The support provided by the podium and tower columns and core along the central and southern zone are offset from the western edge of the Landbridge to provide a new slip lane off Harbour Street and into Wheat Road. In these areas cantilevering concrete structure is provided to extend the support line to the western edge of the Landbridge. In this zone there are significant spans between support elements. To provide the continuous vertical support required by the Landbridge a full storey high reinforced concrete wall is provided in these zones to span between the available points of support, see image below.

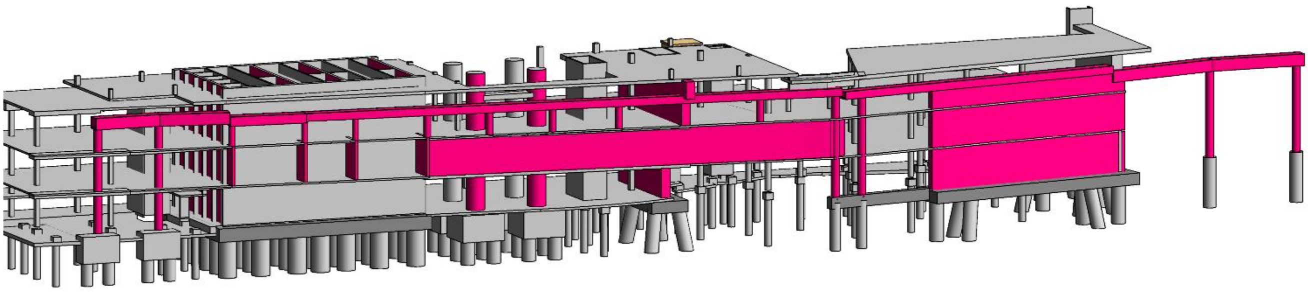


Figure 13 – Western Landbridge Support at Podium

2) Existing Darling Park Car Park

Along the Western edge of the existing darling park structure, landbridge columns have been strategically spaced at approximately 7 to 9m centres to suit existing car park layouts. Consideration has been made to isolate the existing structure from the new landbridge plank structure by providing a movement joint that transfers the vertical load imposed by the planks to the headstock beams while allowing for horizontal movement. This ensures the existing structural design conditions of the Darling Park structure remains as close as possible to the original design intent.

Columns supporting the headstock beams will be designed as cantilevers above the crescent garden level utilising a 50MPa concrete mix to allow for an appropriate transition and minimise bearing stresses on existing floorplates further down the structure. The intent is to limit the amount of strengthening required to the existing structure by providing a transition detail that will comprise of doweled reinforcement bars through the existing floor plates. This will enable standard formwork practices to be utilised in combination with letterbox pouring or pumping from a main point and providing weep holes as required at the top of the column to ensure correct concrete placement has been achieved.

Throughout, column sizes vary above the crescent garden level due the columns height and load imposed by the landbridge planks, however as the columns transition through the existing carpark structure one size has been typically maintained throughout.

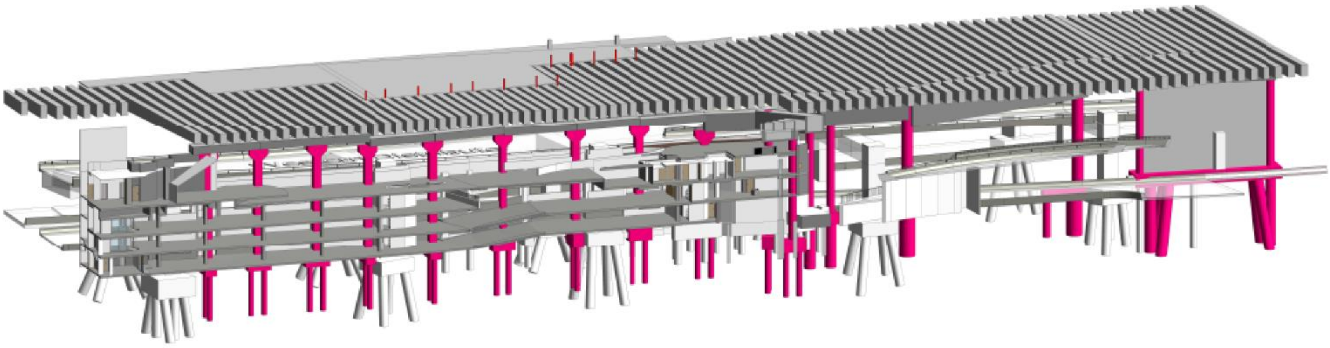


Figure 14 – Eastern Landbridge Support through Darling Park

3) Columns in the road corridor

Columns and walls within the proposed Cockle Bay Park podium have been located to meet planning requirements of the proposed development. The dense network of existing infrastructure within the road corridor has undergone a detailed assessment by the project team and TfNSW to reconcile support locations with existing infrastructure, planned infrastructure expansion and clearances required, with the column locations on plan representing a resolution of these requirements.

These supports are designed as reinforced concrete columns with sufficient capacity to support the proposed landbridge and also resist code impact loading from the adjacent roads.

Due to the nature of the build being over a roadway, precast headstock beams will need to be temporarily supported by way of a corbel. This will be installed at the top level of the column to provide temporary support of the headstock beam prior to it being fully poured tying the two elements together.

Further, construction of the columns was considered with respect to impacts to the road network and a formwork arrangement was proven which utilises shutters braced to supports adjacent the road to minimise impacts on the network.

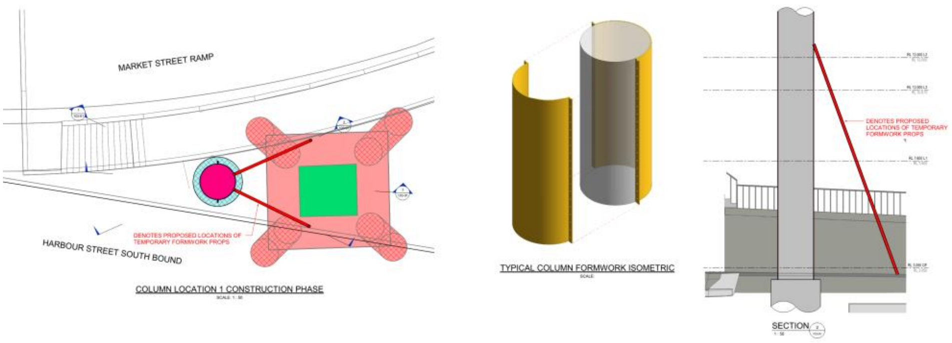


Figure 15 – Typical Column Within Road Network Formwork Concept

7. Lateral Support

The Landbridge deck has been provided with an east/west running movement joint due to the length of the deck in the north south direction. To accommodate this the lateral structure for the Landbridge is split into northern and southern zones to keep either half of the deck independent of the other.

The lateral systems for both zones are incorporated into the podium and tower planning, with dedicated lateral walls or enhanced core capacity providing the required support.

Northern Zone

The lateral structure for the northern zone of the Landbridge consists of the following elements:

- North/south shear wall along the eastern edge of the Landbridge within the existing Darling Park structure. Further investigation of this shear wall is required once detailed in-ground services survey is completed to determine the arrangement of the foundations required for a shear wall at this position to confirm it can be achieved given the existing electrical cables and conduits that are known to be within this area. If it is found that the required foundations cannot be achieved this shear wall will be deleted and replaced with columns and the remaining lateral elements in the northern zone strengthened to allow for this removal.
- North/south shear wall within the road corridor. This shear wall will be located between the northern and southern lanes of the Western Distributor within the support zones approved in-principle by TfNSW.
- North/south shear wall at the western edge of the Landbridge along the edge of the podium structure.
- East/west shear wall within the podium structure.

The lateral elements for the northern zone have been arranged so that there is only a single lateral element in the east/west direction located close to the centre of mass in the north/south direction so that creep, shrinkage and thermal movements of the deck in both directions are centred on this wall. The multiple north/south lateral elements have been located close to the centre of mass in the east/west direction also.

As the north/south shear walls are uncoupled elements they allow the creep, shrinkage and thermal movements of the deck in the east/west direction to be accommodated by rotation of these walls about their weak axis. The lateral system will be integrated into deck/podium structure with isolation of the deck from the Darling Park structure occurring along the eastern edge of the deck where bearings are provided.

Southern Zone

The lateral structure for the southern zone of the Landbridge consists of the following elements:

- Tower structure lateral core system.
- East/west shear wall within the podium structure to the north of the core.

The lateral elements for the southern zone have been arranged so that there is only a single lateral element in the north/south direction which is the tower core so that creep, shrinkage and thermal movements of the deck in both directions are centred on core. The east/west shear wall has been located close to the east/west centre of stiffness of the tower core ensuring that creep, shrinkage and thermal movements of the deck in the north/south direction can be accommodated by rotation of this shear wall about its weak axis. The lateral system will be integrated into deck/podium structure with isolation of the deck from the Darling Park structure occurring along the eastern edge of the deck where bearings are provided.

8. *Foundations*

Site Geotechnical Investigation

An interim geotechnical investigation report has been produced by Douglas Partners (R.001.DftA, dated 6/08/21) to assess and understand the subsurface soil and groundwater conditions across the site, with advice provided on the following:

- Excavation conditions
- Temporary excavation support
- Foundation design and suitable construction methodologies
- Earthworks and groundwater
- Other geotechnical construction related issues considered relevant to the proposed development

To date, the drilling of 11 boreholes has been carried out with three of these being converted into groundwater monitoring wells. Borehole locations have been noted across the extent of the site below.

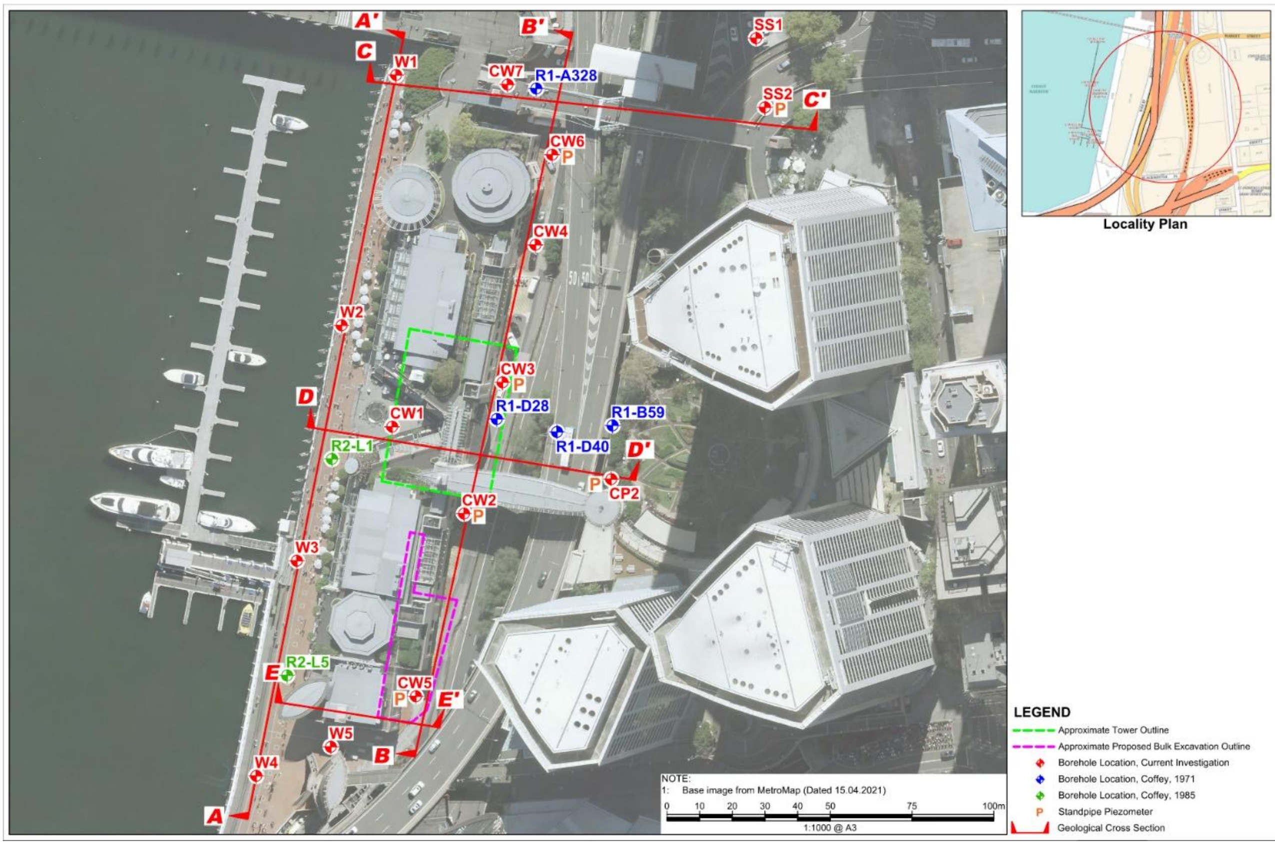


Figure 16 – Geotechnical Borehole Location Plan

The ground conditions across the site typically comprises of uncontrolled fill (encountered at depths between RL 1.3 and -7.2m) overlying marine deposits (encountered at depths between RL -6.5 and -18.2m) overlying sandstone bedrock (encountered at depths between RL 1.3 and -20.9m). The top of the sandstone bedrock differs quite significantly across the site, noting that near borehole SS1 and SS2 the depth to the sandstone is as high as RL 1.3 and as low as RL -18.2 across the harbour. This bedrock comprises of 3 different unit strengths at varying depths (very low to low, low to medium and medium to high strength) and will provide incrementally better founding parameters for the structure.

