Master Specification
Part TUN-CIV-DC1

Tunnel Civil Requirements

September 2024

Government of South Australia
Department for Infrastructure and Transport

Build.
Move.
Connect.

Document Information

Document Information	
K Net Number:	
Document Version:	3
Document Date:	30/09/2024

Document Amendment Record

Version	Change Description	Date
0	Initial issue	31/08/2023
1	Update to roadway structures Design Life. Clarity on the credible combinations of events that need to be considered in the design of gully grates (section 12 Drainage system). Update to buoyancy requirements (section 9.2)	31/01/2024
2	Update to risk management Reference Document name	12/08/2024
3	Updated cover page	30/09/2024

Document Management

 This is a controlled document and it will be updated and reissued as approved changes are made.

Contents

Contents 3
TUN-CIV-DC1 Tunnel Civil Requirements 4

1 General 4
2 Reference Documents 5
3 Contractor's personnel 6
4 Application of the Master Specification 7
5 Documentation 7
6 Durability 11
7 Design Life 12
8 Excavation and support 12
9 Design loadings 15
10 Groundwater control and seepage requirements 18
11 Tunnel finishes and barriers 21
12 Drainage system 23
13 Fire resistance of Tunnel infrastructure 25
14 Tunnel pavements 25
15 Construction requirements 25
16 Hold Points and Witness Points 35

TUN-CIV-DC1 Tunnel Civil Requirements

1 General

a) This Master Specification Part sets out the civil requirements for the design and construction of Tunnels, including:

i) the Reference Document requirements, as set out in section 2;

ii) the Contractor's personnel requirements, as set out in section 3;

iii) the application of the Master Specification, as set out in section 4;

iv) the documentation requirements, as set out in section 5;

v) the durability requirements, as set out in section 6;

vi) the Design Life requirements, as set out in section 7;

vii) the excavation and support requirements, as set out in section 8;

viii) the design loadings requirements, as set out in section 9;

ix) the groundwater control and seepage requirements, as set out in section 10;

x) the requirements for Tunnel finishes and barriers, as set out in section 11;

xi) the drainage system requirements, as set out in section 12;

xii) the fire resistance of Tunnel infrastructure requirements, as set out in section 13;

xiii) the Tunnel pavement requirements, as set out in section 14;

xiv) the construction requirements, as set out in section 15; and

xv) the Hold Point and Witness Point requirements, as set out in section 16.

b) Without limiting the Contractor's obligation to comply with the Contract Documents including the Master Specification, the design and construction of Tunnels must comply with the following:

i) RD-BF-D1 "Design of Roadside Safety Barriers";

ii) RD-DK-D1 "Road Drainage Design";

iii) RD-PV-D1 "Pavement Investigation and Design";

iv) RD-PV-D3 "Concrete Road Pavements";

v) TUN-FIRE-DC2 "Tunnel Evacuation Systems";

vi) TUN-FIRE-DC3 "Tunnel Fire Engineering";

vii) TUN-ME-DC1 "Tunnel Hydraulics Treatment and Pumping";

viii) TUN-ME-DC2 "Tunnel Power Systems";

ix) TUN-ME-DC3 "Tunnel Carriageway and Underpass Lighting";

x) TUN-ME-DC6 "Tunnel Ventilation Equipment"; and

xi) TUN-ME-DC7 "Ventilation Design".

c) Where specified in the Contract Documents, the requirements of this Master Specification Part must be applied to sections of lowered motorways.

d) The Contractor must conduct all investigations, including geotechnical investigations and surveys, necessary to satisfy the Tunnel requirements of the Contract Documents, and to ensure WHS is achieved.

2 Reference Documents

a) The design and construction of Tunnels must comply with the Reference Documents, including:

i) the Tunnel Reference Documents (refer to section 2b));

ii) AGRD Part 5A: Drainage: Road Surface, Networks, Basins and Subsurface;

iii) AS/NZS 1170 Structural design actions;

iv) AS 3600 Concrete structures;

v) AS 3610 Formwork for concrete;

vi) AS/NZS 4024.1703 Safety of machinery, Part 1703: Human body measurements - Principles for determining the dimensions required for access openings;

vii) AS 4100 Steel structures;

viii) AS 4312 Atmospheric corrosivity zones in Australia;

ix) AS/NZS 4671 Steel for the reinforcement of concrete;

x) AS 5100 Bridge design;

xi) AS/NZS ISO 9001 Quality management systems - Requirements;

xii) Austroads Guide to Road Tunnels (AGRT);

xiii) BS 8102 Protection of below ground structures against water ingress - Code of practice;

