Appendix O: Geotechnical Report

MetCONNX

Byford Rail Extension

R30-CMW-RPT-GE-560-00007
Geotechnical Design Report – Armadale Precinct

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METRONET

Byford Rail Extension

Document details	
Title	Geotechnical Design Report -Armadale Precinct
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A.	15-Sep-2022	Issued for Reference Design	James Belcher	Andrew Websper	Alyssa Edwards
B.02	10-May-2023	Issued for Detailed Design - IV	James Belcher	Craig Butterworth	Alyssa Edwards

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1. Executive Summary

This Interim Detailed Design (IDD) report provides an updated ground model for the Armadale Station precinct incorporating historical investigation and Stage 1 supplementary geotechnical investigation data. As part of the geological and geotechnical interpretation to update the existing ground model, two engineering geological long sections along the eastern and western sides of the Armadale Station precinct have been produced. These two geological long sections show the shallow ground conditions in greater detail compared to the viaduct geological long sections that show the deeper geology, however, the two sets of sections should be read in conjunction if a greater overview of the site geology is required.

Both the eastern and western sections show very loose to loose layers of sand within the Armadale Station precinct that have also been previously identified in historical investigations. This IDD report provides commentary on the revised locations of the Armadale Station structure, bus station, carpark and other associated structures in relation to the identified areas of very loose to loose sand (fill and/or Colluvium sub-unit).

Based on the above, a general site classification of Class P based on AS2870–2011 has been previously advised. However, an alternative site classification for specific areas of the Armadale Station precinct can be assigned if assessed in accordance with engineering principles and is discussed within Section 5.6.11. A site subsoil class of Ce to Section 4.2 of AS1170.4 has been previously recommended for seismic design purposes of the Armadale Station precinct. As identified above, the very loose to loose sand areas between approximate PTA chainages 29850 to 29125 and 29275 to 29550 a site subsoil class of De (deep or soft soil site) to Section 4.2 of AS1170.4 is recommended for seismic design purposes.

The current 2% AEP design groundwater level (DGWL) is at RL 37 m AHD and it is likely that the proposed shallow foundations for the Armadale Station concourse slab at RL 56.3 m AHD and other associated structures is well above the DGWL. However, due to the potential presence of perched groundwater across the Armadale Station precinct site, a likely conservative shallow design groundwater level at 0.5 mbgl has been considered for the design of shallow foundations.

In situ falling head infiltration testing was completed at two locations within the general Armadale Station precinct area by Advisian, designated BRE-PERM01 and BRE-PERM02. It is likely that the reported BRE-PERM01 and BRE-PERM02 ground and base elevations are incorrect (i.e. have been reported too high) based on a review of Stage 1 supplementary geotechnical investigation locations and elevations. Commentary on this potential error and comparison with typical ground conditions encountered rather than with elevations is provided in Section 5.6.7. Additional infiltration testing has been proposed to be completed at approximate bio-retention cell areas to assist in assessing design infiltration rates for the Final Detailed Design (FDD) report.

The Project Structural Engineer has advised that the proposed Armadale Station concourse slab is to be at RL 56.3 m AHD and has been used as a reference design ground level for strip and pad foundations for the specific Armadale Station structure as summarised in Section 5.8.1. An update of the allowable bearing pressures for strip and pad foundations on the eastern and western sides of the existing rail alignment are summarised in Sections 5.8.1.1 and 5.8.1.2. Assessment of specific strip/pad foundation locations and associated structural loads are to be completed during FDD stage when this information becomes available. This is the same understanding for proposed retaining walls for the Armadale Station concourse and is summarised in Section 5.8.2.

Acknowledgement of Country

MetCONNX acknowledges the Noongar people as the Traditional Custodians of the land and waters, upon which the Byford Rail Extension Project will be delivered. We pay our respects to the Noongar Elders past, present and emerging and respect their continuing connection to Country, Culture and Community.

2. Project Overview

2.1 METRONET Vision and Objectives

As one of the largest single investments in Perth's public transport, METRONET will transform the way the people of Perth commute and connect. It will create jobs and business opportunities and stimulate local communities and economic development to assist communities to thrive. The METRONET vision is for a well-connected Perth with more transport, housing and employment choices. In delivering METRONET, the WA Government has considered peoples' requirements for work, living and recreation within future urban centres with a train station at the heart.

The objectives are to:

- Support economic growth with better-connected businesses and greater access to jobs
- Deliver infrastructure that promotes easy and accessible travel and lifestyle options
- Create communities that have a sense of belonging and support Perth's growth and prosperity
- Plan for Perth's future growth by making the best use of our resources and funding
- Lead a cultural shift in the way government, private sector and industry work together to achieve integrated land use and transport solutions for the future of Perth.

2.2 Byford Rail Extension Overview

The Byford Rail Extension (BRE) Project has been identified as an essential component of the METRONET program. The Project will extend the electrified passenger rail service from Armadale to Byford, providing a strong transport connection between these two centres, supporting economic growth and providing greater access to jobs. The Project has been developed in line with policy objectives for highly integrated transport and land use planning.

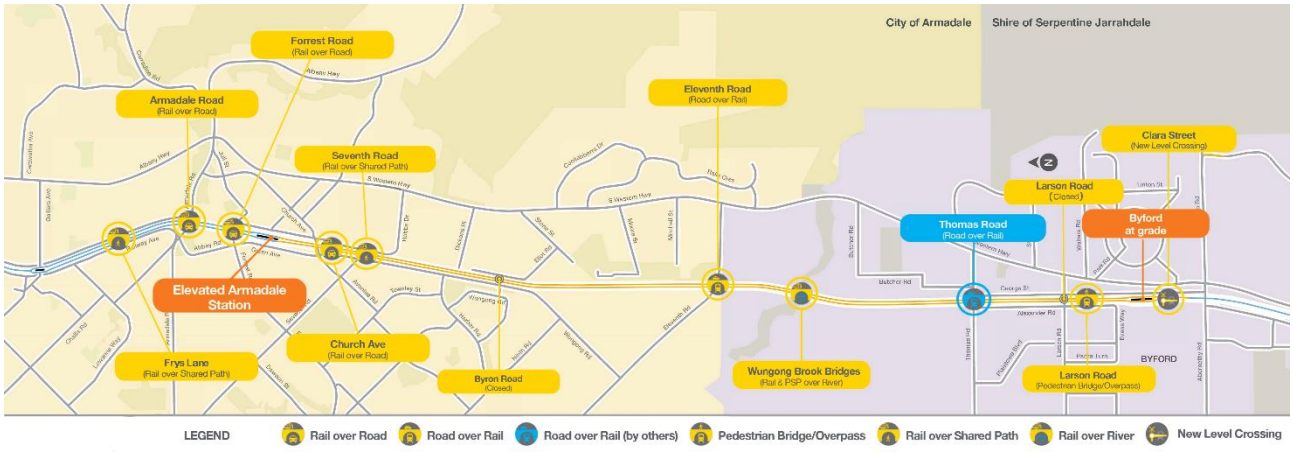


Figure 1: METRONET Byford Rail Extension Project

2.2.1 Project features

Transport infrastructure works for the BRE Project include:

- Demolition of existing station at Armadale and construction of a new elevated station
- Construction of a new Byford station at grade (Base Case)
- Construction of approximately 8km of dual track narrow gauge electrified passenger railway line extending from Armadale station to the newly created Byford station, with a dedicated platform for the Australind line
- Removal of level crossings between the Byford and Armadale stations
- Construction of PSPs and associated infrastructure (including 'rail over road' and 'road over rail' bridges and roads)
- Parking areas at Armadale and Byford stations
- Bus interchange at Armadale and Byford stations
- Upgrade of local roads surrounding both Armadale and Byford stations.

2.2.2 General scope of works

The Project's general scope of works includes designing, procuring, manufacturing, constructing, installing and commissioning all rail infrastructure and ancillary works to support an electrified operational passenger rail between Armadale and Byford Stations. Also, in the case of the Australind train service, tying into the non-electrified rail network south of Byford Station.

The Project activities include all site investigation, design, planning, scheduling, procurement, cost control, approvals, construction, OH&S management, environmental management, quality management, testing and commissioning, Entry Into Service (EIS), training and operational readiness required to tie the rail extension to Byford into the existing rail network including the associated road, utilities and other required works to interface with adjacent works and contracts. This will include bulk earthworks and retaining structures, grade separations, roads, and drainage, the demolition and removal and treatment of waste material and contaminated material resulting from construction of the Works, and temporary works constructed for the purpose of facilitating the Works.

The project scope also includes any new road works, modifications to existing roads and signalised intersections, utilities (diversion, protection, and new installation) and any other ancillary works to enable the BRE Project.

2.2.3 Future Proofing the works

As part of the Project, space must be allowed within the rail corridor for the option of a 4-track scenario for a potential high-speed regional service from Bunbury. The additional 2 tracks shall be constructed in the eastern half of the rail corridor, so that future infrastructure can be constructed without impacting on existing rail operations. The Project should also allow for the possibility of future extension of the electrified line south of Byford to Mundijong, and a future stabling yard south of Abernethy Road.

2.3 Alliance vision and delivery approach

The BRE Project will be delivered under an alliance contract to support the management of project and stakeholder interfaces and to mitigate project risks. A collaborative alliance approach will see

the Works carried out in a cooperative, coordinated and efficient manner, in compliance with the Alliance Principles.

MetCONNX understands that the successful delivery of the Project is critically linked to meeting the PTA's Key Project Objectives. These objectives have shaped our vision for the Project that is around delivering a high-quality product and creating exceptional value-for-money. We are committed to a no-blame culture and to the prompt and mutual resolution of any issues that may arise.

During the AD Stage, an interactive ALT Visioning Workshop was held with representatives from the PTA and MetCONNX to develop a suitable Alliance Vision for the Project, refer Figure 2.