Groundwater was encountered between RL 0.0 and RL -0.1, with water being observed in all boreholes drilled through the suspended deck over the harbour. Temporary batters may be feasible where groundwater is not encountered, however temporary shoring such as trench boxes, sheet piling and pile walls will be required to enable excavation below the groundwater level.

Within the report it has been recommended that all column foundations will require one of the following pile types:

- Continuous flight augured piles
- Steel encased concrete bored piles
- Steel tube piles

These foundation supports have been adopted for all columns across the site, with the extent and size varying column to column as it is strictly dependent on location, load and sub-surface material depths.

Road Corridor

All columns and shear walls within the road corridor will be supported on piled foundations outside the zone of influence for the existing TfNSW foundations or placed to not adversely affect the structural integrity of the existing structure. Assessment and confirmation of avoidance of geotechnical impact to the existing TfNSW foundations will be undertaken by Douglas Partners during further development of the design.

The design and construction of all foundations within and adjacent to the road corridor will be undertaken in accordance with the requirements of GTD 2020/001 - Excavation adjacent to Transport for NSW Infrastructure.

Darling Park Car Park

New columns throughout Darling Park are proposed to be constructed within the existing structure. Existing foundations are bored reinforced concrete piles and the geotechnical engineering report has identified rock at some distance below the existing slab level. The proposed foundations are bored cast in-situ piles, however a low-height drilling rig will be required to install these below the existing suspended car park slab.

Podium

A piled foundation system will be provided throughout the podium, consisting of a number of different pile types which is dependent on the ground conditions across the site at which each pile is located.

Typically, the following types will provide support to the corresponding structural elements.

- Structural Element: Tower columns and core/shear walls:
  Foundation Type: Steel encased reinforced concrete bored pile.
- Structural Element: Podium columns east of boardwalk including landbridge columns
  Foundation Type: Reinforced concrete contiguous flight auger piles with no steel sleeve/tubing.
- Structural Element: Columns West of boardwalk
  Foundation Type: Driven steel tubes with reinforced concrete plug and localised external corrosion protection at the head.

9. Market St Ramp

An existing pedestrian footbridge springing from Market St and traversing Sussex St currently provides pedestrian access to the existing Darling Park towers, the decommissioned Monorail station and through to Pyrmont Bridge and Darling Harbour.

The current alignment lands on the Darling Park side at approximately RL13, which will require modification to achieve connection with the higher design landbridge finished level. The existing supports on either side of Sussex St have been surveyed and modelled to compare with the CBDRL exclusion zones, which were also surveyed. The existing supports and foundations are located in Zone 4, which permits vertical downward loads that are limited in magnitude, as agreed with TfNSW.

A new proposed pedestrian bridge will be located at the existing support locations with new foundation structure with loads of a similar magnitude to the existing condition. This design has been presented to TfNSW with a view to understanding any additional requirements to be satisfied. This consultation is currently being finalised with no adverse commentary received at the time of writing.

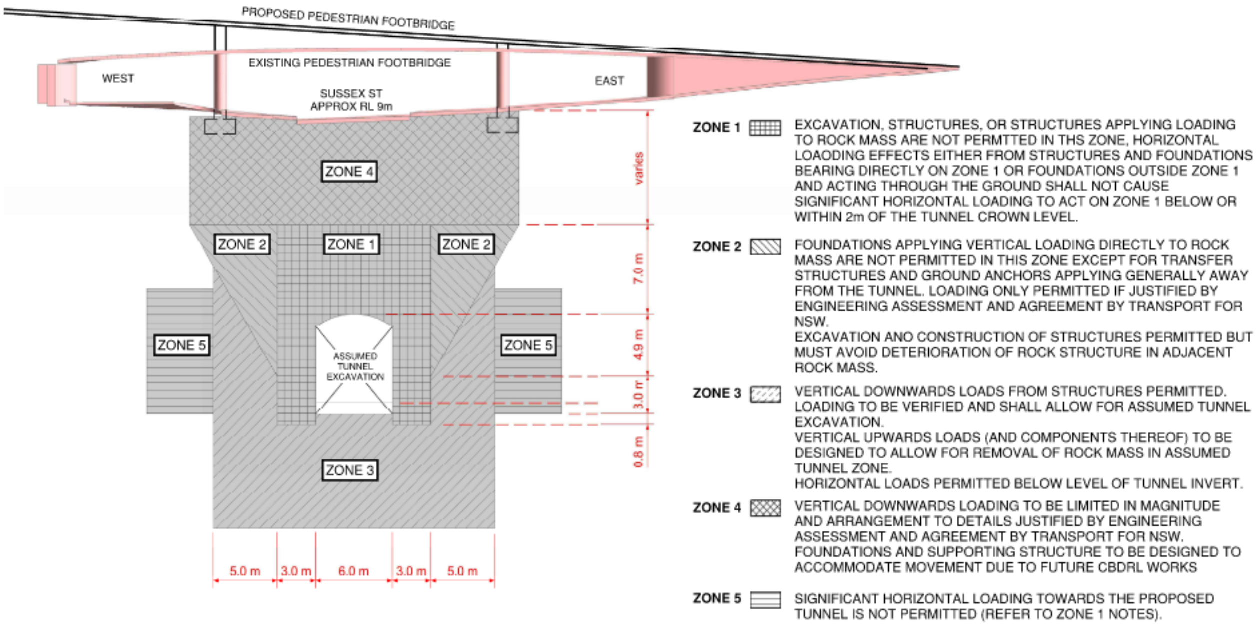


Figure 17 – Pedestrian Footbridge over CBDRL Sussex Street corridor

10. Stormwater Diversion

Existing stormwater drainage is generally located to the east of the Cockle Bay Park site and includes assets owned and maintained by the City of Sydney Council (CoS) and Sydney Water Corporation (SWC). Two main underground drainage lines convey flows through the Cockle Bay Park site including a 1500 mm diameter line in the central part of the site and an 1800 mm diameter line in the southern part of the site.

Due to the location of the proposed Cockle Bay Park building, the 1500 mm diameter line requires relocation as it clashes with the buildings proposed core. This line is registered as S.W.C No 30L by Sydney Water and was amplified in 1974. The line is currently located under the existing Cockle Bay Wharf podium building on the site and is independent of the existing building.

Existing major street drainage lines will remain undisturbed in their current locations, aside from some proposed inlet modifications at the eastern edge of the property to improve drainage during extreme floods in Harbour Street.

To accommodate the proposed Cockle Bay Park development S.W.C No 30L is proposed to be relocated. This relocation commences on the eastern side of Harbour St across the Cockle Bay Park site to the harbour.

To facilitate construction via either trenching or boring the section of the stormwater diversion crossing Harbour St has been sized as a precast circular pipe. Allowing the contractor to select the preferred construction methodology to minimise impact to Harbour St during construction.

The stormwater diversion crossing the Cockle Bay Park site has been sized as a rectangular culvert integral with the building structure.

The alignment selected for the stormwater diversion has ensured all existing Western Distributor in-ground structure is avoided as well as all proposed structure for the Cockle Bay Park development.

The diversion of the stormwater line has been approved in principle by Sydney Water.

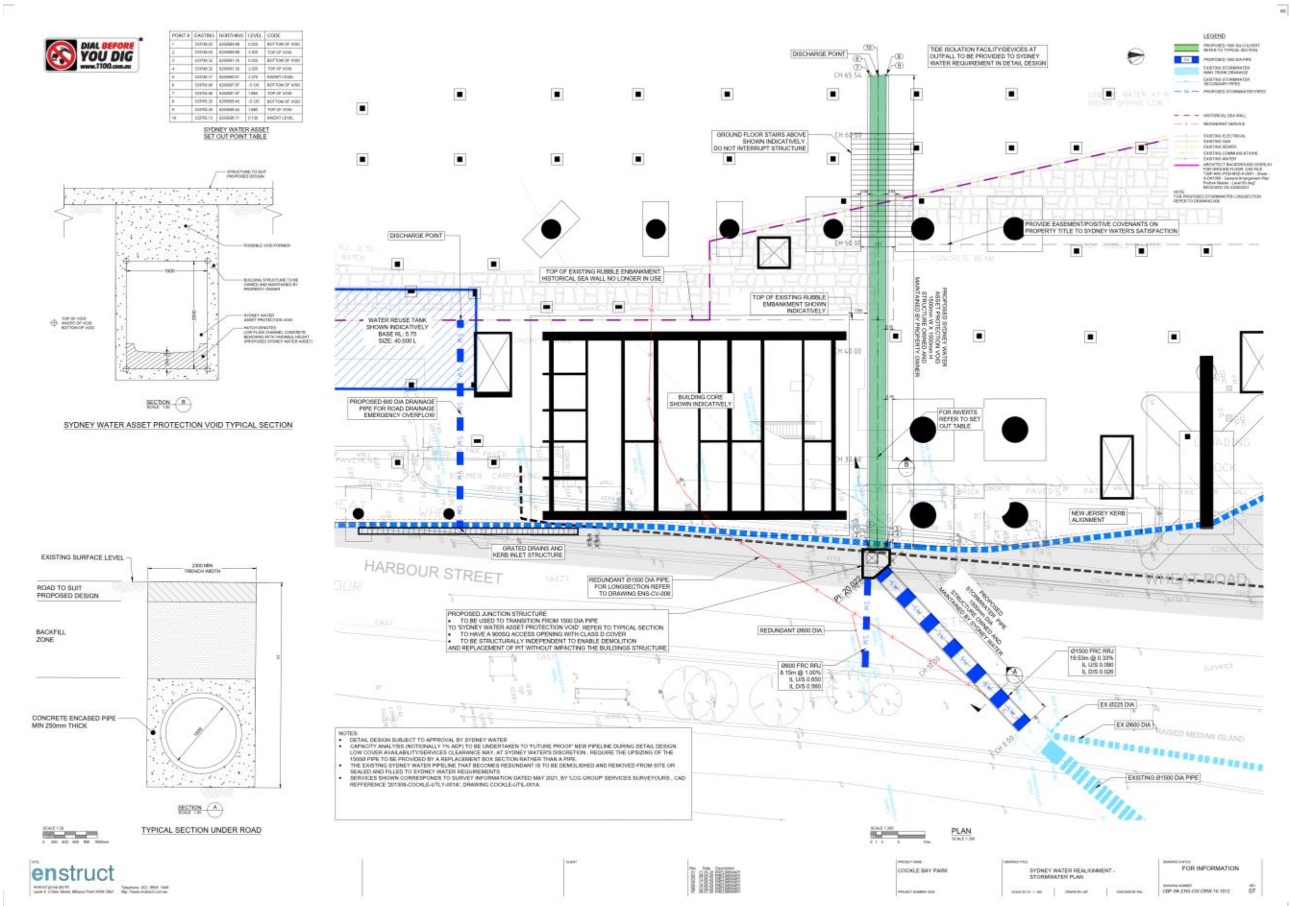


Figure 18 – Stormwater Diversion Plan

11. Clearances

Road Clearances

A critical planning constraint incorporated into the design is maintaining minimum vertical clearance between the proposed landbridge structure and the existing Western Distributor roadway. A minimum clearance of 5.4m has been adopted everywhere with an additional 0.4m services zone added and achieved at all locations. It has been identified that the services clearance zones could be reduced in some areas which will be investigated as the design progresses and if possible utilised to minimise the elevation of the Landbridge in these areas.

An additional horizontal clearance between the road edge and any vertical structure has been incorporated into the design at all new column locations.