xiv) CIRIA C766 Control of cracking caused by restrained deformation in concrete;

xv) CIRIA C760 Guidance on embedded retaining wall design;

xvi) Eurocode 2: Design of concrete structures - Part 1-1: General rules and rules for buildings;

xvii) fib Model Code for Concrete Structures and related fib papers;

xviii) Hashash Y.M.A., Hook J.J., Schmidt B. & Yao J.I. (2001), ““Seismic design and analysis of underground structures”“, Tunnelling and Underground Space Technology, Vol. 16, no. 4;

xix) National Seismic Hazard Assessment NSHA-18;

xx) SafeWork Australia - Guide for tunnelling work;

xxi) SafeWork SA - Excavation Work Code of Practice;

xxii) TR26 (ICS 93.020) Technical Reference for Deep Excavation; and

xxiii) WorkCover NSW - Tunnel Under Construction Code of Practice.

b) The Tunnel Reference Documents in order of precedence for each category are as follows:

i) risk management:

A. International Tunnelling and Underground Space Association (ITA-AITES) and the International Association of Engineering Insurers (IMIA), A Code of Practice for Risk Management of Tunnel Works;

ii) Tunnel civil design and construction:

A. British Tunnelling Society and The Institution of Civil Engineers, Specification for Tunnelling;

B. PAS 8810 Tunnel design - Design of concrete segmental tunnel linings - Code of practice;

C. Australian Tunnelling Society, Tunnel Design Guideline; and

D. British Tunnelling Society and The Institution of Civil Engineers, Monitoring Underground Construction; and

iii) fibre reinforced concrete and shotcrete:

A. fib Model Code for Concrete Structures, section 5.6;

B. Recommended Practice - Shotcreting in Australia, (Concrete Institute of Australia - Australian Shotcrete Society);

C. BS EN 14889-1 Fibres for Concrete Part 1: Steel Fibres Definitions, Specifications and Conformity;

D. BS EN 14651 Test method for metallic fibre concrete. Measuring the flexural tensile strength;

E. RILEM TC 162-TDF “Test and design methods for steel fibre reinforced concrete, Materials and Structures, Vol. 36, Oct 2003, pp. 560 - 567; and

F. ITA Guidelines for Good Practice of Fibre Reinforced Precast Segment, Vol. 2: Production Aspects.

c) For the design of Tunnels, where there is any ambiguity, discrepancy, or inconsistency between AGRD and AGRT, the requirements set out in AGRT will apply.

3 Contractor’s personnel

The Contractor must appoint the following personnel in relation to Tunnels as set out in Table TUN-CIV-DC1 3-1. For the avoidance of doubt, not all the roles specified are Key Personnel (refer to the Contract Documents).

Table TUN-CIV-DC1 3-1 Contractor’s personnel

Role	Minimum experience in similar role	Additional qualification and experience requirements
Engineering Geologist	Bachelor degree, experience in underground geological mapping and assessment procedures	10 years
Instrumentation and Monitoring Engineer	Bachelor degree, experience in instrumentation and monitoring of underground civil engineering projects	10 years
Lead Geologist	Bachelor degree, membership of professional institution, experience in at least 2 projects with TBM tunnelling and cross passage excavation involving mixed face condition	15 years
Lead Geotechnical Engineer	Bachelor degree, membership of professional institution, experience in at least 2 projects with TBM tunnelling and cross passage excavation involving mixed face condition, in particular on the impacts of ground movement and ground-borne vibration	15 years
TBM Operator	Experience in at least one project with TBM tunnelling using the same type of machine proposed by the Contractor	5 years
Tunnel Manager	Experience in at least 2 projects with TBM tunnelling and cross passage excavation	15 years
Tunnel Shift Boss	Experience in at least one project with TBM tunnelling and cross passage excavation	10 years
Tunnel Superintendent	Experience in at least 2 projects with TBM tunnelling and cross passage excavation	15 years

4 Application of the Master Specification

For the avoidance of doubt, the requirements of all other Master Specification Parts apply to the design and construction of Tunnels, unless Tunnels have been explicitly excluded from the scope of that Master Specification Part.

5 Documentation

5.1 TBM Tunnel diameter

a) In accordance with the TBM procurement program, the Contractor must confirm the inner and outer diameters of the TBM Tunnels and whether there are any changes compared to the Tender Design. Any proposed changes must be in accordance with the requirements of section 3 of PC-EDM1 “Design Management” (Changes from the Tender Design).

b) Confirmation of the inner and outer diameters of the TBM Tunnels will constitute a **Hold Point**. Finalisation of TBM design and commencement of TBM manufacturing must not occur until this Hold Point has been released.