Figure 2: AD Stage Alliance Vision Development Outcomes (developed with the PTA)

To support the realisation of this vision, we will develop a robust and highly collaborative alliance culture in which everyone challenges 'business-as-usual' and pursues better outcomes in the design and construction of the Project. In line with this, during the AD Stage the MetCONNX team refined their priorities for the Project as being:

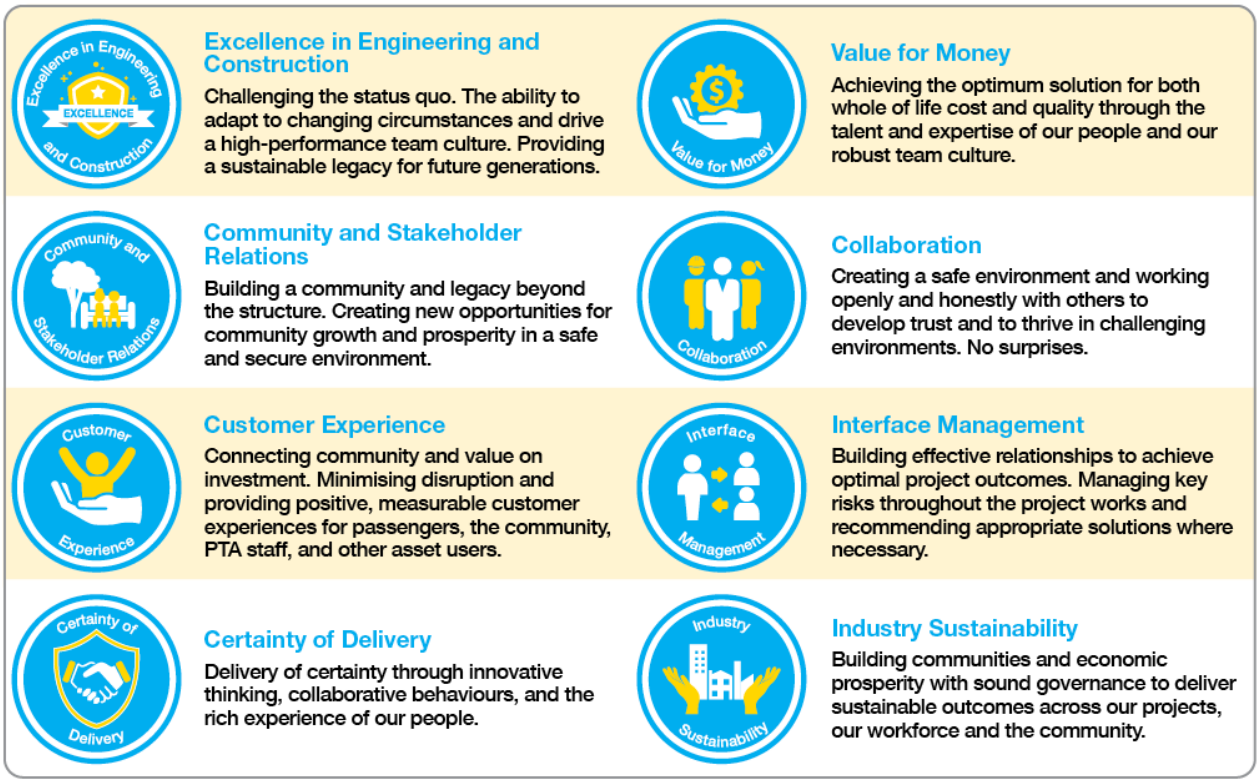


Figure 3: MetCONNX Priorities aligned with Key Project Objectives

2.4 Purpose of the Report

This Design Report presents the geotechnical design information for the Armadale Station - Station Structures (excluding viaduct) Design Package (Design Lot ST235) for inclusion in Design Report R30-MET-RPT-ST-235-00001. This report shall provide the geotechnical design's rationale and context of the foundation and retention design works for review by the PTA and stakeholders.

Table 1 - Project Interfaces

Design Package ID	Title	Description of Interface
CI-001	Temporary Facilities at Sherwood & Armadale including Temporary Carparks (Include lighting, security etc), bus infrastructure, staff facilities.	Provide geotechnical advice for temporary facilities
UT-040	Utilities (Optus, Telstra, NBN, Vocus, ATCO, WaterCorp, Western Power)	Earthworks and drainage/ culverts consider the location of utilities
CI-080	Temp MCR	No direct interface with this package
TR-100	Permanent Way - Alignment Design	Track alignment determines arrangement for formation, earthworks, and drainage.
SI-120	Signalling	The signalling equipment located in the corridor has been considered in terms of access provisions.
TL-130	Communications & Controls Sitewide	No direct interface with this package
OH-140	Overhead Wiring	Overhead Wiring structure locations are considered as part of the earthworks and formation

3. Design Description

3.1 Scope of this Design Package

This design report has been prepared to provide a documented record of the geotechnical design information for the design of the following referenced structures.

- Armadale Station and associated structures (excluding Armadale Viaduct)
- Any other structures associated with the project are covered in separate submissions

This design report provides the following information:

- Approach, methodology and assumptions made for the geotechnical design
- Geotechnical shallow foundation design information for the Armadale Station precinct
- Geotechnical design information for the civil design works around the Armadale Station precinct
- Geotechnical design information for the proposed retaining walls around the Armadale Station precinct (excluding approach embankments)

The structures covered in this report have been designed in accordance with the relevant sections of the SWTC, PTA Specifications and Australian Standards, except as noted through this report. The geotechnical design information has been developed in collaboration with the structural designers.

The design of the structures is contained in the main package design report.

3.2 Relationship with other Design Packages

This Design Report presents the geotechnical design information for the Armadale Station - Station Structures (excluding viaduct) Design Package (Design Lot ST235) for inclusion in Design Report R30-MET-RPT-ST-235-00001.

3.3 External Interfaces

N/A

3.4 Changes Since Previous Design Submission

3.4.1 Alliance Development (AD) Phase to Reference Design (RD) Phase

The overall Armadale Station precinct has had limited design changes between AD and RD phase with the Armadale Station viaduct/piles and new Armadale Station likely to be supported on shallow foundations still currently proposed.

3.4.2 Reference Design (RD) Phase to Interim Detailed Design (IDD) Phase

The Armadale Station precinct has had multiple layout changes between RD and IDD phase that has included the following:

- Relocation of the bus interchange and associated canopy structure from the south to the north of the proposed new Armadale Station
- An accessway to the south of the proposed new Armadale Station to be retained for a taxi rank, accessible bays, short-term parking and ‘Kiss N Ride’ bays
- Relocation of the portion of the Principal Shared Path (PSP) within the proposed new Armadale Station from east of the existing railway line to the west with the PSP to be at grade over Church Avenue

3.5 Works Required to Progress the Design to Final Detailed Design (FDD) Phase

Whilst an IDD geotechnical design report for the Armadale Precinct (this document) has been prepared, the assessments and recommendations provided herein are limited due to a revision and subsequent update of the Armadale Precinct Reference Design. The following items (but not limited to) are required to be addressed to progress the design to FDD stage:

- Assessment of structural loads for the station structure and concourse retaining walls, bus station canopies and other associated minor structures.
- A review of the final foundation design and advise on specific subgrade preparation, dewatering requirements & potential temporary piling/crane platform design incorporation for proposed strip and pad foundations within different areas of the Armadale Precinct as outlined in Section 5.6.4.
- Commentary regarding the foundation interaction between the viaduct and station structures once further detailed drawings of both structures together are available for review.
- Incorporation of Stage 2 & 3 supplementary geotechnical investigation data, specifically near surface ground conditions, material consistency/density and infiltration rates via proposed test pits to be undertaken during Stage 2B along the rail alignment.

3.6 Armadale Station Structure

The proposed Armadale Station structure is a multi-level structure that will support the elevated platforms to access the Armadale Up and Down main lines on top of the proposed Armadale Viaduct.

Structural station columns and lift bases are currently proposed to be supported on shallow foundations. The approximate extent of the station structure is shown on the updated Reference Design civil and structural drawings, some of which have been included in Appendix C. The approximate extent of the station structure has also been shown on the Armadale Station Site Investigation Plan and is presented in Appendix C.

3.7 Retaining Walls

Retaining walls are proposed to retain the Armadale Station concourse adjacent to the Park 'N' Ride and PTA staff car parking bays on the western side of the Armadale Station precinct. Design of other retaining walls along the alignment will be included in the retaining walls package.

4. Design Inputs

4.1 Project Design Requirements

Reference design and drawings for the Armadale Station structure have been updated following initial Reference Design submission with the updated RD stage drawings having been supplied for additional IDC and have been used for this IDD stage Geotechnical Design submission. The Armadale Station Site Investigation Plan indicates the approximate extent of the proposed new Armadale Station structure with PTA chainages and reference with historic and Stage 1 supplementary geotechnical investigation locations also presented. Reference should be made to the main design package for the latest civil and structural drawings.

A full set of design actions will be developed by the structural engineer depending on the structural layout for the Final Detailed Design (FDD) report. In order to provide initial geotechnical design advice and manage geotechnical risk, the structural and civil engineers have indicated the following:

- Proposed Armadale Station structural columns and lift bases to be supported on pad footings up to 2.0 m deep.
- The proposed Armadale Station concourse slab is to be at RL 56.3 m AHD.
- Indicative locations of pad footings and lift pits within the proposed new Armadale Station structure.
- Indicative locations of proposed bus interchange, associated canopy structure and accessways/car parking areas.
- Indicative locations of bio retention cell areas and base elevations of these basins.

4.2 Design Software Used for this Package

In-house design calculation spreadsheets and Settle3 developed by Rocscience have been used for this package.

4.3 Applicable Codes and Standards

The applicable standards, codes and guidelines are in accordance with SWTC Appendix 3 and applicable codes and standards are summarised in Table 2.