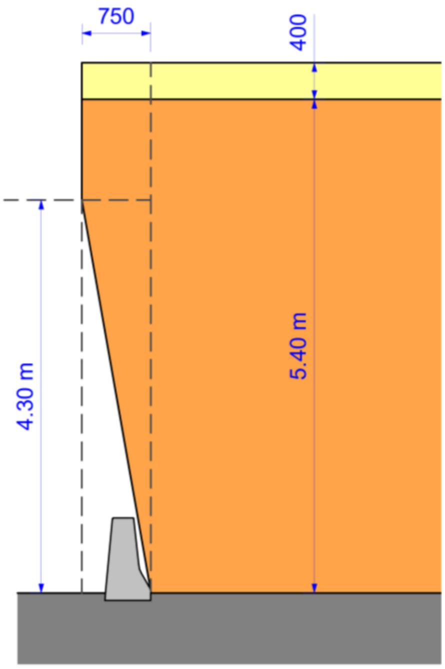


Figure 19 – Road Clearance Requirements

enstruct has incorporated 2D and 3D point cloud survey of the existing road infrastructure into the project structural BIM model. All elements of the existing road infrastructure have been assessed relative to the planned landbridge structure. The required clearances have been demonstrated at all critical cross sections.

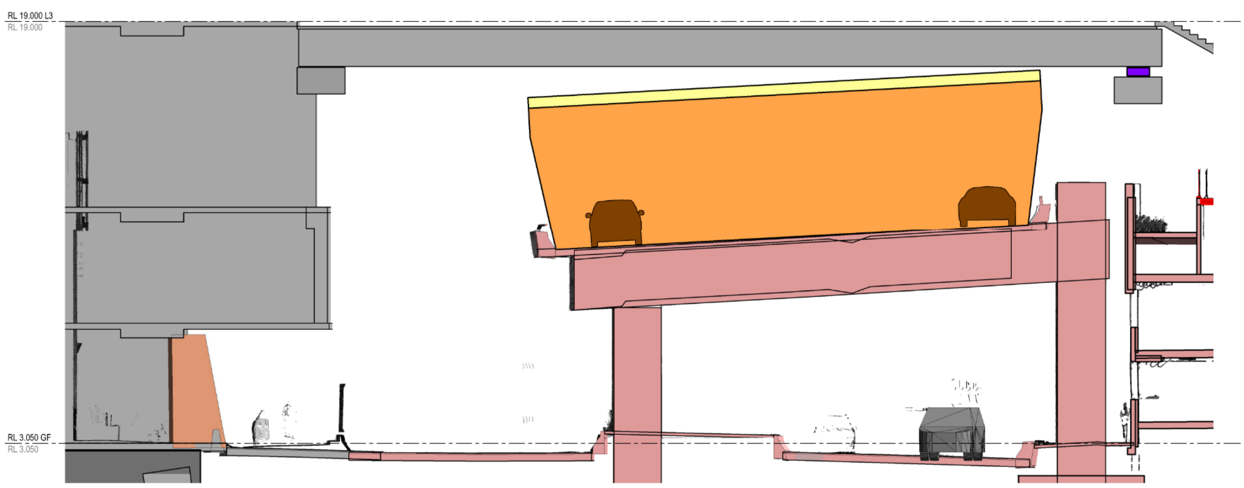


Figure 20 – Typical Road Clearance Section

Horizontal Clearances to the Western Distributor

Adequate clearance has been identified as a key planning consideration to ensure the proposed vertical elements do not compromise TfNSW's ability to maintain the existing road infrastructure. To this end, a detailed co-ordination process was undertaken to identify any locations where clearance was less than 2m, a threshold identified by TfNSW as needing further consideration. At each of the four relevant locations, it was demonstrated that less than 2m clearance to the proposed landbridge would not compromise TfNSW's ability to maintain the existing infrastructure.

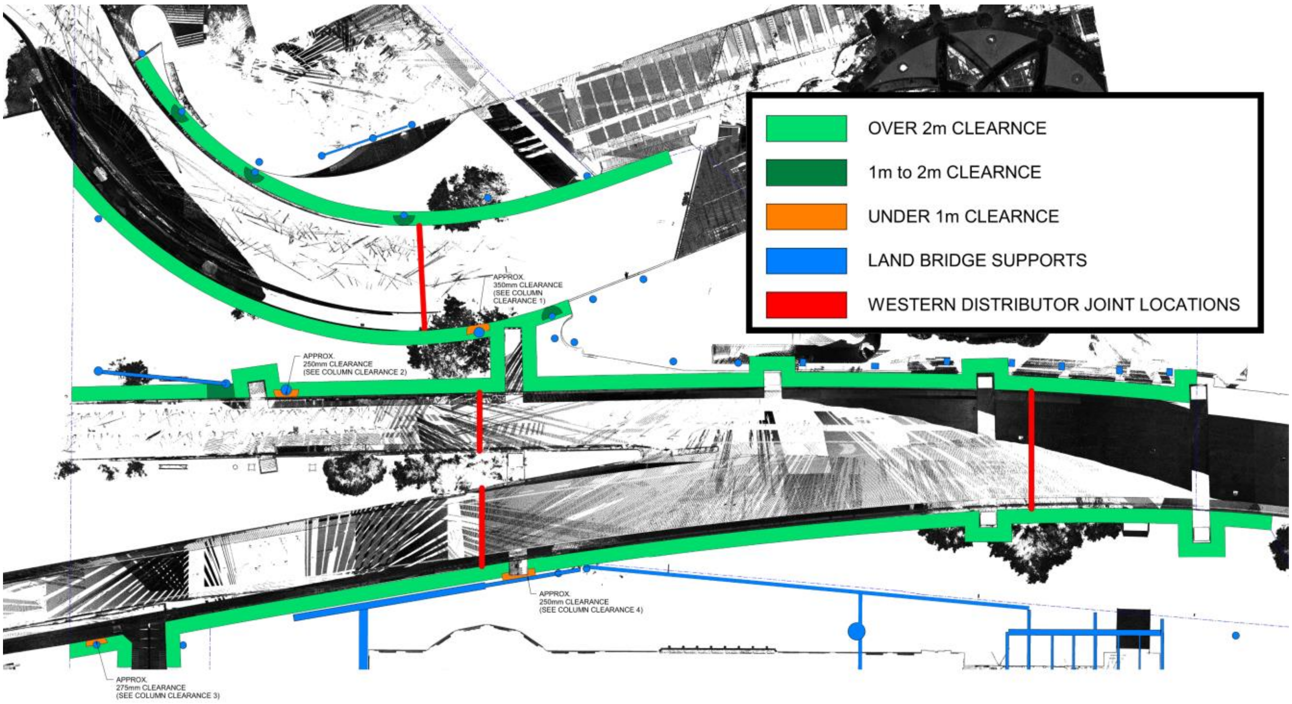


Figure 21 – Clearance Diagram between Western Distributor and New Structure

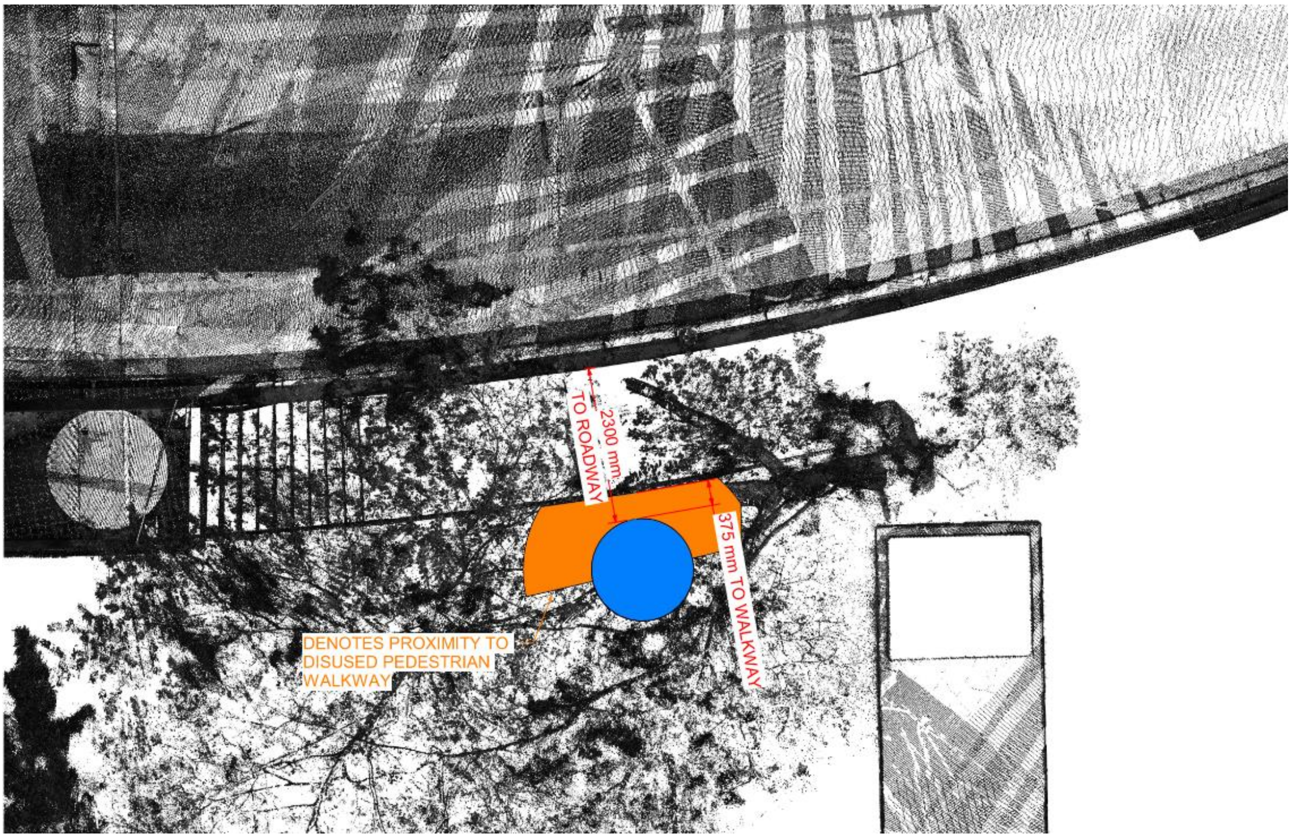


Figure 22 – Typical Detailed Clearance Investigation Plan

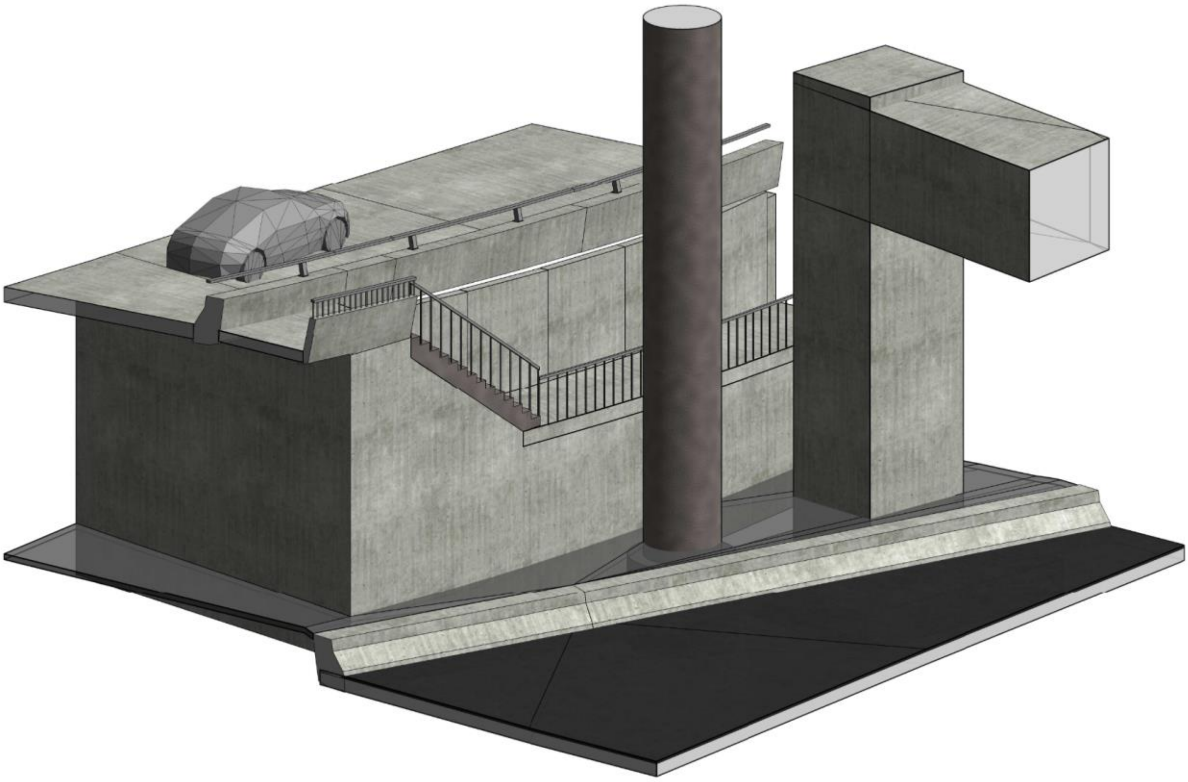


Figure 23 – Typical Detailed Clearance Investigation ISO

12. Conclusion

This report has been prepared to address planning conditions relating to the structural design of a proposed landbridge spanning the Western Distributor.