5.2 Design Basis

In addition to the requirements of PC-EDM1 “Design Management”, the Design Basis must:

a) include details of multi-disciplinary space proofing design requirements and considerations for defining the clear internal dimensions of the Tunnels, including the confirmed inner and outer diameters of TBM Tunnels;

b) include the geotechnical model as set out in section 15.11.1; and

c) define the surface and subsurface infrastructure acceptability criteria as set out in section 15.11.2.

5.3 Durability Report

The Durability Report for the Tunnels must:

a) demonstrate how the design of the Tunnels meets the durability requirements set out in ST-SD-D1 “Design of Structures”; and

b) detail how the Contractor has addressed each of the additional durability design considerations specified in section 6.

5.4 Design Documentation

In addition to the requirements of PC-EDM1 “Design Management”, the Design Documentation must include:

a) all aspects of the Tunnel design to demonstrate compliance with this Master Specification Part, including all Design Drawings and Design Reports;

b) in relation to the use of unreinforced permanent structural linings for Tunnels, the evidence required by section 8.2a)ii);

c) in relation to the design of uplift and buoyancy for Tunnels, the information required by section 9.2g);

d) if required, a report setting out details of the proposed groundwater recharge prior to implementation, in accordance with section 10.1c)iii);

e) a detailed hydrogeological impact assessment, in accordance with section 10.1d);

f) the locations of all anticipated major geological features, including those providing uncertain or complex ground conditions and zones affected or predicted to be affected by contaminated or saline groundwater, and the corresponding ground support design;

g) inflow criteria from probe holes to initiate pre-grouting, inflow criteria to commence excavation, and criteria to undertake post grouting of geological defects;

h) a design approach with contingency measures or a modification plan of alternative construction methodologies or design solutions in accordance with CIRIA C760 Guidance on embedded retaining wall design, where an observational approach is adopted;

i) as part of the Preliminary Design Documentation, TBM Hazard and Risk Assessments, as required by section 15.4.1b);

j) the geotechnical model as set out in section 15.11.1; and

k) in relation to Architectural Panels:

   i) evidence of how the Architectural Panels can be removed safely for maintenance and inspection reasons in accordance with section 11e)vi); and

   ii) effective and efficient maintenance access and maintainability provisions of the Architectural Panels and all assets located in or behind the Architectural Panels, in accordance with section 11f)ii).

5.5 Construction Documentation

In addition to the requirements of PC-CN3 “Construction Management”, the Construction Documentation must address all aspects of the Tunnel construction requirements to demonstrate compliance with this Master Specification Part, including:

a) in relation to permanent hold-down anchorages or tension piles, the information required by section 8.4d) to be included in the Construction Methodology;

b) the construction specifications and procedures required by section 15.1; and

c) a complete compilation of all documentation required for commencement of Tunnelling, including a readiness review process.

5.6 Maintenance Plans

In addition to the requirements of PC-CN2 “Asset Handover”, the Maintenance Plan must include all performance, maintenance, rehabilitation and reconstruction requirements required during operations as set out in this Master Specification Part, including procedures for the replacement of assets and asset components in accordance with the Design Life requirements in section 7.1.

5.7 Quality Management Records

In addition to the requirements of PC-QA1 “Quality Management Requirements” or PC-QA2 “Quality Management Requirements for Major Projects” (as applicable), the Quality Management Records must include:

a) the TBM reporting and data required by section 15.4;

b) written certification from the TBM manufacturer of full and complete design coordination, ensuring compatibility with the backup equipment, segment erector and lining systems, as required by section 15.4.1f);

c) the TBM reporting required by section 15.4.2;

d) the ring build tolerance data required by section 15.4.3c);

e) the secondary grouting record data required by section 15.4.4b);

f) the geological mapping records and inferred ground conditions, required by section 15.6g); and

g) the survey records required by section 15.7d).

5.8 Construction Management Plan

As part of the Construction Management Plan required by PC-CN3 “Construction Management”, the Contractor must include the following procedures in accordance with the requirements of section 15:

a) daily review meetings;

b) development, issue and updating of the permits to excavate; and

c) crack width monitoring.