Table 2 – Applicable Codes and Standards

Reference	Revision	Description/Title
AS1170.0	2002	Structural design actions: General Principles
AS1170.4	2007	Structural design actions: Earthquake Actions in Australia
AS4678	2002	Earth retaining structures
AS2159	2009	Piling – Design and Installation
BRE-PTAWA-PM-RPT-00001	0	SWTC Book 1A: General Scope
BRE-PTAWA-PM-RPT-00002	0	SWTC Book 1B: Limit of Works
BRE-PTAWA-PM-RPT-00003	0	SWTC Book 2: Management Plan Requirements
BRE-PTAWA-PM-RPT-00004	0	SWTC Book 3A: Scope of Works
BRE-PTAWA-PM-RPT-00006	0	SWTC Book 3C: Elevated Option
BRE-PTAWA-PM-RPT-00007	0	SWTC Book 4 : Technical Criteria
BRE-PTAWA-PM-RPT-00007	0	SWTC Book 5: Appendices to the SWTC
8103-400-004	5	Working In and Around PTA Rail Reserve
8190-400-002	2.5	Narrow Gauge Main Line Track and Civil Infrastructure Code of Practice
8880-450-010	2	Specification Design Actions, Asset Design Life and Maintenance Free Period
8880-450-053	1	Specification Retaining Walls and Shallow Foundations
8880-450-059	1	Specification Buildings and Station Structures
8880-450-070	0	Specification Geotechnical Investigations
8880-450-074	1	Specification Earthworks Slope Stability Geotextiles and Erosion Protection
8880-450-077	1	Specification Deep Foundations

4.4 Reference Information

The project specific reference information and reports that have been used as inputs into the development of the design are included in Table 3.

Table 3 – Geotechnical and Hydrogeological Information

Document Reference	Description/Title	Revision
BRE-ADV-GE-RPT-00004	Geotechnical Investigation Factual Report, Advisian (18 Oct 2021)	1
BRE-ADV-GE-RPT-00005	Geotechnical Interpretative Report, Advisian (6 October 2021)	0

Document Reference	Description/Title	Revision
BRE-MNO-WSP-GE-RPT-0001	Geotechnical Factual and Interpretive Report, WSP	A
R30-CMW-RPT-GE-560-00001	Geotechnical Investigation Factual Report	A
BRE-ADV-GE-RPT-00012	Monthly Groundwater Monitoring (February 2022), Advisian, 28 February 2022	-
311012-00745-GT-MEM-0011	Monthly Groundwater Monitoring (April 2022), Advisian, 10 May 2022	-

4.5 Design Criteria

The design criteria utilised in the development of this design package are outlined below. These design criteria include material properties, design loading and serviceability requirements.

In accordance with PTA Specification 8880-450-059-Rev1 (Specification: Buildings and Station Structures) and 8880-450-053-Rev1 (Specification: Retaining Walls and Shallow Foundations):

- All retaining walls within the PTA rail reserve shall be Classification C in accordance with Table 1.1 of AS4678.
- The design groundwater levels shall not be lower than the 1% AEP groundwater levels
- Maximum allowable settlement/heave and horizontal deflection of any type of foundation through the design life are summarised in Table 4 and Table 5

Table 4 – Maximum Allowable Settlement/Heave

Foundation Type	Total Settlement/Heave		Differential Settlement/Heave	
	Short Term	Long Term	Short Term	Long Term
Shallow	20 mm	20 mm	1:1,000	1:1,000
Deep raft	20 mm	20 mm	1:1,000	1:1,000
Deep foundation element piles (DFEs)	15 mm	25 mm	1:1,000	1:1,000

Table 5 – Maximum Allowable Horizontal Deflection

Foundation Type	Horizontal Deflection		Horizontal Deflection	
	Short Term	Long Term	Short Term	Long Term
Laterally loaded DFEs	15 mm	25 mm	1:1000	1:1000
Gravity walls including cantilever reinforced concrete walls	15 mm	25 mm	1:1000	1:1000

Notes to Table 5:

- Settlement/heave/horizontal deflection are defined as the movement occurring from the time at which a foundation/retaining wall is cast and shall be measured at the structural surface of the foundation.

- The long term total allowable displacement magnitudes are inclusive of short-term displacement magnitudes.

4.6 Design Life

The design life requirements related to this design package are outlined in Table 6. These design life requirements are based on the minimum requirement specified in Clause 4.1 of the PTA Specification – Design Actions, Asset Design Life and Maintenance Free Period (8880-450-010). All works shall be designed and constructed to satisfy the required minimum design life.

Table 6 – Design Life

Item	Asset Element of the Works	Durability Design Life (Years)
1	Armadale Station	100 years (1), 50 years (2), 120 years (3)

Notes to Table 6:

- (1) Design Life for the considerations of structural design actions on structures
- (2) Service life for secondary structural elements. Classification on primary and secondary structural elements shall refer to Table 8 in 8880-450-010.
- (3) Design life for durability design and considerations on primary structural elements. Classification on primary and secondary structural elements shall refer to Table 8 in 8880-450-010.

4.7 Durability Requirements

Details of durability issues and risks, and measures to comply with the durability requirements will be outlined in the Durability package produced under separate cover.

4.8 Access and Maintenance – Structural Input

N/A

4.9 Constructability Requirements

See construction methodology section.

4.10 Environmental & Sustainability Design Criteria

Details of environmental & sustainability issues and risks, and measures to comply with the design criteria will be outlined in the Environmental & Sustainability package produced under separate cover.

4.11 Future Proofing

No input provided at IDD stage.

4.12 Value Engineering

No input provided at IDD stage.

4.13 Third Party Operational Stakeholders

N/A

4.14 Design Input from Stakeholders and Community Involvement Process

N/A

4.15 Design Assumptions, Dependencies, and Constraints (ADC's)

See Project Design Requirements section.

4.15.1 Design Assumptions

4.15.2 Design Dependencies

4.15.3 Design Constraints

4.16 Requests for Information (RFI)

No Requests for Information have been submitted at IDD stage.

5. Design Outputs

5.1 Design Reviews and Ce Deliverables List

N/A

5.2 Specifications

See Geotechnical Design Advice and Calculations section and Table 2.

5.3 Standard Reference Drawings

No geotechnical standard reference drawings provided at IDD stage.

5.4 System Coordination Drawings and Models

N/A

5.5 Type Approvals

N/A

5.6 Summary of Subsurface Conditions

5.6.1 Available Geotechnical Investigation

The available geotechnical information is contained in the reports listed in Table 3 and includes Stage 1 supplementary geotechnical investigation data. This information has been reviewed to develop east and west geological long sections along the Armadale Station precinct and used to update geotechnical design profiles and parameters for the structures covered in this report.

The existing and Stage 1 supplementary geotechnical investigation locations are shown in Appendix C with the geotechnical investigation data used to develop east and west geotechnical sections to indicate the investigation locations considered and to approximate areas classified in Section 5.6.4.

5.6.2 Supplementary Geotechnical Investigation

Stage 1 supplementary geotechnical investigation has been completed with Stage 2 works ongoing to confirm the ground conditions, in particular the suitability of Uncontrolled Fill (Type 2) as foundation subgrade and/or extent of well cemented Colluvium / Yoganup Formation / Duricrust across the station precinct.

The scope of the investigation has been designed in accordance with PTA Specifications 8880-450-053 and 8880-450-070.

The investigation works have been phased in order to provide timely information to the design and to align with access constraints of the project.

5.6.3 Geological Model Appreciation

Refer to Rail Alignment (At Grade) report Ref. R30-CMW-RPT-GE-560-00002 for general discussion of the geological conditions along the alignment, including the Armadale Station area. Some specific comments are provided in the following Section 5.6.4.

5.6.4 Subsurface Conditions

Updated geotechnical advice has been provided with the addition of Stage 1 supplementary geotechnical investigation data, Table 7, Table 9 and Table 11 have been updated as ground models for IDD geotechnical advice at Armadale Station (east of existing rail alignment). Table 13, Table 15 and Table 17 have been updated as a ground models at Armadale Station (west of existing rail alignment). Table 8, Table 10, Table 12, Table 14, Table 16 and Table 18 present the geotechnical design parameters for each area based on the geotechnical interpretation summarised in Appendix E1 and presented in Figures E1.1 to E1.10. An assessment of when the Yoganup Formation changes from predominantly clay to sand has been made and is shown graphically in Figures E1.1, E1.2, E1.5, E1.7 and E1.9. Refer to Appendix C for the Armadale Station Geotechnical Investigation Location plan with Stage 1 supplementary geotechnical investigation completed to date.

The supplementary geotechnical investigations performed by CMW obtained limited information within the shallow ground profile, owing to the service clearance potholing requirements (i.e. removal of the upper 1 m to 2 m prior to drilling/sampling). However, the Armadale Station precinct has a limited amount of additional fill material information as hand augers and Dynamic Cone Penetrometer (DCP) tests required for temporary works designs.

The fill material encountered within Area 02-A (south of the existing Armadale Station and north of Church Avenue) of the temporary piling/crane platform designs across Armadale consisted of a dense to very dense, pale yellow sandy gravel (crushed limestone) layer overlying a very loose to medium dense gravelly sand comprising a mixture of sand and ash/furnace slag (similar to the Type 2 material described by Advisian below). Based on a desktop review of the available historical aerial imagery, earthworks to the west of the existing rail alignment were undertaken in the early 1980's and again in between 2005 and 2011 when Armadale Station was being upgraded to include additional car parking. The presence of ash/furnace slag was observed on the historical aerial imagery between 2005 (refer to Figure 4) and 2011.