Outlined are the relevant structural systems, clearances, and construction requirements to build the proposed landbridge, demonstrating compliance with condition C25.

The structural planning has incorporated requirements of GTD 2012/001 and progression of the design will maintain compliance with these requirements in accordance with condition C24.

The proposed new pedestrian bridge over Sussex St is consistent in scale and support to the existing bridge and does not meaningfully worsen the current loads imposed on the proposed CBDRL, demonstrating compliance with condition C31.

APPENDIX A

Landbridge Structural Drawings

COCKLE BAY REDEVELOPMENT
LAND BRIDGE GENERAL ARRANGEMENT

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LAND BRIDGE STRUCTURAL DRAWING LIST

SHEET NUMBER	SHEET NAME
103-20	LAND BRIDGE - GENERAL ARRANGEMENT
103-21	LAND BRIDGE - DEMOLITION PLAN
103-22	LAND BRIDGE - SUPPORTS
103-23	LAND BRIDGE - HEADSTOCKS
103-24	LAND BRIDGE - PRECAST BEAMS
103-25	LAND BRIDGE - CONCRETE PROFILE
103-26	LAND BRIDGE - JOINTS
103-27	LAND BRIDGE - BEARINGS
103-28	LAND BRIDGE - LATERAL SUPPORTS
103-29	LAND BRIDGE - EXISTING SITE
103-31	LAND BRIDGE - SECTIONS SHEET 1
103-32	LAND BRIDGE - SECTIONS SHEET 2
103-33	LAND BRIDGE - SECTIONS SHEET 3
103-34	LAND BRIDGE - SECTIONS SHEET 4
103-35	LAND BRIDGE - SECTIONS SHEET 5
103-36	LAND BRIDGE - SECTIONS SHEET 6

LAND BRIDGE STRUCTURAL DRAWING LIST

SHEET NUMBER	SHEET NAME
103-70	LAND BRIDGE - LOADING DIAGRAM
103-80	LAND BRIDGE - CLEARANCES TO ELEVATED WESTERN DISTRIBUTOR
103-81	LAND BRIDGE - COLUMN CLEARANCE 1
103-82	LAND BRIDGE - COLUMN CLEARANCE 2
103-83	LAND BRIDGE - COLUMN CLEARANCE 3
103-84	LAND BRIDGE - COLUMN CLEARANCE 4
103-85	LAND BRIDGE - LONG SECTION
103-86	LAND BRIDGE - WESTERN DISTRIBUTOR FOUNDATION OVERLAY
103-87	LANDBRIDGE - SUPPORT COLUMNS
103-90	LAND BRIDGE - COLUMN CONSTRUCTION OVERALL
103-91	LAND BRIDGE - COLUMN CONSTRUCTION LOCATION 1
103-92	LAND BRIDGE - COLUMN CONSTRUCTION LOCATION 2
103-93	LAND BRIDGE - COLUMN CONSTRUCTION LOCATION 3
103-94	LAND BRIDGE - COLUMN CONSTRUCTION LOCATION 4
103-95	LAND BRIDGE - COLUMN CONSTRUCTION FORMWORK AND SCAFFOLD

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PROJECT NAME
COCKLE BAY PARK
PROJECT NUMBER: 6054

DRAWING TITLE
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Supports within owner site boundary

Supports behind barriers within road network

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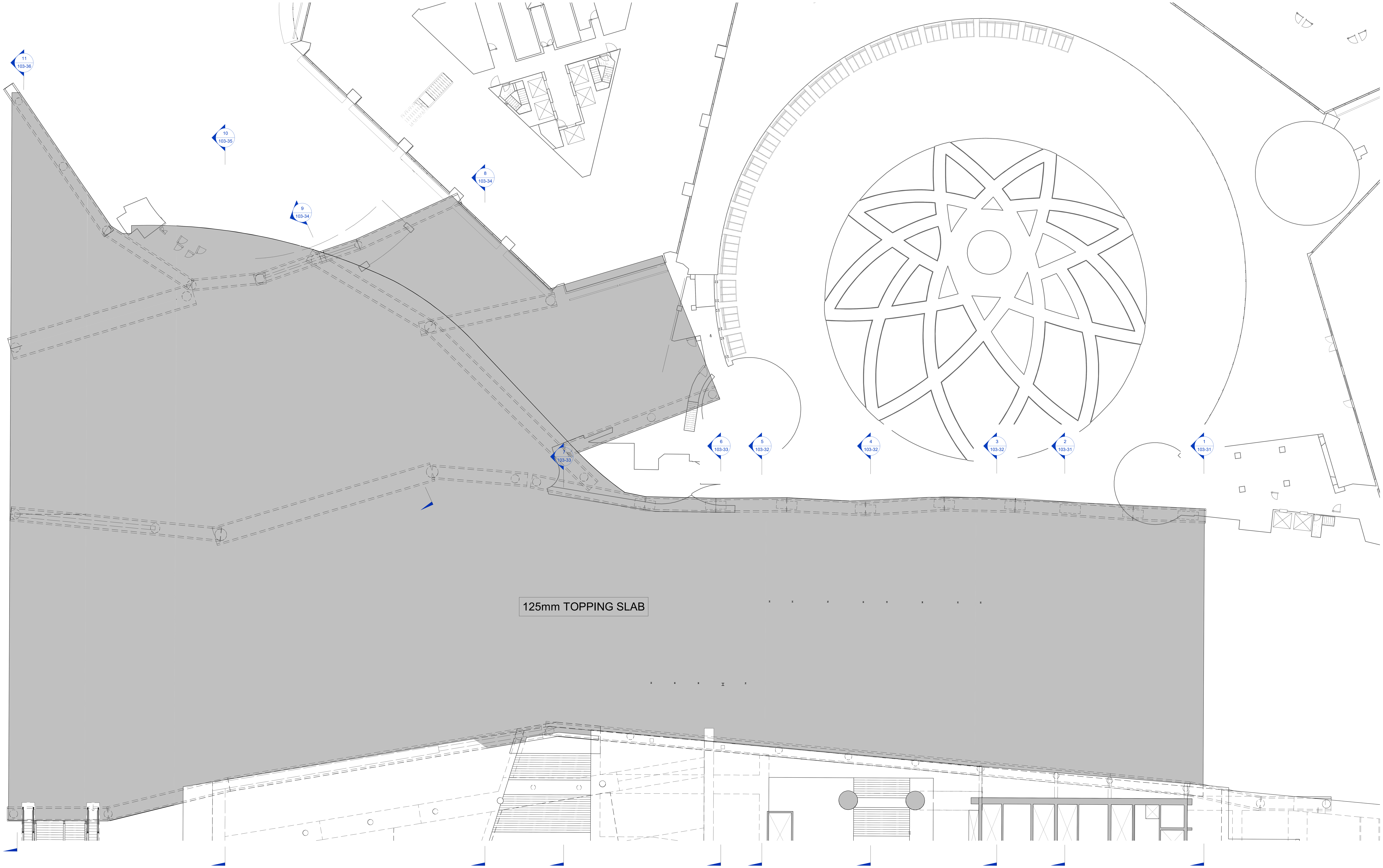

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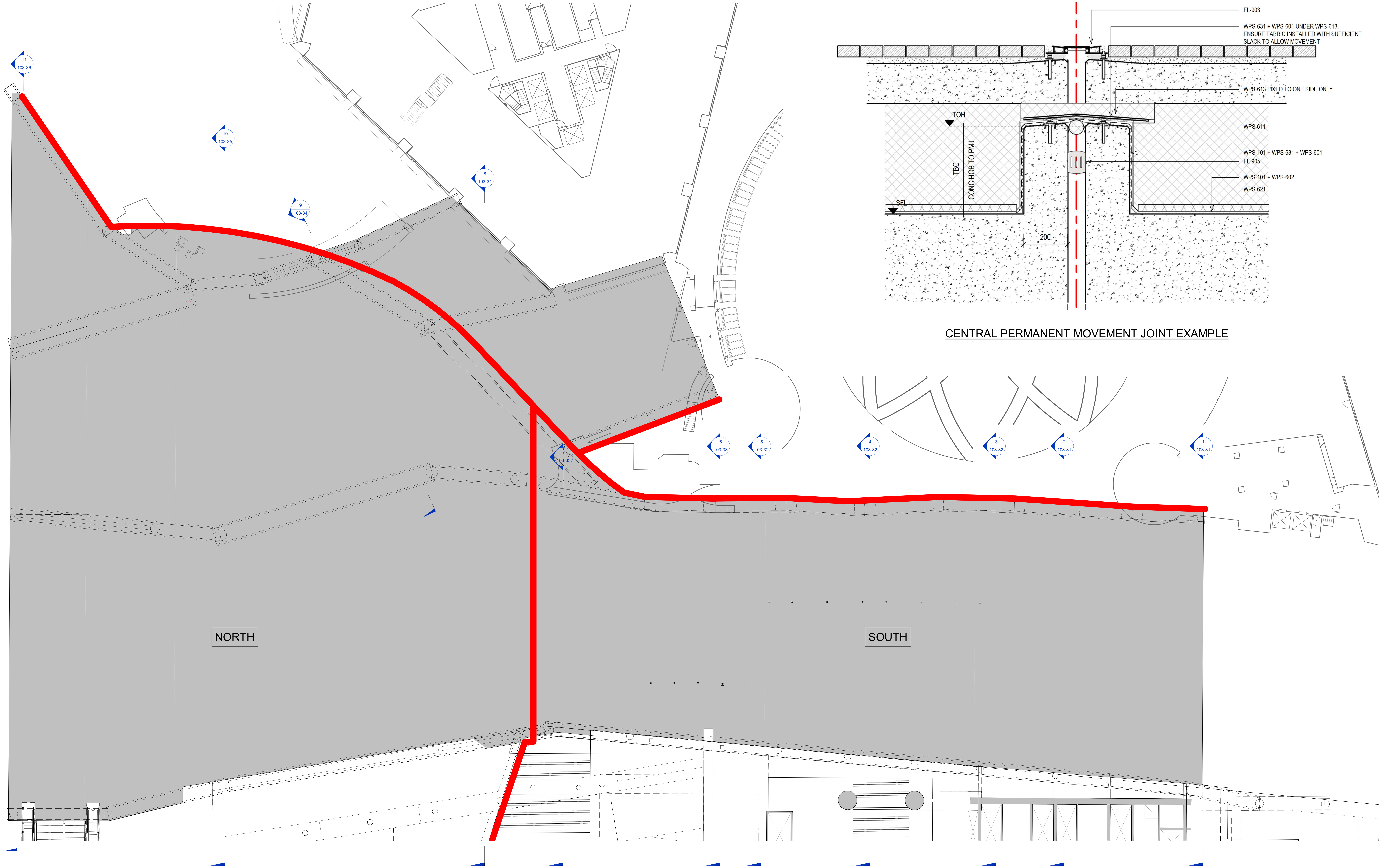