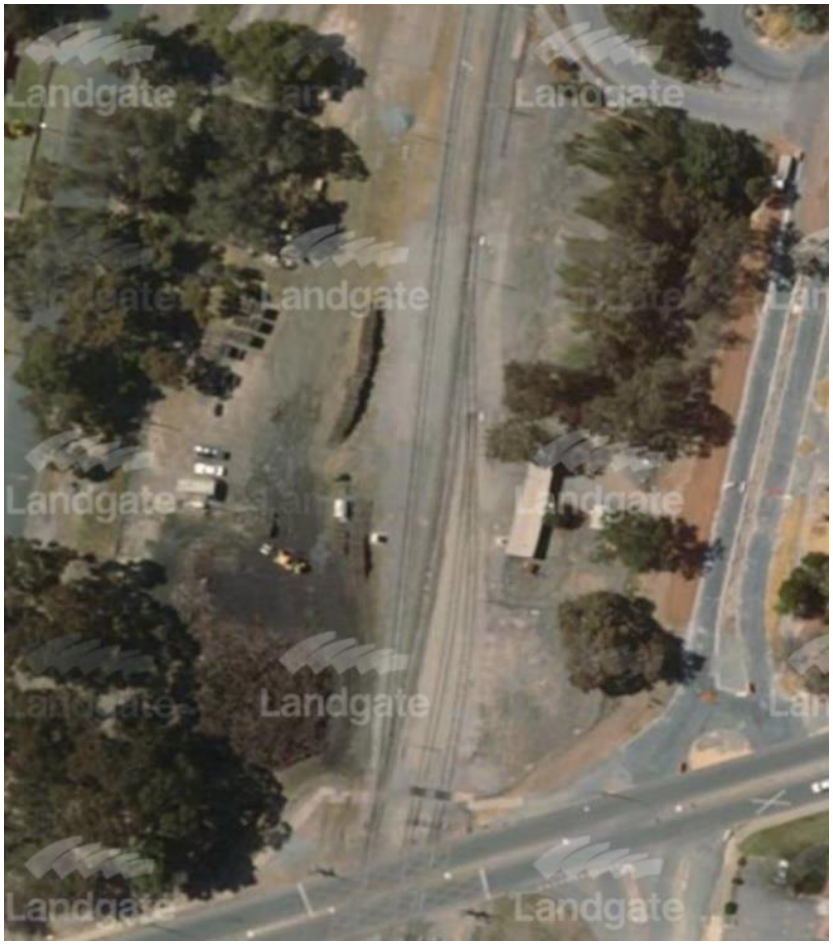


Figure 4: Armadale Station Area 02-A aerial image dated 10 December 2005. Source: Landgate Map Viewer

The fill material encountered within Area 03-A (north of the existing Armadale Station and south of Forrest Road) of the temporary piling/crane platform designs across Armadale consisted of a dense to very dense, yellow sand up to about 0.7 m depth. Underlying this dense to very dense layer is a very loose to loose sand layer that is likely to have been placed but insufficiently compacted when previous Armadale Station earthworks have been completed. Based on a desktop review of the available historical aerial imagery, earthworks just to the north-west of the existing Armadale Station structure between 2008 and 2009 including the removal of large trees.

Uncontrolled Fill (Type 2) has been identified within the Armadale Station precinct and as also noted by Advisian, appears to be associated with previous re-contouring of the ground surface (cut to fill earthworks) during the construction phase/s of the Armadale Station complex. Type 2 Fill material has been classified by Advisian predominantly as mixtures of sand and sandy gravel,

generally comprising a yellow-orange sandy layer overlying a dark grey to black layer that commonly includes various industrial and construction waste materials (i.e. brick, rail ballast and furnace slag) with minor proportions of organic fines and fragments.

Underlying the Type 2 fill material, colluvium sub-units consisting of very loose to loose sand fill and medium dense to dense clayey gravelly sand have been interpreted with the addition of Stage 1 supplementary ground investigation data. These sub-units must be accounted for in both temporary and permanent works designs within the Armadale Station precinct and are described in the following sections.

5.6.4.1 Armadale Station (North-East of existing rail alignment CH 28950 to 29120)

The inferred generalised stratigraphy at the Armadale Station precinct (North-East) from about PTA chainage 28950 to 29120 is summarised in Table 7 and has been prepared based on the following geotechnical investigation locations (refer to east section of Armadale Station precinct): BH+CPT28, BRE-BH01, BRE-CPTU14 and BH+CPT35.

Table 7 - Armadale Station (North-East) - Generalised Stratigraphy

Unit	Description	Approximate Elevation	
		From (m AHD)	To (m AHD)
Uncontrolled Fill (FILL)	Comprises a highly variable Uncontrolled Fill profile (Type 2) up to 2.5 m thick (typically about 1.5 to 2.0 m)	55.7 to 56.1 55.9 (avg)	53.6 to 55.0 54.3 (avg)
Colluvium (COL) – sub-unit[1]	Poorly graded, very loose to loose SAND; trace clay	53.6 to 55.0 54.3 (avg)	52.3 to 54.0 53.1 (avg)
Colluvium (COL)	Medium to high plasticity Sandy CLAY, Very Stiff to Hard / Medium dense to dense Clayey SAND / Clayey GRAVEL / Gravelly SAND, weakly iron-cemented (in part)	52.3 to 54.0 53.1 (avg)	51.3 to 51.9 51.6 (avg)
Duricrust	Poorly graded, medium dense to very dense Clayey SAND / Sandy CLAY (VSt to H) / Gravelly SAND, weakly to well iron-cemented (in part)	Variable[2] – refer to BRE-CPTU14	
Yoganup Formation (YOG)	Poorly graded, medium dense to very dense SAND with clay, grading to Sandy CLAY, dense to very dense/very stiff to hard	51.3 to 51.9 51.6 (avg)	-

[1] Very loose to loose sand Colluvium sub-unit likely to vary in both vertical and horizontal extents.

[2] Duricrust can occur as discrete lenses intercalated within primary units of both Colluvium and Yoganup Formation with preferential development at the interface between the two primary units. See further discussion in Section 0.

Geotechnical design parameters of the engineering geological units summarised in Table 7 for IDD are presented in Table 8.

Table 8 - Armadale Station (North-East) – Geotechnical Design Parameters

Unit	Y (kN/m^3)	c' (kPa)	φ' (°)	Su (kPa)	E' (MPa)
Uncontrolled Fill (FILL)	18	0	32	-	10 to 15
Colluvium (COL) – sub-unit	18	0	34	-	20 to 30
Colluvium (COL)	18	-	-	125	45
Duricrust	19	-	-	400	60
Yoganup Formation (YOG) – clay/sandy clay	19	-	-	150	100
Yoganup Formation (YOG) – sand/clayey sand	19	0 to 5	36 to 38	-	80 to 100

Notes: γ = *unit weight, c' = effective cohesion,* ϕ' = *effective friction angle,* s_u = *undrained shear strength, E' = Young's Modulus*

5.6.4.2 Armadale Station (Central-East of existing rail alignment CH 29120 to 29340)

The inferred generalised stratigraphy at the Armadale Station precinct (Central-East) from about PTA chainage 29120 to 29340 is summarised in Table 9 and has been prepared based on the following geotechnical investigation locations (refer to east section of Armadale Station precinct): BRE-CPTU15, BH13, BRE-CPTU17, BH+CPT42 and BRE-BH04.

Table 9 - Armadale Station (Central-East) – Generalised Stratigraphy

Unit	Description	Approximate Elevation	
		From (m AHD)	To (m AHD)
Uncontrolled Fill (FILL)	Comprises a highly variable Uncontrolled Fill profile (Type 2) up to 3.6 m thick, (typically about 2.5 to 3.0 m)	55.5 to 56.5 56.0 (avg)	51.9 to 54.0 53.0 (avg)
Colluvium (COL)	Medium to high plasticity Sandy CLAY, Very Stiff to Hard / Medium dense to dense Clayey SAND / Clayey GRAVEL / Gravelly SAND, weakly iron-cemented (in part)	51.9 to 54.0 53.0 (avg)	49.0 to 51.4 49.7 (avg)
Duricrust	Poorly graded, medium dense to very dense Clayey SAND / Sandy CLAY (VSt to H) / Gravelly SAND, weakly to well iron-cemented (in part)	Variable[1] – refer to BH13, BH+CPT42, BRE-CPTU17 & BRE-BH04	
Yoganup Formation (YOG)	Poorly graded, medium dense to very dense SAND with clay grading to Sandy CLAY, dense to very dense/very stiff to hard	49.0 to 51.4 49.7 (avg)	-

[1] Duricrust can occur as discrete lenses intercalated within primary units of both Colluvium and Yoganup Formation with preferential development at the interface between the two primary units. See further discussion in Section 0.

Geotechnical design parameters of the engineering geological units summarised in Table 9 for IDD are presented in Table 10.

Table 10 - Armadale Station (Central-East) – Geotechnical Design Parameters

Unit	Y (kN/m^3)	c' (kPa)	φ' (°)	Su (kPa)	E' (MPa)
Uncontrolled Fill (FILL)	18	0	32	-	15 to 20
Colluvium (COL)	18	-	-	125	45
Duricrust	19	-	-	400	60
Yoganup Formation (YOG) – clay/sandy clay	19	-	-	150	100
Yoganup Formation (YOG) – sand/clayey sand	19	0 to 5	36 to 38	-	80 to 100

Notes: γ = *unit weight, c' = effective cohesion,* ϕ' = *effective friction angle,* s_u = *undrained shear strength, E' = Young's Modulus*

5.6.4.3 Armadale Station (South-East of existing rail alignment CH 29340 to 29550)

The inferred generalised stratigraphy at the Armadale Station precinct (South-East) from about PTA chainage 29340 to 29550 is summarised in Table 11 and has been prepared based on the following geotechnical investigation locations (refer to east section of Armadale Station precinct): BH+CPT47 and BRE-SCPTU21.

Table 11 - Armadale Station (South-East) – Generalised Stratigraphy

Unit	Description	Approximate Elevation	
		From (m AHD)	To (m AHD)
Uncontrolled Fill (FILL)	Comprises a highly variable Uncontrolled Fill profile (Type 2) up to 2.5 m thick, (typically about 1.5 to 2.0 m)	55.0 to 55.1 55.1 (avg)	51.9 to 53.0 52.4 (avg)
Colluvium (COL) – sub-unit[1]	Poorly graded, very loose to loose SAND; trace clay	51.9 to 53.0 52.4 (avg)	50.5 to 51.9
Colluvium (COL)	Medium to high plasticity Sandy CLAY, Very Stiff to Hard / Medium dense to dense Clayey SAND / Clayey GRAVEL / Gravelly SAND, weakly iron-cemented (in part)	50.5 to 51.9	51.0
Duricrust	Poorly graded, medium dense to very dense Clayey SAND / Sandy CLAY (VSt to H) / Gravelly SAND, weakly to well iron-cemented (in part)	Variable[2] – refer to BH+CPT47	
Yoganup Formation (YOG)	Poorly graded, medium dense to very dense SAND with clay grading to Sandy CLAY, stiff	51.0	-

[1] Very loose to loose sand Colluvium sub-unit likely to vary in both vertical and horizontal extents.

[2] Duricrust can occur as discrete lenses intercalated within primary units of both Colluvium and Yoganup Formation with preferential development at the interface between the two primary units. See further discussion in Section 0.

Geotechnical design parameters of the engineering geological units summarised in Table 11 for IDD are presented in Table 12.

Table 12 - Armadale Station (South-East) – Geotechnical Design Parameters

Unit	Ɣ (kN/m³)	c' (kPa)	φ' (°)	Su (kPa)	E' (MPa)
Uncontrolled Fill (FILL)	18	0	32	-	5 to 10
Colluvium (COL) – sub-unit	18	0	34	-	5 to 10
Colluvium (COL)	18	-	-	125	45
Duricrust	19	-	-	400	60
Yoganup Formation (YOG) – clay/sandy clay	19	-	-	100	30 to 40
Yoganup Formation (YOG) – sand/clayey sand	19	0 to 5	36 to 38	-	80 to 100

Notes: γ = *unit weight, c' = effective cohesion,* ϕ' = *effective friction angle,* s_u = *undrained shear strength, E' = Young's Modulus*

5.6.4.4 Armadale Station (North-West of existing rail alignment CH 28950 to 29100)

The inferred generalised stratigraphy at the Armadale Station precinct (North-West) from about PTA chainage 28950 to 29100 is summarised in Table 13 and has been prepared based on the following geotechnical investigation locations (refer to west section of Armadale Station precinct): BRE-SCPTU13, BH11, Test Pile 02, BH+CPT31, BH+CPT33 and BH12.

Table 13 - Armadale Station (North-West) – Generalised Stratigraphy

Unit	Description	Approximate Elevation	
		From (m AHD)	To (m AHD)
Uncontrolled Fill (FILL)	Comprises a highly variable Uncontrolled Fill profile (Type 2) up to 3.6 m thick, (typically about 2.5 to 3.0 m)	55.1 to 55.8 55.5 (avg)	52.2 to 53.6 52.9 (avg)
Colluvium (COL) – sub-unit[1]	Poorly graded, very loose to loose SAND; trace clay	52.2 to 53.6 52.9 (avg)	50.9 to 51.3 51.1 (avg)
Colluvium (COL)	Medium to high plasticity Sandy CLAY, Very Stiff to Hard / Medium dense to dense Clayey SAND / Clayey GRAVEL / Gravelly SAND, weakly iron-cemented (in part)	50.9 to 51.3 51.1 (avg)	49.1 to 51.3 50.2 (avg)
Yoganup Formation (YOG)	Poorly graded, medium dense to very dense SAND with clay grading to Sandy CLAY, dense to very dense/very stiff to hard	49.1 to 51.3 50.2 (avg)	-

[1] Colluvium sand sub-unit likely to vary in both vertical and horizontal extents.

Geotechnical design parameters of the engineering geological units summarised in Table 13 for IDD are presented in Table 14.

Table 14 - Armadale Station (North-West) – Geotechnical Design Parameters

Unit	Y (kN/m^3)	c' (kPa)	φ' (°)	Su (kPa)	E' (MPa)
Uncontrolled Fill (FILL)	18	0	32	-	20 to 30
Colluvium (COL) – sub-unit	18	0	34	-	10 to 15
Colluvium (COL)	18	-	-	125	45
Yoganup Formation (YOG) – clay/sandy clay	19	-	-	150	100
Yoganup Formation (YOG) – sand/clayey sand	19	0 to 5	36 to 38	-	80 to 100

Notes: γ = *unit weight, c' = effective cohesion,* ϕ' = *effective friction angle,* s_u = *undrained shear strength, E' = Young's Modulus*

5.6.4.5 Armadale Station (Central-West of existing rail alignment CH 29100 to 29340)

The inferred generalised stratigraphy at the Armadale Station precinct (Central-West) from about PTA chainage 29100 to 29340 is summarised in Table 15 and has been prepared based on the following geotechnical investigation locations (refer to west section of Armadale Station precinct): BH+CPT36, BRE-CPTU16, BH+CPT39, BH14 and BH+CPT46.

Table 15 - Armadale Station (Central-West) – Generalised Stratigraphy

Unit	Description	Approximate Elevation	
		From (m AHD)	To (m AHD)
Uncontrolled Fill (FILL)	Comprises a highly variable Uncontrolled Fill profile (Type 2) up to 3.0 m thick, (typically about 2.5 to 3.0 m)	54.7 to 55.2 55.0 (avg)	52.0 to 52.8 52.4 (avg)
Colluvium (COL) – sub-unit[1]	Poorly graded, dense Clayey Gravelly SAND, moderate iron-cemented (in part)	52.0 to 52.8 52.4 (avg)	50.8 to 52.0 51.4 (avg)
Yoganup Formation (YOG)	Poorly graded, medium dense to very dense SAND with clay grading to Sandy CLAY, dense to very dense/very stiff to hard	50.8 to 52.0 51.4 (avg)	-

[1] Colluvium sand sub-unit likely to vary in both vertical and horizontal extents.

Geotechnical design parameters of the engineering geological units summarised in Table 15 for IDD are presented in Table 16.

Table 16 - Armadale Station (Central-West) – Geotechnical Design Parameters

Unit	Y (kN/m^3)	c' (kPa)	φ' (°)	Su (kPa)	E' (MPa)
Uncontrolled Fill (FILL)	18	0	32	-	20 to 30
Colluvium (COL) – sub-unit	18	0	34	-	10 to 15
Yoganup Formation (YOG) – clay/sandy clay	19	-	-	150	100
Yoganup Formation (YOG) – sand/clayey sand	19	0 to 5	36 to 38	-	80 to 100

Notes: *γ = unit weight, c' = effective cohesion, ϕ' = effective friction angle, s_u = undrained shear strength, E' = Young's Modulus*

5.6.4.6 Armadale Station (South-West of existing rail alignment CH 29340 to 29550)

The inferred generalised stratigraphy at the Armadale Station precinct (South-West) from about PTA chainage 29340 to 29550 is summarised in Table 21 and has been prepared based on the following geotechnical investigation locations (refer to west section of Armadale Station precinct): BH+CPT48, BH15, BRE-CPTU19, BH+CPT49, BH+CPT52, BH16, BH+CPT54, BRE-BH02, BRE-CPTU20 and BH+CPT55.

Table 17 - Armadale Station (South-West) – Generalised Stratigraphy

Unit	Description	Approximate Elevation	
		From (m AHD)	To (m AHD)
Uncontrolled Fill (FILL)	Comprises a highly variable Uncontrolled Fill profile (Type 2) up to 3.5 m thick, (typically about 2.5 to 3.0 m)	54.3 to 54.7 54.5 (avg)	50.6 to 51.9 51.3 (avg)
Colluvium (COL) – sub-unit[1]	Poorly graded, very loose to loose SAND; trace clay	50.6 to 51.9 51.3 (avg)	46.5 to 50.9 48.7 (avg)
Colluvium (COL)	Medium to high plasticity Sandy CLAY, Very Stiff to Hard / Medium dense to dense Clayey SAND / Clayey GRAVEL / Gravelly SAND, weakly iron-cemented (in part)	50.5 to 51.9	51.0
Duricrust	Poorly graded, medium dense to very dense Clayey SAND / Sandy CLAY (VSt to H) / Gravelly SAND, weakly to well iron-cemented (in part)	Variable[2] – refer to BRE-CPTU19	
Yoganup Formation (YOG)	Poorly graded, medium dense to very dense SAND with clay grading to Sandy CLAY, dense to very dense/very stiff to hard	46.5 to 50.9 48.7 (avg)	-

[1] Very loose to loose sand Colluvium sub-unit likely to vary in both vertical and horizontal extents.

[2] Duricrust can occur as discrete lenses intercalated within primary units of both Colluvium and Yoganup Formation with preferential development at the interface between the two primary units. See further discussion in Section 0.

Geotechnical design parameters of the engineering geological units summarised in Table 15 for IDD are presented in Table 16.

Table 18 - Armadale Station (South-West) – Geotechnical Design Parameters

Unit	Y (kN/m^3)	c' (kPa)	φ' (°)	Su (kPa)	E' (MPa)
Uncontrolled Fill (FILL)	18	0	32	-	5 to 10
Colluvium (COL) – sub-unit	18	0	34	-	5 to 10
Yoganup Formation (YOG) – clay/sandy clay	19	-	-	100	30 to 40
Yoganup Formation (YOG) – sand/clayey sand	19	0 to 5	36 to 38	-	80 to 100

Notes: *γ = unit weight, c' = effective cohesion, ϕ' = effective friction angle, s_u = undrained shear strength, E' = Young's Modulus*

5.6.5 Variably Cemented Materials

Duricrust or cemented material (Ferricrete) is intermittently present through the project alignment, of variable thickness and strength and has been classified by Advisian in the investigations carried out to date in accordance with AS1726-2017, as follows:

- Grade DIII - (Nodular/Fragmental) Less than 50% of the ground consists of gravel and cobble sized nodules (rounded or sub-rounded) or fragments (angular or subangular) of duricrust rock material and is described as a soil.
- Grade DII - (Vuggy or Patchy) Between 50% and 90% of the ground consists of duricrust rock material which forms a continuous framework and is described as a rock (Ferricrete).
- Grade DI - (Massive) More than 90% of the ground consists of duricrust rock material with forms a continuous framework and is described as a rock (Ferricrete).