CENTRAL PERMANENT MOVEMENT JOINT EXAMPLE

PERMANENT MOVEMENT JOINTS

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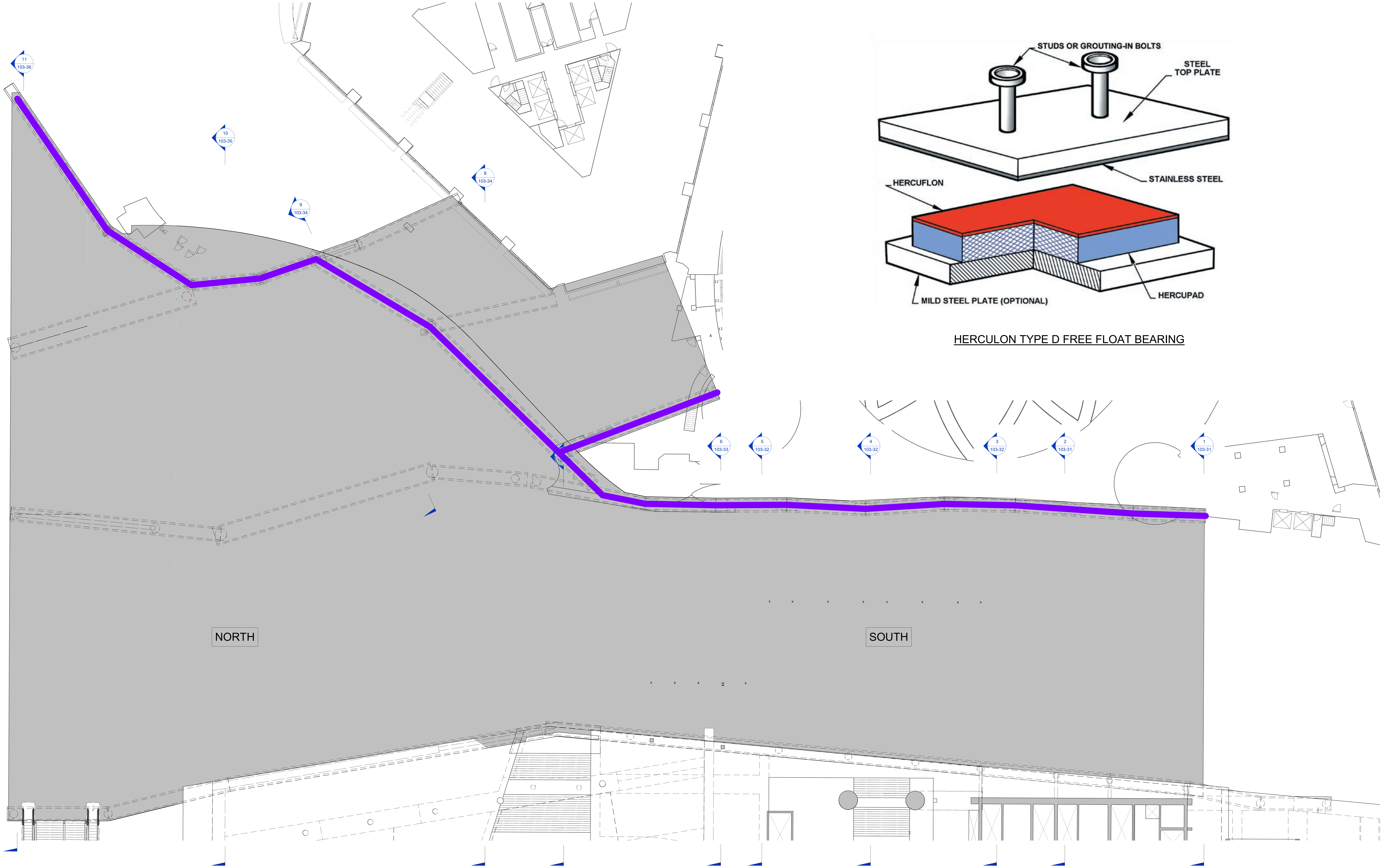

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LINE OF ISOLATION BEARINGS

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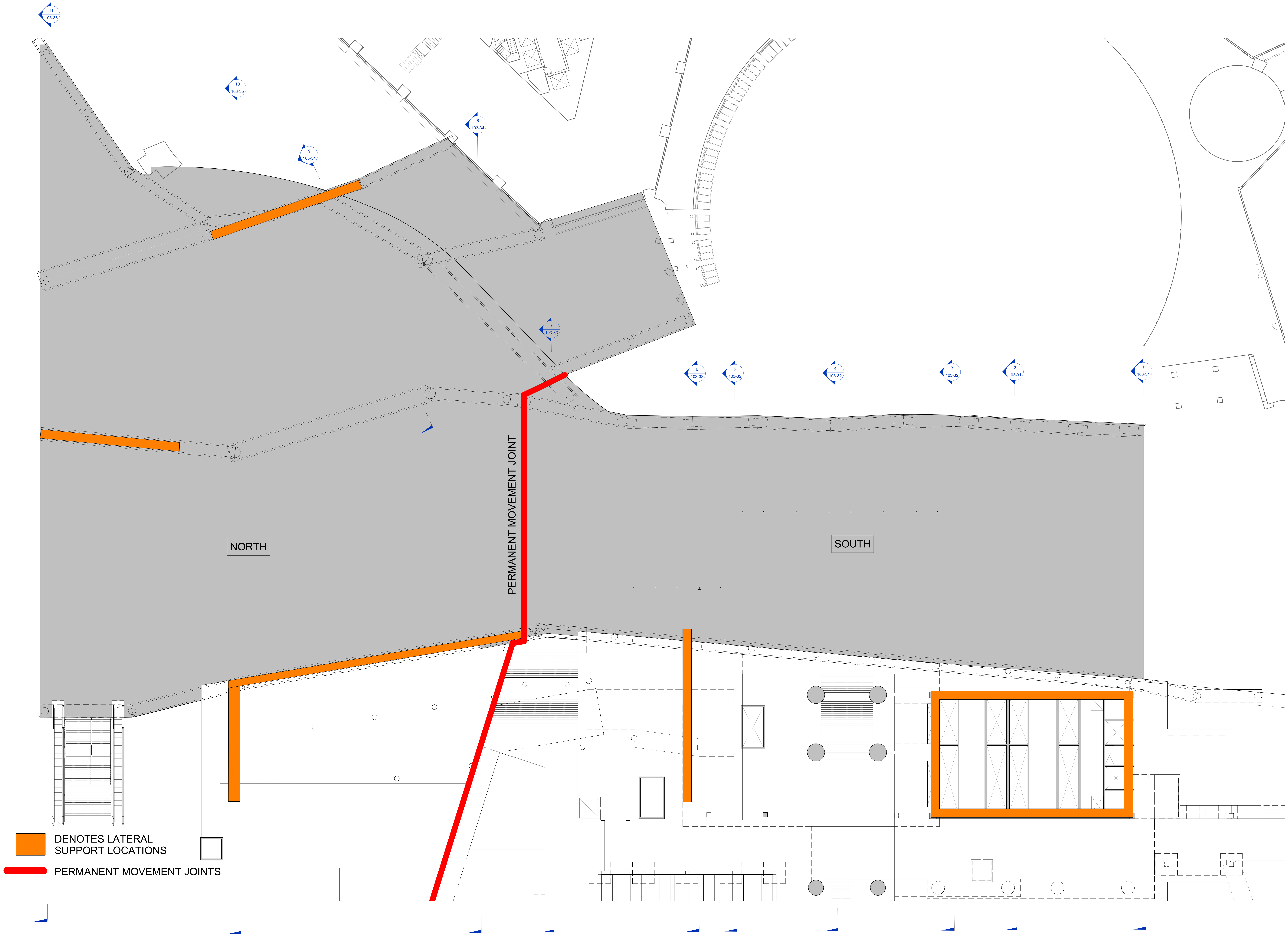

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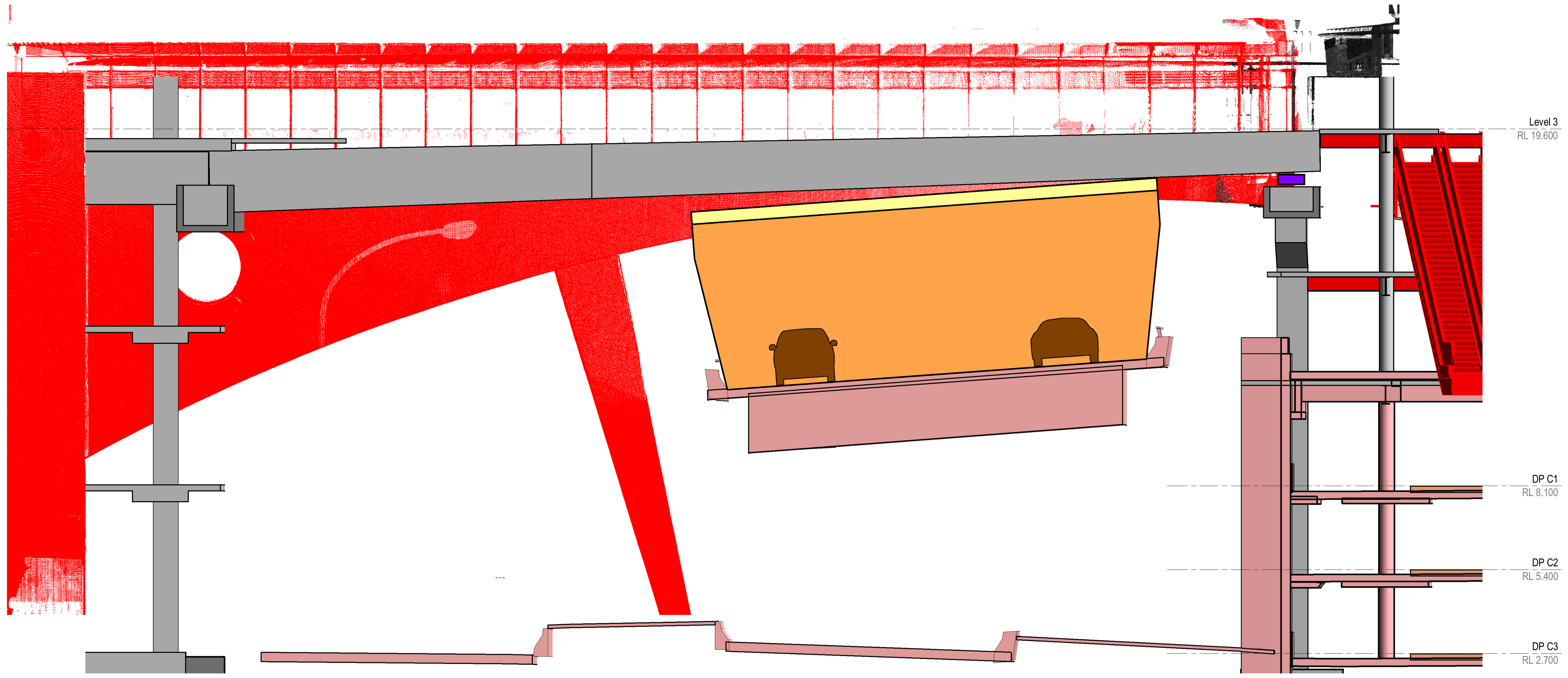

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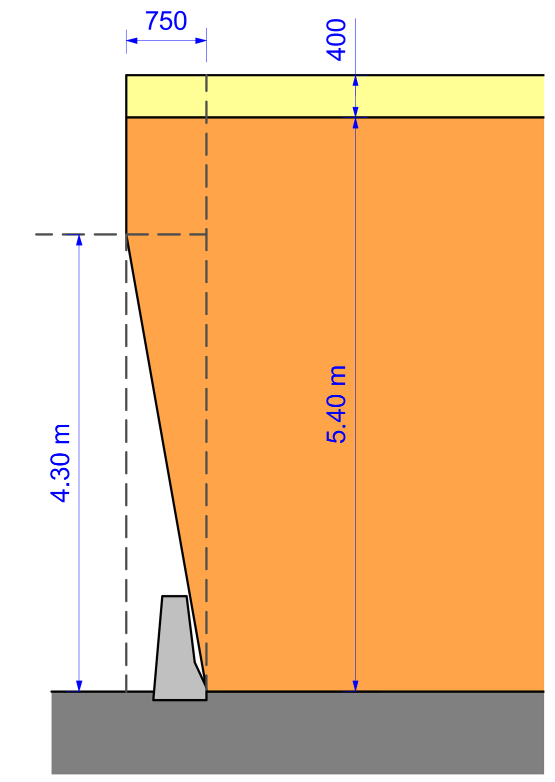
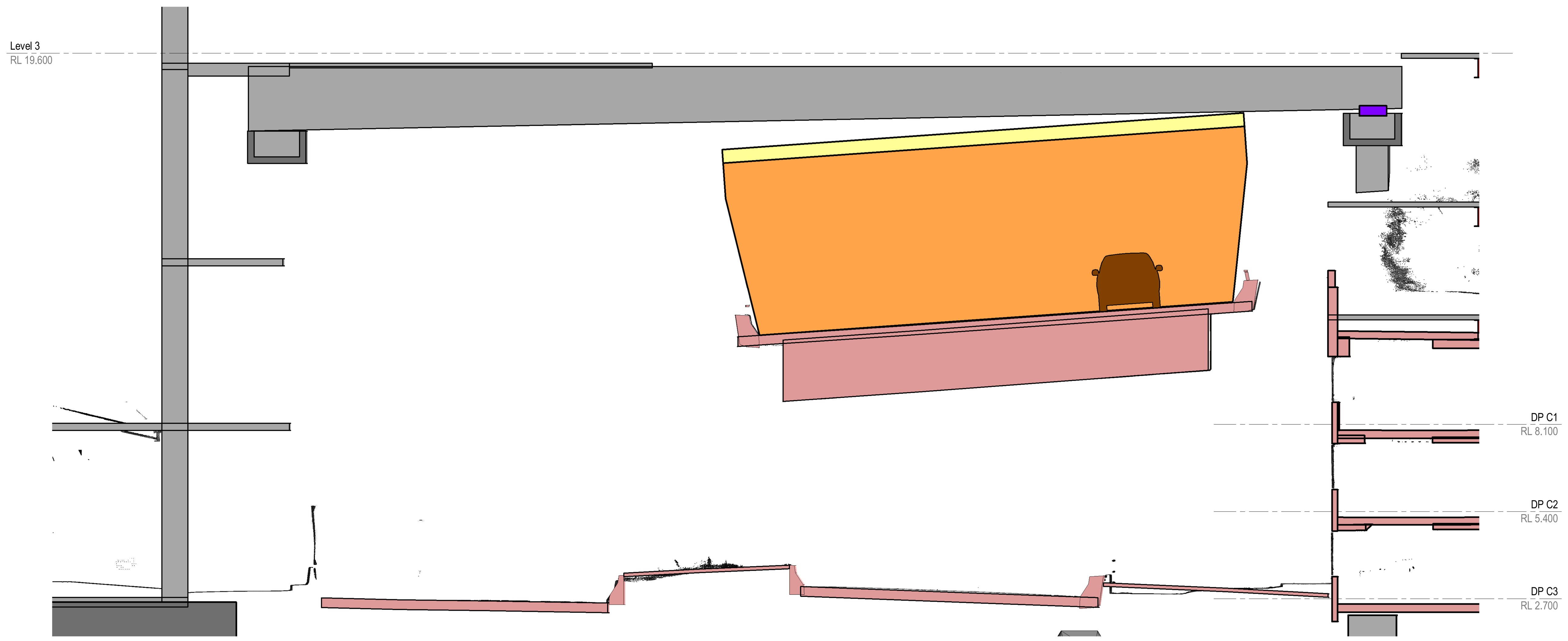


ROLL OVER CLEARANCES

Denotes Existing Structure

Denotes Proposed Land Bridge Structure

Denotes Demolished Structure



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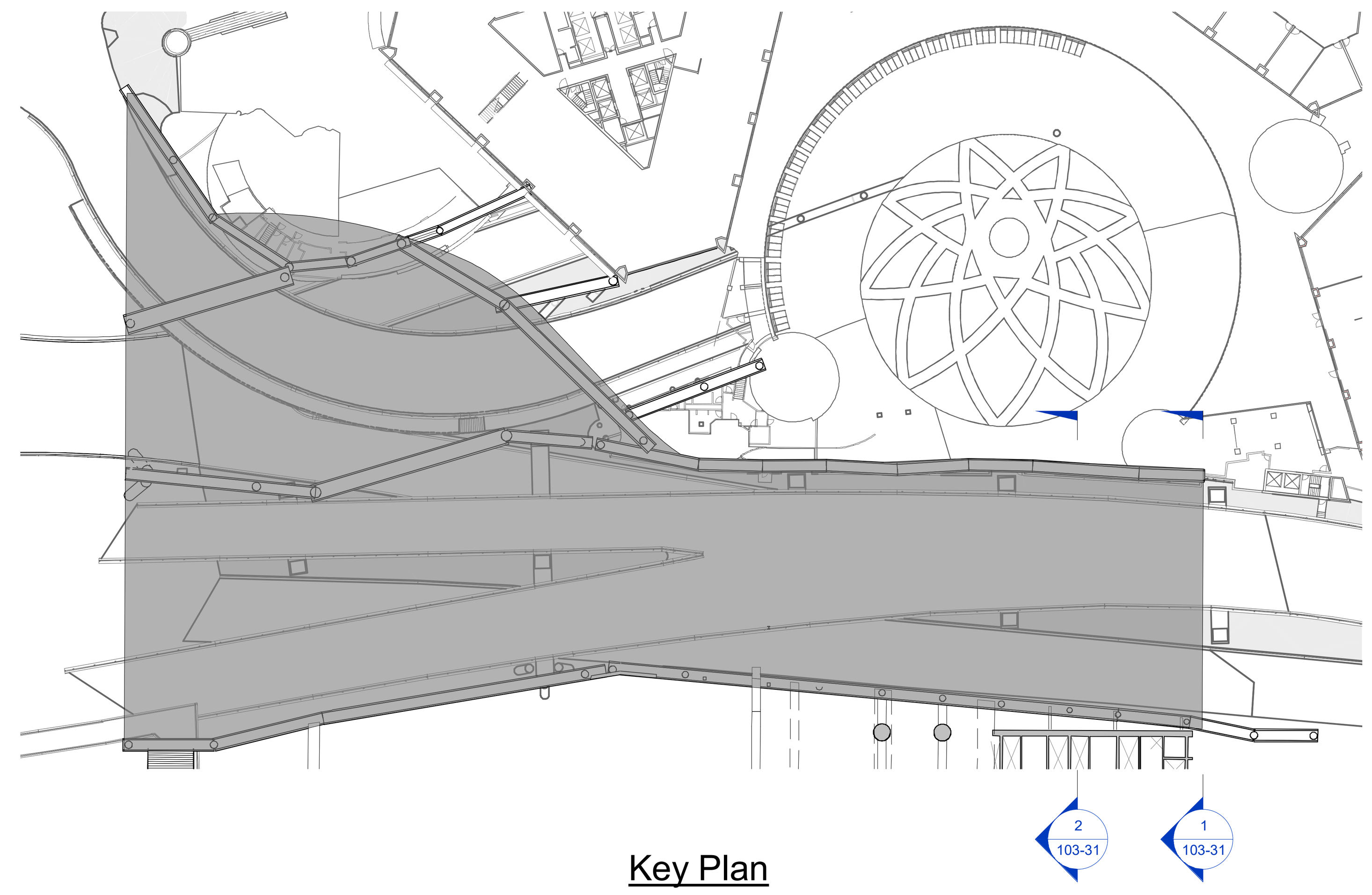

Key Plan
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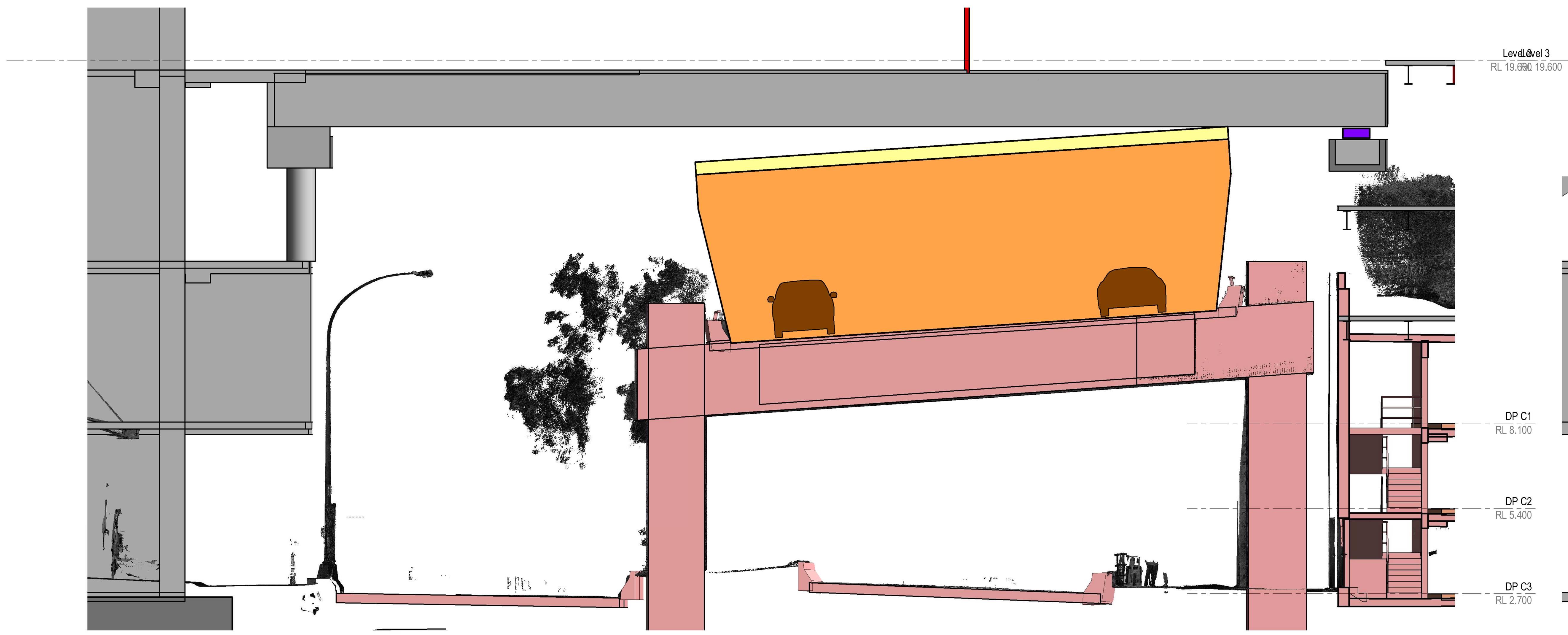

SECTION 3 (103-22)
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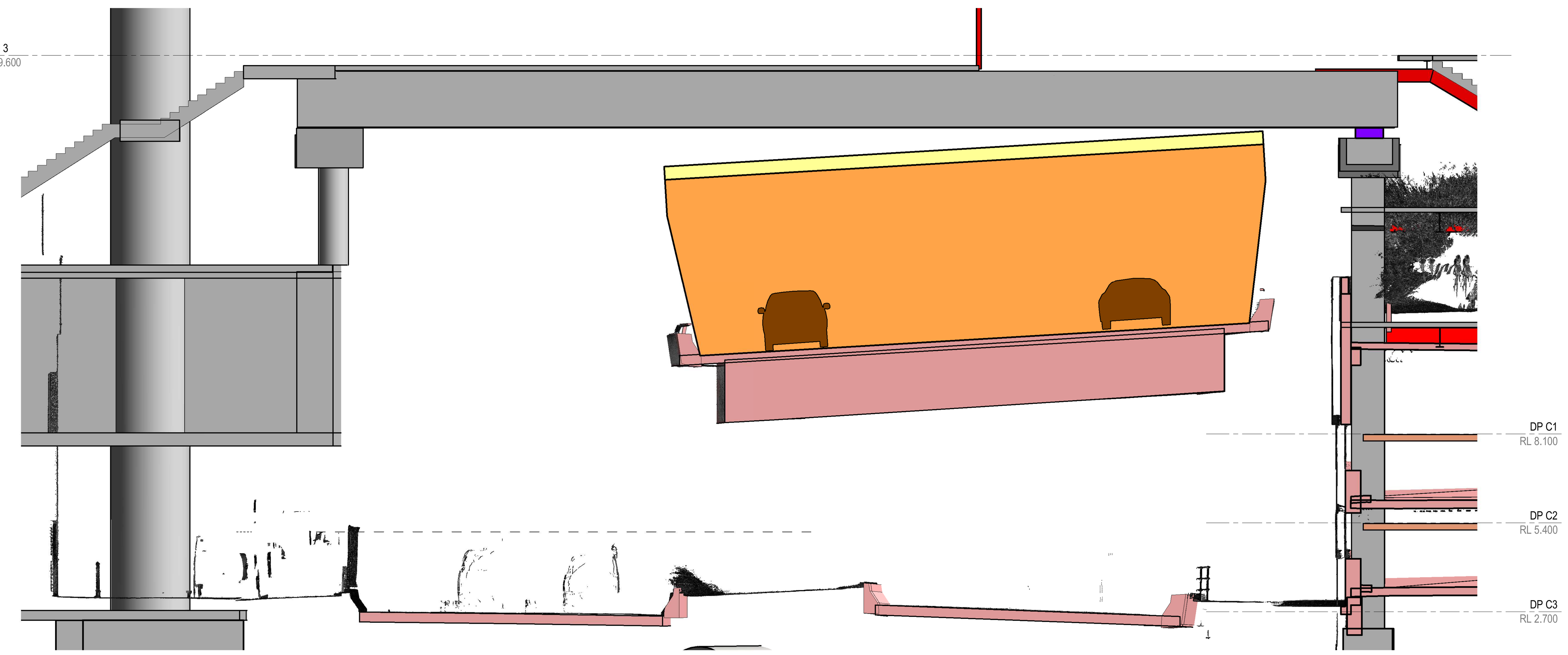