Where present the duricrust may provide a good founding stratum or the capability to excavate with steep temporary batters, however the variable thickness and grade of cementing may form obstructions or zones of difficult excavation/piling, similar to the difficulties that have been experienced with advancing certain investigation methods (e.g. CPTs). In addition, although cemented, the duricrust layer is also likely to exhibit variable permeability depending on the grade of cementing.

Location specific assessments will need to be made where this layer is critical to foundation solutions or temporary works.

5.6.6 Design Groundwater Level

Advisian has assessed the following design groundwater levels (DGWLs) and have been checked within the Flood and Hydrology report Ref. R30-CMW-RPT-GE-560-00009.

- DGWL – 1% AEP RL 37 m AHD
- DGWL – 2% AEP RL 37 m AHD

The assessed 1% and 2% AEP levels are the same.

The above DGWLs are for the "deeper" aquifer within the Yoganup Formation. It is likely that the proposed shallow foundations for the Armadale Station concourse slab at RL 56.3 m AHD and other associated structures will be well above the 2% AEP DGWL of RL 37 m AHD. However, due to the likely presence of perched groundwater, a similar geotechnical design approach used for the shallow foundation design at the Thomas Road over Rail Bridge project is to be adopted (see below).

There remains a risk that perched groundwater may occur in and on the Colluvium which typically consists of sandy clay and sandy gravelly clay. Shallow fill material and the sandy Colluvium sub-unit is typically coarse grained and should have a lesser risk of perched groundwater, however, small changes in the fines content and uncontrolled fill within this material can result in significantly lower infiltration rates than expected.

A design groundwater study is being carried out for the alignment and will be reported within the Flood and Hydrology report Ref. R30-CMW-RPT-GE-560-00009. At IDD Stage for geotechnical design, a likely conservative shallow design groundwater level at 0.5 mbgl has been considered for the design of shallow foundations. Design groundwater levels will be confirmed within the IDD Flood and Hydrology report.

5.6.7 Drainage Design

In situ falling head infiltration testing was completed by Advisian within dedicated hand auger boreholes at two locations within the general Armadale Station precinct area, designated BRE-PERM01 and BRE-PERM02 (refer to Appendix C for infiltration test locations). Both infiltration tests were completed using a 50 mm diameter PVC pipe inserted into the hand auger borehole with the founding material logged as clay and sandy gravel (Colluvium) respectively. The ground level for BRE-PERM01 and BRE-PERM02 were reported to be at RL 59.3 m AHD and RL 57.4 m AHD.

However, upon review of the existing ground levels, it is likely that the reported BRE-PERM01 and BRE-PERM02 ground and base elevations are incorrect (i.e. have been reported too high). For reference, BH10 completed during the Stage 1 supplementary geotechnical investigation and in close proximity to BRE-PERM01 has a reported ground level at RL 56.64 m AHD. Whilst BH+CPT48 completed during the Stage 1 supplementary geotechnical investigation and in close proximity to BRE-PERM02 has a reported ground level at RL 54.15 m AHD. It should also be noted that BRE-PERM02 was completed near an existing infiltration basin located to the north of the test location.

The reported average CIRIA R113 (Somerville, 1986) values for BRE-PERM01 and BRE-PERM02 were 1.2 m/day and 6.8 m/day (refer to Appendix E2 for infiltration test results). The reported average Hvorslev (1951) values for BRE-PERM01 and BRE-PERM02 were 0.26 m/day and 1.68 m/day. It should be noted that these tests were completed in late summer (February 2021) and are unlikely to have been influenced by perched groundwater. No additional infiltration testing has been completed prior to the issue of this IDD report.

Proposed bio-retention cells (refer to Appendix C for approximate locations) to the north of the proposed Armadale Station structure are likely to have infiltration rates between 0.2 m/day and 1 m/day reported from BRE-PERM01 due to the shallow depths of fill and the sandy Colluvium sub-unit overlying the clay/sandy clay Colluvium layer. Proposed bio-retention cells (refer to Appendix C for approximate locations) to the south of the proposed Armadale Station structure are likely to have infiltration rates between 1.5 m/day and 6 m/day reported from BRE-PERM02 due to deeper depths of fill and the sandy Colluvium sub-unit overlying the Yoganup Formation (Clay).

The requirements of PTA Specification 8880-450-090 (Design of Drainage for PTA Infrastructure) should be noted which limits the infiltration rate used in design to 8 m/day without approval by the PTA. Depending on the software and method of design, the drainage designer should assess a suitable clogging factor. Infiltration values can change significantly with only minor changes in the soil characteristics (grain size / fines content) and with two infiltration test locations completed to date, is a geotechnical & drainage risk that needs to be addressed and mitigated. Thus, additional

infiltration testing has been proposed to be completed at approximate bio-retention cell areas to assist in assessing design infiltration rates for the Final Detailed Design (FDD) report.

5.6.8 Liquefaction

Liquefaction during an earthquake is a process resulting in saturated soils exhibiting a drastic loss in strength and stiffness. Liquefaction is the result of a rapid pore water pressure increase in response to the cyclic earthquake shaking. Materials that are typically susceptible to liquefaction during an earthquake are usually geologically young granular materials with low fines content in a relatively loose condition below the water table.

The materials present at the site do not generally fall under this general description and based on a preliminary qualitative assessment the materials are generally not considered liquefiable.

The exception may be the shallow fill materials in the vicinity of Armadale Station site and a further assessment will be made of these materials following the supplementary geotechnical investigation and further assessment of the potential presence of perched groundwater. It is noted however, that based on the investigation to date, loose zones appear to be discrete and discontinuous.

5.6.9 Soil and Groundwater Aggressivity

Soil and groundwater aggressivity testing has been carried out and commented on in the reports listed in Table 3.

Based on our review of the soil chemical testing carried out at the site and broader results from the project, conditions are indicated to be non-aggressive to mild for pile design, in accordance with AS2159–2009. On this basis, at this stage we recommend the following exposure classifications for reinforced concrete (in accordance with AS3600–2018 Table 4.8.1):

- Shallow reinforced concrete foundations – Category B1

The results of the aggressivity testing will be reviewed by the durability consultant to develop the project specific durability management plan.

5.6.10 Contamination and Acid Sulphate Soils

Uncontrolled Fill (Type 2) may potentially be contaminated in select areas within the Armadale Station precinct as noted by Advisian and is to be further investigated during the supplementary geotechnical investigation. An assessment of the level and extent of any contamination will be carried out by the environmental consultant under separate cover.

The Perth Metropolitan Acid Sulfate Soils Map shows that the Armadale Station precinct is located in an area of “no known” ASS disturbance risk occurring within 3 m of natural surface. An assessment of PASS and ASS will be carried out by the environmental consultant under separate cover.

5.6.11 Site Classification

The proposed new Armadale Station precinct is not a residential development, however to provide guidance as requested by the Structures and Civils teams, a site classification of Class P based on AS2870–2011 is applicable due to the potential for excessive foundation settlement if proposed shallow foundations are placed on uncontrolled fill material. However, as per Clause 2.5.3(c) of AS2870–2011 a site with controlled fill and classified P may be given an alternative site classification if assessed in accordance with engineering principles.

The proposed new Armadale Station structure is approximately between PTA chainage 29125 and 29275 which is outside identified areas of very loose to loose sand as shown on the east and west Armadale Station geological long sections presented in Appendix C. The fill material between PTA chainage 29125 and 29275 is not considered to be uncontrolled based on the borehole logs within this area. However, to be considered as controlled fill, construction documentation of historic Armadale Station works must be reviewed to confirm the fill was placed using a controlled method. Assuming that controlled fill is within this area, an alternative equivalent site classification of Class S based on the underlying very stiff to hard/dense to very dense Colluvium (consisting of a mixture of sandy clay and clayey gravelly sand).

To the north of the proposed new Armadale Station structure (between PTA chainage 29850 and 29125), a new bus interchange and associated canopy structure is proposed. This area is underlain by fill material (assumed to be uncontrolled based on low SPT N values and CPT tip resistance) and a very loose to loose Colluvium sub-unit sand layer up to about 3.5 m depth. To the south of the proposed new Armadale Station structure (between PTA chainage 29275 and 29550), a new accessway for a taxi rank, accessible bays, short-term parking and 'Kiss N Ride' bays is proposed. This area is underlain by fill material (uncontrolled based on borehole logs, low SPT N values and CPT tip resistance) and very loose to loose Colluvium sub-unit sand layer up to about 7 m depth.

Whilst the above areas are considered to have an equivalent site classification of Class P based on AS2870–2011, certain portions of these areas have had piling/crane platforms constructed to enable the installation of test piles and pre-possession piles to the west of the existing rail alignment. The piling/crane platforms have been designed for temporary works and consist of compacted crushed limestone overlying a placed geogrid and prepared subgrade. Refer to CMW technical memorandums that summarise the piling/crane platform designs for pre-possession areas 02-A and 03-A, Doc Reference PER2022-0237AA Rev0 dated 13 October 2022 and PER2022-0237AB Rev0 dated 25 October 2022. The temporary piling/crane platforms constructed could be adopted within the geotechnical design ground models summarised in Section 5.6.4 for permanent works within these areas if accepted by the PTA.

5.6.12 AS1170 Hazard Factor and Site Sub-Class

Based on the general geology beneath the site (i.e. typically dense to very dense or very stiff to hard soils overlying rock by about 25 to 35 m depth), historical investigation and Stage 1 supplementary investigation data and the recommendations provided in AS1170.4-2007, a site subsoil class of Ce to Section 4.2 of AS1170.4 is recommended for seismic design purposes. This subsoil class is limited to between approximately PTA chainage 29125 and 29275 (i.e. the extent of the proposed new Armadale Station structure).

The hazard factor (Z) for the site is shown on Figure 3.2(D) of AS1170.4 as 0.09.

The Spectral Shape Factor (Ch(T=0s)) for Ce sub-soil class is 1.3.

Between approximate PTA chainages 29850 to 29125 and 29275 to 29550 a site subsoil class of De (deep or soft soil site) to Section 4.2 of AS1170.4 is recommended for seismic design purposes.

The Spectral Shape Factor (Ch(T=0s)) for De sub-soil class is 1.1.

5.7 Design Approach and Methodology

5.7.1 Integration with Structural Design

The design process with the structural and civil designers will be an iterative process. At this stage general geotechnical design information has been provided for use in developing the initial designs. This advice and information will be refined following the Stage 2 supplementary investigation and upon receipt of the initial structural and civil designs (structural loads/layouts and civil layouts and levels etc.).

5.7.2 Shallow Foundation Design

The bearing capacity of shallow footings is assessed in accordance with AS5100.3-2017. The footings shall be proportioned such that $R_{dg} = \phi_g \times R_{ug} \geq E_d$ where:

- R_{dg}: design geotechnical strength of the footing (or factored bearing capacity).
- R_{ug}: ultimate geotechnical strength of the footing using unfactored characteristic values of material parameters (ultimate/unfactored bearing capacity).
- ϕ_g: geotechnical strength reduction factor which was taken as 0.4 for shallow footings based on the current level of geotechnical investigation, ground conditions and footing preparation procedures carried out in accordance with the Project Specifications.
- E_d: factored structural design action effects (Ultimate Limit State, ULS).

R_{ug} is assessed using either the Terzaghi or Brinch-Hansen bearing capacity formulae.

Influence of the groundwater level is allowed for by adjusting the unit weight of the soil above and below the base of the footing based on recommendations provided in the Canadian Foundation Engineering Manual (Canadian Geotechnical Society, 2006) and summarised in Table 19.

Table 19 - Groundwater Level and Soil Unit Weight for Bearing Capacity of Footings

Depth of groundwater below finished ground surface	Unit weight of soil below the base of the footing	Unit weight of soil above base of the footing
0 ≤ z <D	γ'	$\gamma - \left(\frac{z}{D}\right)\gamma_w$
D ≤ z < D + B	$\gamma' + \frac{z - D}{B}\gamma_w$	γ
Z ≥ D + B	γ	γ

Notes:

D = depth below ground level to base of footing, B = footing width, γ = bulk unit weight, γ = effective bulk unit weight, γ_w = unit weight of water

5.7.2.1 Design for Serviceability

Shallow foundations are designed to comply with the design criteria in Section 4.5.

5.7.3 Retaining Wall Design

The design/sizing of the reinforced concrete and/or limestone blockwork gravity retaining walls for the Armadale Station concourse, including structural design is completed by others based on the geotechnical information provided in this report.

This report provides a preliminary assessment of the retaining wall footings and will provide external stability check (sliding, overturning, bearing pressures) at future stages once geometry is set, as well as other geotechnical input for the design of the retaining walls.

Reference must be made to the SWTC Book 4: Technical Criteria and to PTA specification 888-450-053, Retaining Walls and Shallow Foundations. In particular:

- Any substructure elements within the PTA reserve shall retain 2.5 m clear depth from existing or future ground surface level (clear zone for PTA services and/or third party services or future development etc.).
- The foundation depth must be designed for provision of proposed and future services, such that services do not traverse under the foundations zone of influence.
- If embedded walls are considered (e.g. piled walls etc. – not currently considered) then the passive resistance 1 m below the design ground level must not be relied upon.

5.7.3.1 Design for Serviceability

The retaining wall footings/shallow foundations are designed to comply with the design criteria in Section 4.5.

5.7.3.2 Bearing Capacity, Sliding and Overturning

Refer to Section 5.7.2 noting that the bearing capacity of the retaining wall footings must be checked considering moment induced load eccentricity using approaches recommended by Meyerhof or similar. Sliding and overturning checks are understood to be completed by the Structures team based on the geotechnical design advice provided in Sections 5.8.2.1 and 5.8.2.3

5.7.3.3 Global Stability

The global stability verification is carried out using the commercially available software Slide (Rocscience) and the General Limit Equilibrium/Morgenstern-Price method using unfactored soil properties and loads. This approach is adopted because the factoring of the unit weight has two effects as follows:

- an increase in driving forces, which is the effect sought after by increasing the dead weight of fill
- an increase of the shear strength (as it is related to the vertical stress) and therefore of the resisting forces.

Based on the approach adopted for the global stability analysis, a minimum factor of safety (FS) of 1.35 has been adopted. This criterion is in accordance with PTA Specification 8880-450-074 recommended minimum FS for slope stability.

5.8 Geotechnical Design Advice and Calculations

5.8.1 Shallow Foundations – Allowable Bearing Pressures

Geological long sections have been developed based on the currently available geotechnical data and are presented in Appendix C. Adopted design profiles and parameters are presented in Section 5.6.4.

It is assumed that the top 1.0 m below the base of proposed strip and pad foundations will comprise engineered fill or compacted in-situ material (and is not unsuitable fill material as summarised in Section 2.4.3 of PTA Specification 8880-450-074) and that the excavation base is compacted to 96% MMDD in accordance with PTA Specification 8880-450-074. Table 20 below

summarises the assumed parameters for imported or compacted in situ fill material in which the following assessment of allowable bearing pressures have been made.

The Project Structural Engineer has advised that the proposed Armadale Station concourse slab is to be at RL 56.3 m AHD and has been used as a reference design ground level herein. The following sections only provide the allowable bearing pressures for strip and pad foundations within the proposed Armadale Station structure area approximately between PTA chainage 29120 and 29340. Due to the variable near surface ground conditions to the north and south of the proposed Armadale Station structure area (north & south of PTA chainages 29120 and 29340 respectively), crane/piling platforms constructed or to be constructed as part of the temporary works and the limited information of associated structures at IDD stage, it is recommended specific shallow foundation/subgrade assessments are completed at FDD stage.

Table 20 - Geotechnical design parameters for imported/compacted in-situ fill

Unit	Y (kN/m^3)	c' (kPa)	φ' (°)	Su (kPa)	E' (MPa)
Imported FILL (suitable) or compacted in situ FILL	18	0	34	-	50

5.8.1.1 Armadale Station (Central-East of existing rail alignment CH 29120 to 29340)

Based on the preliminary ground model summarised in Table 9 and the Armadale Station concourse slab at RL 56.3 m AHD, it is assumed that shallow foundations up to 1.5 m depth (RL 54.8 m AHD) will be founded within suitable fill material or Colluvium with a minimum drained Young's Modulus of 45 to 50MPa (refer to design ground model summarised in Table 9). Geotechnical design parameters assumed are shown in Table 10 and Table 20.

The design of available foundation bearing pressures for strip and pad footings at the Armadale Station precinct (Central-East) from about PTA chainage 29120 to 29340 has been carried out using Terzaghi bearing capacity equation & Settle3 and is presented in Table 21. These values are based on a geotechnical strength reduction factor of 0.4 as specified in AS 5100.3: 2017 (equivalent factor of safety = 2.5).

It should be noted that the allowable bearing pressures assume isolated vertical, non-eccentric loads. Dewatering requirements must be considered to complete foundation excavation and to achieve sufficient subgrade compaction depending on the perched groundwater level (assumed to be at 0.5 mbgl for design purposes) in relation to the proposed founding level.

Table 21 - Summary of Shallow Footing Design Bearing Pressure for Armadale Station precinct (Central-East)

Embedment depth (m)	Footing Width (m)	Footing Length (m)	Allowable Bearing Pressure (kPa)*	Settlement (mm)**
0.5	0.5 strip		150	5 to 10
	1.0 strip		180	10 to 15
	2.0 strip		180	≈ 20
	1.0	1.0	170	5 to 10
	2.0	2.0	200	15 to 20
	3.0	3.0	180	≈ 20
1.0	0.5 strip		200	5 to 10
	1.0 strip		220	10 to 15
	2.0 strip		200	≈ 20
	1.0	1.0	230	5 to 10
	2.0	2.0	270	15 to 20
	3.0	3.0	210	≈ 20
1.5	0.5 strip		280	10 to 15
	1.0 strip		300	15 to 20
	2.0 strip		240	≈ 20
	1.0	1.0	300	10 to 15
	2.0	2.0	300	15 to 20
	3.0	3.0	250	≈ 20

*Most allowable bearing pressures stated are limited by settlement.

**Note: Maximum allowable settlement/heave for shallow foundations is 20 mm for both short term and long term (long term allowable is inclusive of short-term displacement magnitudes), as stated in PTA Specification 8880-450-053. Differential settlement must not be more than 1:1000 for both short and long term, as stated in PTA Specification 8880-450-053.

5.8.1.2 Armadale Station (Central-West of existing rail alignment CH 29120 to 29340)

The Armadale Station precinct (Central-West) from about PTA chainage 29120 to 29340 is expected to consist of varying Uncontrolled Fill and sub-unit Colluvium (clayey gravelly sand) layer depth and thickness.

Based on the preliminary ground model summarised in Table 9 and the Armadale Station concourse slab at RL 56.3 m AHD, it is assumed that shallow foundations up to 1.5 m depth (RL 54.8 m AHD) will be founded within suitable fill material or sub-unit Colluvium (clayey gravelly sand) with a minimum drained Young's Modulus of 50MPa (refer to design ground model

summarised in Table 15). Geotechnical design parameters assumed are shown in Table 16 and Table 20.

The design of available foundation bearing pressures for strip and pad footings at the Armadale Station precinct (Central-West) from about PTA chainage 29120 to 29340 has been carried out using the Terzaghi bearing capacity equation & Settle3 and is presented in Table 22. These values are based on a geotechnical strength reduction factor of 0.4 as specified in AS 5100.3: 2017 (equivalent factor of safety = 2.5).

It should be noted that the allowable bearing pressures assume isolated vertical, non-eccentric loads. Dewatering requirements must be considered to complete foundation excavation and to achieve sufficient subgrade compaction depending on the perched groundwater level (assumed to be at 0.5 mbgl for design purposes) in relation to the proposed founding level.