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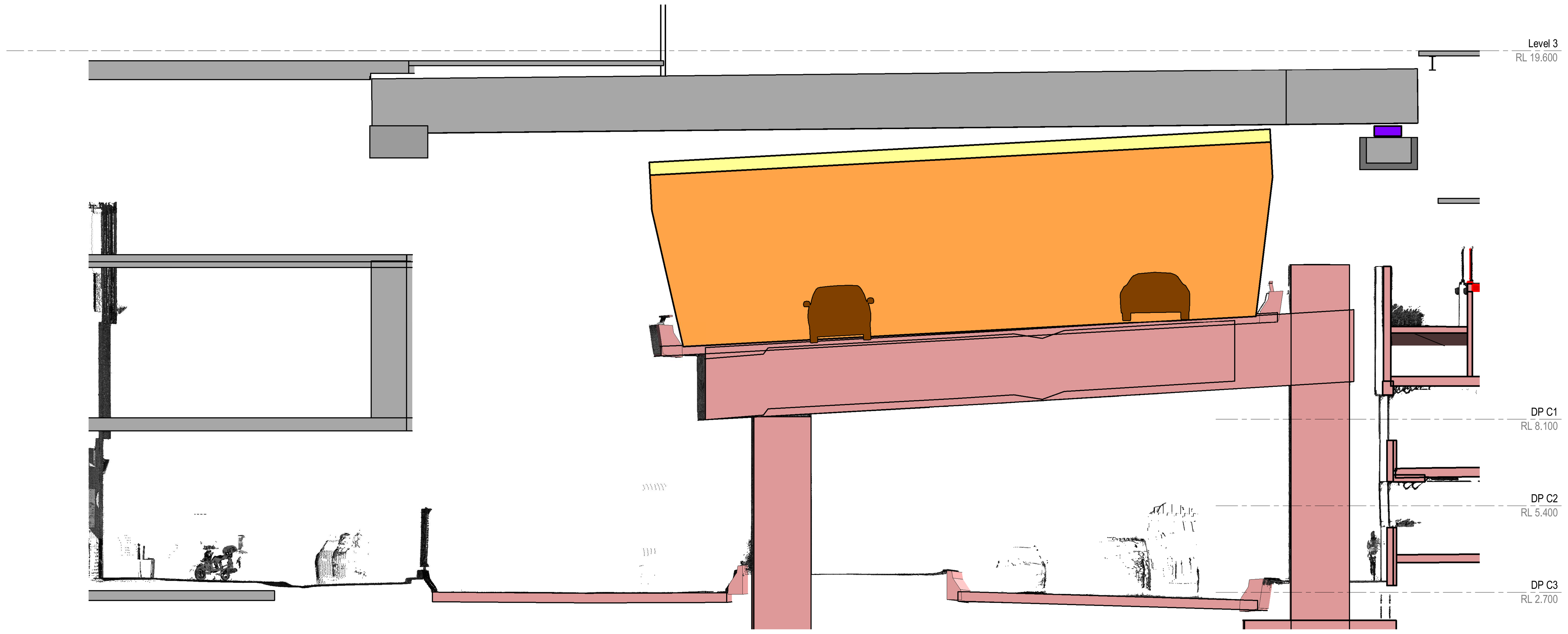
1 : 100

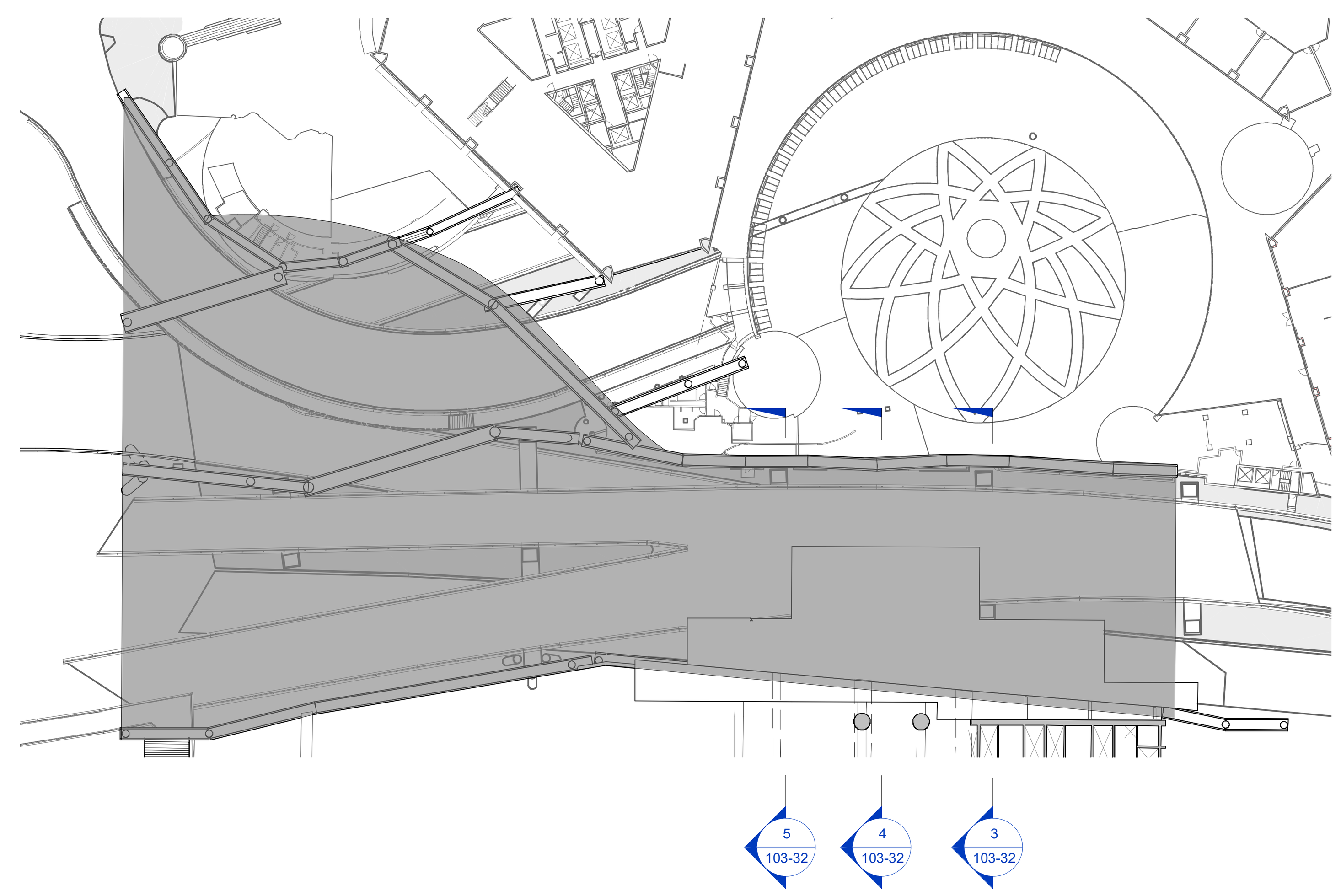


SECTION 5 (103-22)
1 : 100

Denotes Existing Structure

Denotes Proposed Land Bridge Structure

Denotes Demolished Structure



Key Plan
SCALE:1 : 700

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C	05.08.20	ISSUED FOR INFORMATION
D	12.05.21	ISSUED FOR INFORMATION
E	03.09.21	ISSUED FOR INFORMATION

PROJECT NAME
COCKLE BAY PARK
PROJECT NUMBER: 6054

DRAWING TITLE
LAND BRIDGE - SECTIONS SHEET 2
SCALE AT B1: As indicated
DRAWN BY: MTL
CHECKED BY: TBB

DRAWING STATUS
FOR INFORMATION

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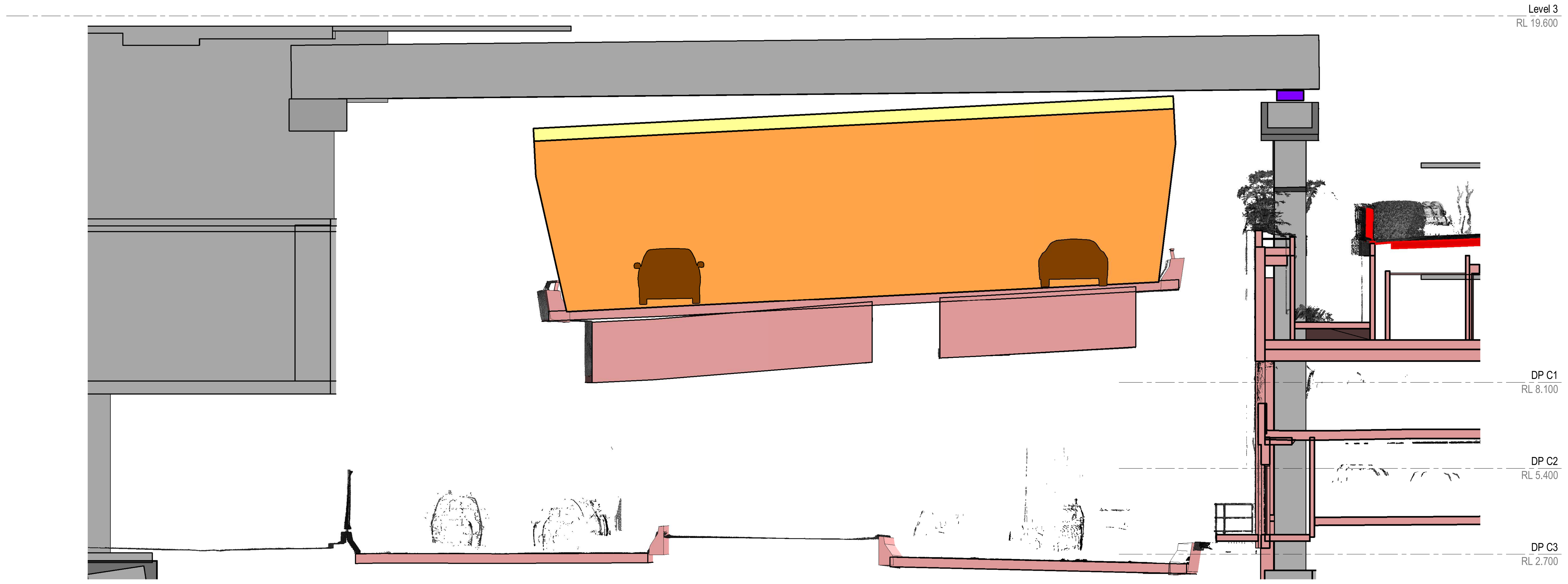
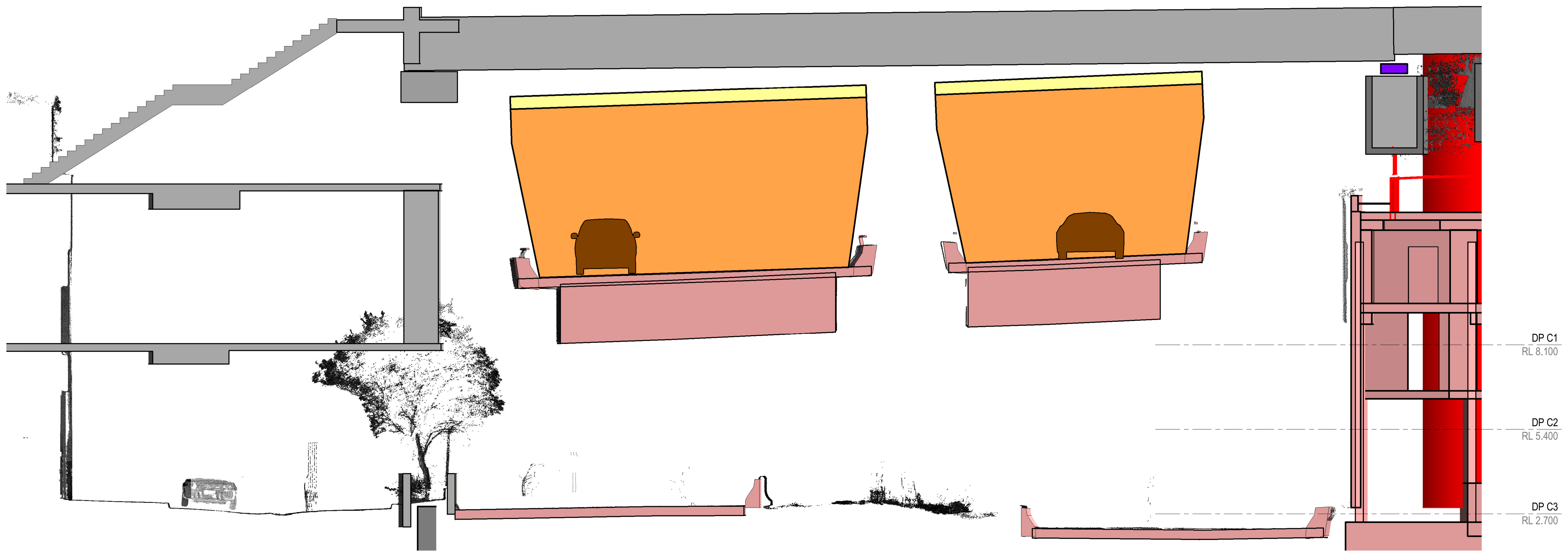