Table 22 - Summary of Shallow Footing Design Bearing Pressure for Armadale Station precinct (Central-West)

Embedment depth (m)	Footing Width (m)	Footing Length (m)	Allowable Bearing Pressure (kPa)*	Settlement (mm)**
0.5	0.5 strip		170	5 to 10
	1.0 strip		210	10 to 15
	2.0 strip		200	≈ 20
	1.0	1.0	190	5 to 10
	2.0	2.0	250	15 to 20
	3.0	3.0	210	≈ 20
1.0	0.5 strip		240	5 to 10
	1.0 strip		280	15 to 20
	2.0 strip		220	≈ 20
	1.0	1.0	270	10 to 15
	2.0	2.0	300	15 to 20
	3.0	3.0	230	≈ 20
1.5	0.5 strip		320	10 to 15
	1.0 strip		350	15 to 20
	2.0 strip		240	≈ 20
	1.0	1.0	340	10 to 15
	2.0	2.0	320	15 to 20
	3.0	3.0	250	≈ 20

*Most allowable bearing pressures stated are limited by settlement.

**Note: Maximum allowable settlement/heave for shallow foundations is 20 mm for both short term and long term (long term allowable is inclusive of short-term displacement magnitudes), as stated in PTA Specification 8880-450-053. Differential settlement must not be more than 1:1000 for both short and long term, as stated in PTA Specification 8880-450-053.

5.8.2 Retaining Walls

Retaining walls proposed to retain the Armadale Station concourse adjacent to the Park ‘N” Ride and PTA staff car parking bays on the western side of the Armadale Station precinct are likely to be up to 3 to 4 m in height. At IDD stage, insufficient information on retaining wall locations and details have been supplied to assess and provide geotechnical design advice.

Preliminary sizing of walls can be completed using the recommendations provided in the following sections. Geotechnical assessment and design of the proposed retaining walls at Armadale Station to be completed during the FDD stage.

5.8.2.1 Earth Pressures

The retaining wall may be designed using the parameters presented in Table 23 below, which assumes a compacted well graded granular sand fill at foundation level.

Table 23 - Limestone Retaining Walls – Earth Pressure Design Parameters for Compacted Granular Fill

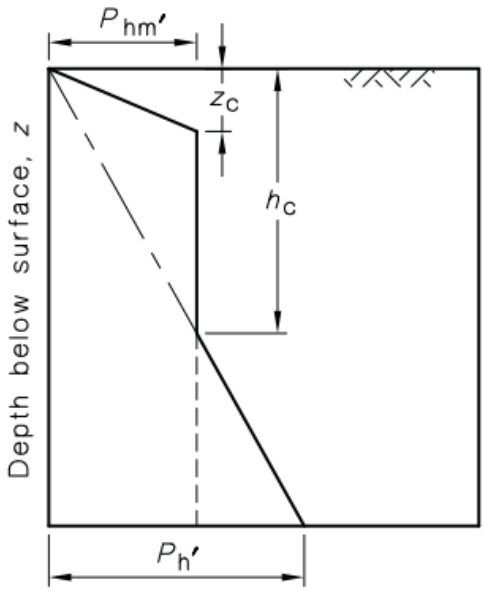
Soil Unit	γ (kN/m3)	ϕ' (°)	E' (MPa)	K_0	Soil-Wall friction = 0.5ϕ'	
					K_a	K_p
Compacted Granular Fill	19	36	60	0.6	0.22	6.5

Notes:
γ : soil unit weight; ϕ': angle of internal soil friction; K_0: coefficient of earth pressure at rest, K_a: coefficient of active earth pressure, K_p: coefficient of passive earth pressure; E' – long term Young's modulus.
Values of K_0 are based on estimated initial conditions following compaction.
The above parameters are based on the condition of a horizontal ground surface behind the retaining structure. Applicable surcharge loads behind the wall must also be considered in the design.

Retaining structures should be designed in accordance with AS 4678-2002 "*Earth Retaining Structures*" or an alternate approved factor of safety approach (e.g. AS5100). A geotechnical reduction factor of 0.50 for overturning and sliding calculations, and 0.40 for bearing assessment is recommended based on the requirements of AS5100. These may be reviewed following the supplementary ground investigation.

In addition to the above loads, pressures due to compaction must be considered. Induced compaction pressures are dependent on the stiffness of the wall, as the deflection of the wall will act to dissipate the pressure on the back of the wall. Some general advice on assessing compaction pressures is provided below.

The calculation of earth pressure behind retaining structures can be idealised using Figure J5 in AS4678:2002, based on Ingold (1979), as shown on Figure 5Figure 5 below.



$$P_{hm'} = \sqrt{\frac{2Q_1\gamma}{\pi}}$$

$$P_{h'} = K\gamma Z$$

$$z_c = K\sqrt{\frac{2Q_1}{\pi\gamma}}$$

$$h_c = \frac{1}{K}\sqrt{\frac{2Q_1}{\pi\gamma}}$$

LEGEND:

K = earth pressure coefficient (see Note 2)

Q_1 = intensity of effective line load imposed by compaction plant (see Note 3)

z_c, h_c = critical depths as shown

γ = soil unit weight

$P_{hm'}$ = maximum horizontal earth pressure induced by compaction

$P_{h'}$ = horizontal earth pressure induced by overburden stress

Figure 5: Compaction-Related Earth Pressures (AS4678:2002 Fig J5, based on Ingold 1979)

For the use of the above equations, the Q_1 value should be calculated as follows, expressed in kN/m:

$$Q_1 = \frac{(Weight\ of\ Plant + Centrifugal\ Compaction\ Force)}{Smallest\ of\ Plate/Roller\ Plan\ Dimensions}$$

The above equations generally result in a load $P_{hm'}$ of between 20-30kPa for small to large plate compactors respectively. Where heavier vibrating rollers/compaction is proposed, roller loads between 50 kPa and 73.5 kPa may be assumed.

Compaction-induced horizontal pressures can be considered as an increase in the effective K_0 for a given section of wall. For the assessment of geotechnical ULS stability cases where the retaining wall under consideration fails via overturning, sliding or bearing capacity failure and the destabilising pressures would ordinarily reduce from K_0 to K_A as part of this assessment, compaction pressures need not be considered.

For the structural assessment of walls (e.g. shear/moment capacity), compaction-related pressures generally form a temporary load condition, which must be assessed within standard load combinations for temporary loads. Unless the walls are rigid, this temporary load should not normally be combined with other live or temporary loads (e.g. wind/surcharge or impact loads). Horizontal flexibility of at least 0.1% of the retained height (e.g. 1mm per 1m of retained height) is generally required to release compaction-induced pressures and classify a wall as non-rigid.

5.8.2.2 Bearing Capacity

Refer to Section 5.8.1 for allowable bearing pressures, assuming that footings are not located on or adjacent to sloping ground (such footings will need to be assessed separately) and the permanent embedment depth remains in place for the duration of the design life.

5.8.2.3 Sliding

Sliding resistance on the base of the retaining wall will depend on how the retaining wall foundation is formed. If the foundation is cast in situ on the soil, then the interface friction angle may be taken as the peak friction angle of the soil, ϕ' (in this case a value of 35 degrees may be assumed). Where the retaining wall relies on some passive resistance to resist sliding the interface friction able should be limited to the critical state friction angle (30 degrees).

Where the retaining wall footing is formed by a precast element placed on the soil, the interface friction angle δ, should be reduced to a value of between 0.6ϕ' to 0.8ϕ' for fully drained granular soils.

5.8.2.4 Global Stability

The global stability of the retaining walls will be checked during future design stages once the retaining wall design has progressed.

5.9 Schedules

No geotechnical schedules provided at IDD stage.

6. Design Reviews and Certification

6.1 Interdisciplinary Design Coordination (IDC) Review

IDC review has been completed and comments incorporated in this IDD submission.

6.2 IDC Certificate

See main design package for IDC certificate.

6.3 Design Checking and Verification

In accordance with internal procedures.

6.4 Independent Verification

To be carried out.

6.5 BCA

N/A

6.6 DDA

N/A

6.7 PTA Design Submission Reviews.

To be carried out.

7. Safety Assurance

See main design package and SiD report.

8. Systems Engineering

See main design package.

9. Sustainability in Design

See main design package.

10. Human Factors

N/A

11. Reliability, Availability and Maintainability (RAM)

See main design package.

12. Construction Methodology

12.1 Construction Methods

When constructing the proposed shallow foundations for the new Armadale Station structure, temporary localised dewatering during excavation will be considered to at least 0.5 m depth from the underside of the shallow foundation blinding layer. Dewatering assessments will be completed under separate cover at the next design stage.

12.2 Operational Staging

Where relevant information will be provided in future stages.

12.3 Works in Track Occupancies

13. Asset Operations Strategy

See main design package.

14. Non Compliances

The following have been identified as potential non-compliances at the IDD Stage which may require further consultation with PTA:

- No geotechnical non-compliances have been identified at this stage.

Appendix A: Deliverables List

Refer to Appendix A

Appendix B: Specifications (Not in Use)

Appendix C: Drawings

Refer to Appendix C

Appendix D: Engineering Change Approvals (Not in Use)

Appendix E: Calculations

Refer to Appendix E

Appendix F: Schedules (Not in Use)

Appendix G: IDC Certificates (Not in Use)

Appendix H: Independent Verification Certificates (Not in Use)

Appendix I: PTA Comments Review Register (Not in Use)

Appendix J: Third Party Approvals (Not in Use)

Appendix K: RFIs (Not in Use)

Appendix L: Project Interfaces (Not in Use)

Appendix M: Departures (Not in Use)

Appendix N: Deviations (Not in Use)

Appendix O: RATM Extract (Not in Use)

Appendix P: Project Hazard Log (Not in Use)

Appendix Q: Safety in Design (Not in Use)

Appendix R: Human Factors (Not in Use)

Appendix S: Reliability, Availability, Maintainability (Not in Use)

Appendix T: Durability Assessment (Not in Use)

Appendix U: Sustainability (Not in Use)

Appendix V: ITP Strategy (Not in Use)

Appendix W: BCA Certificates (Not in Use)

Appendix X: DDA Certification (Not in Use)

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