SECTION 6 103-22
1 : 100

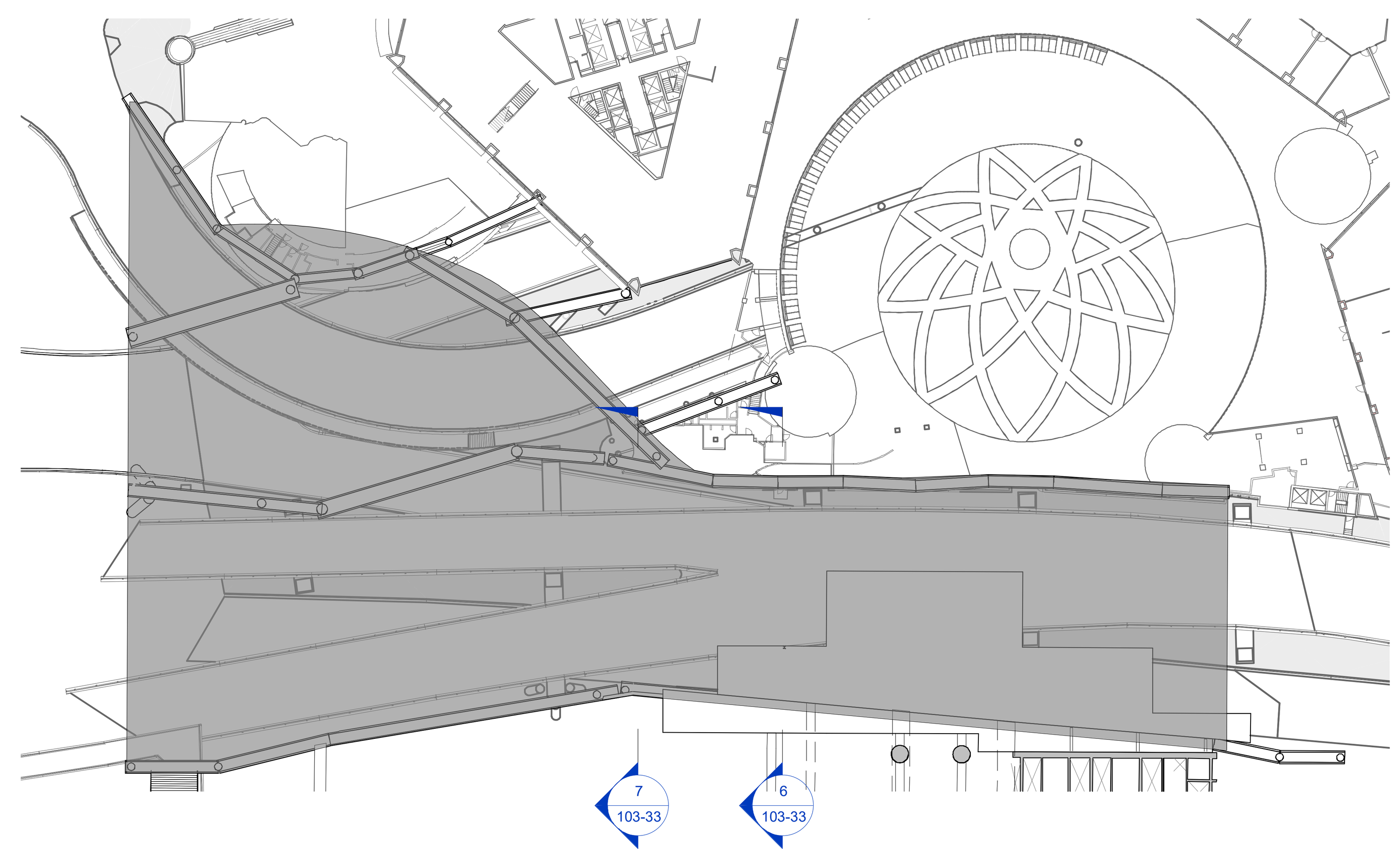


SECTION 7 103-22
1 : 100

Denotes Existing Structure

Denotes Proposed Land Bridge Structure

Denotes Demolished Structure



Key Plan
SCALE:1 : 700

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PROJECT NAME
COCKLE BAY PARK
PROJECT NUMBER: 6054

DRAWING TITLE
LAND BRIDGE - SECTIONS SHEET 3
SCALE AT B1: As indicated
DRAWN BY: MTL
CHECKED BY: TBB

DRAWING STATUS
FOR INFORMATION
DRAWING NUMBER
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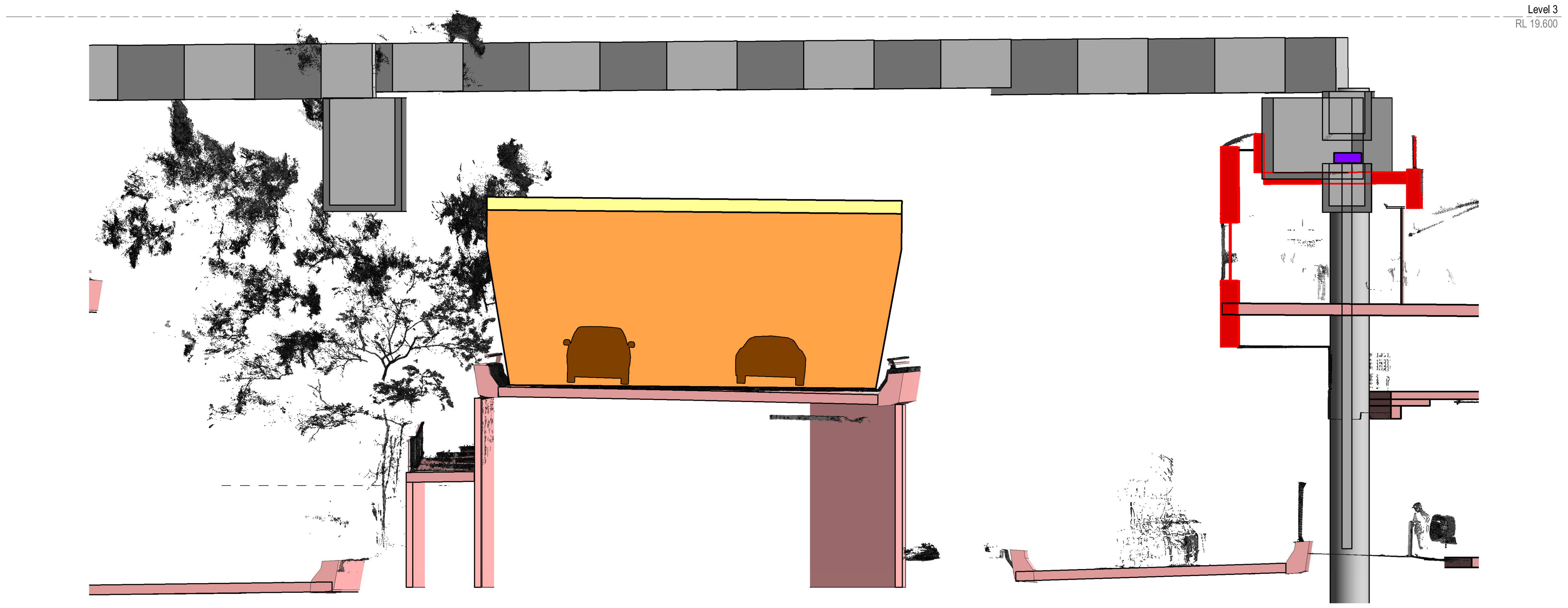
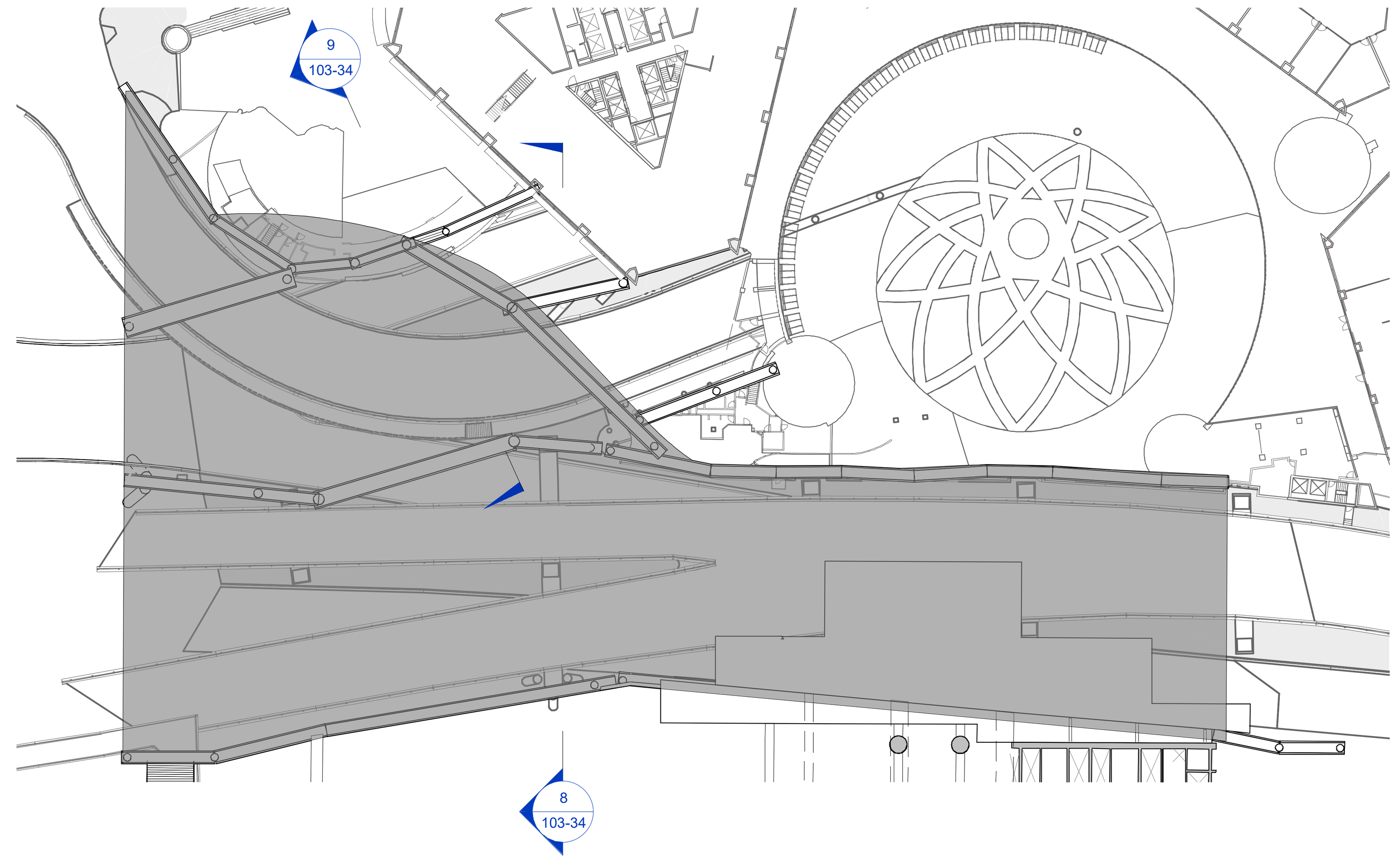
SECTION 8
1 : 100
103-22

- Denotes Existing Structure
- Denotes Proposed Land Bridge Structure
- Denotes Demolished Structure



SECTION 9
1 : 100
103-22



Key Plan
SCALE:1 : 700

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D	12.05.21	ISSUED FOR INFORMATION
E	03.09.21	ISSUED FOR INFORMATION

PROJECT NAME
COCKLE BAY PARK
PROJECT NUMBER: 6054

DRAWING TITLE
LAND BRIDGE - SECTIONS SHEET 4
SCALE AT B1: As indicated
DRAWN BY: MTL
CHECKED BY: TBB

DRAWING STATUS
FOR INFORMATION
DRAWING NUMBER
CBP-SK-ENS-STR-DRW-103-34
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