5.9 TBM Management Plan

a) The Contractor must prepare a TBM Management Plan, that as a minimum includes:

i) key features and measures to be incorporated at the design stage to ensure safety during assembly, installation, commissioning, initial launch, back up configuration, normal, degraded, accident and emergency TBM operation, maintenance and interventions, breakthrough, dismantling and retrieval;

ii) the particular features and systems, such as alarms and interlocks, incorporated into the TBM design to protect personnel and the machine during the TBM advance, ring building, and general back up activity;

iii) details of the approach to the design of the TBM and associated tunnelling operations, including the design reviews process, the opportunity for the Principal to observe the stage reviews, and the submission of the design to the Principal;

iv) details of the organisational approach to TBM management, including the roles and responsibilities of the personnel involved in the tunnelling process;

v) details of the proposed operations and maintenance approach, incorporating preventative maintenance and intervention strategy which includes associated methodologies for undertaking works in the expected range of geological and hydrogeological conditions, planning for cutterhead interventions including identification of suitable locations and safe work procedures, and the inventory and logistics for replacement parts, wear items, consumables and related materials to facilitate maintenance activities;

vi) methods for controlling ground movement, ground-borne vibration and groundwater movements, including movement of contaminated groundwater, to minimise the impact on third party assets and infrastructure. These may include, for example, use and monitoring of face pressure, reconciling excavation weight and theoretical excavation volume, improving grouting system performance and real-time monitoring with communications between monitoring systems;

vii) details of the approach to integrating instrumentation and monitoring information with TBM driving and operating parameters including in relation to:

A. ground movement (settlement / heave) and calculation of volume loss;

B. groundwater movements and contamination migration;

C. hydraulic fracturing of the ground; and

D. ground-borne noise and vibration;

viii) a TBM emergency response plan that details the strategy for developing and implementing emergency response to significant risks and the associated plan for re-entry (where applicable), including:

A. fire along the length of the TBM or in the completed Tunnel section;

B. excessive groundwater pressure;

C. inundation;

D. excessive over-excavation;

E. caving;

F. clogging or mechanical failure leading to jamming or stoppage of TBM;

G. obstruction inspection and removal;

H. loss of power or communication;

I. injury during free air or compressed air intervention;

J. an air quality event; and

K. leaking of soil conditioning products through natural or artificial conduits;

ix) controls and procedures to accommodate outages and failures, including:

A. the grouting and slurry systems not achieving the flow and pressure required;

B. damaged main bearing and various seals requiring replacement from within shields; and

C. restoring any affected systems within an appropriate timeframe without causing adverse impacts to any assets and infrastructure;

x) details of early warning systems to be provided which communicate warning information for significant risks to improve emergency response times for critical situations; and

xi) details of the capability of the TBM guidance system to predict deviation from alignment tolerances and a procedure for adjusting back to the required alignment.

b) The TBM Management Plan must be prepared, submitted, and updated in accordance with the requirements of PC-PM1 “Project Management and Reporting”.

5.10 Ground Movement Plan

a) The Contractor must prepare a Ground Movement Plan, that at a minimum:

i) demonstrates how the Contractor will comply with the relevant requirements of PC-SI3 “Condition Surveys”;

ii) addresses the location of surface and subsurface infrastructure which may be susceptible to damage by ground movement and ground-borne vibration resulting from the Contractor’s Activities, having particular regard to heritage places;

iii) nominates appropriate impact acceptability criteria for surface and subsurface infrastructure after consultation with the various stakeholders, in compliance with section 15.11.2;

iv) nominates appropriate mitigation measures in consultation with the owners of the relevant surface and subsurface infrastructure prior to excavation and tunnelling works to ensure where reasonably practicable that the surface and subsurface infrastructure will not experience exceedances of the relevant criteria;

v) nominates techniques for limiting settlement of surface and subsurface infrastructure and protecting surface and subsurface infrastructure from damage. Where these may apply to heritage places, the techniques must be developed in consultation with South Australia Heritage Council and other relevant Authorities (as applicable);

vi) addresses additional measures to be adopted if acceptability criteria are not met, such as reinstatement of any property damage resulting from the Contractor’s Activities;

vii) sets out the planned instrumentation and monitoring program to measure settlement, distortion and strain (as required), which will measure consistency with the predicted model, including monitoring frequencies, commencement and cessation of monitoring, real-time monitoring requirements, criteria related to predicted movements and acceptability criteria; and

viii) includes contingency planning in consultation with the owners of the relevant surface and subsurface infrastructure where monitoring results indicate that predetermined ground movement and vibration trigger levels could be breached.

b) The Ground Movement Plan must be prepared, submitted, and updated in accordance with the requirements of PC-PM1 “Project Management and Reporting”.

c) The Ground Movement Plan may form a sub-plan to the Contractor’s Environmental Management Plan (CEMP).

6 Durability

a) The Tunnels must be designed and constructed to meet the durability requirements set out in ST-SD-D1 “Design of Structures”.

b) In addition to the durability requirements set out in ST-SD-D1 “Design of Structures”, the Contractor must ensure that the durability design of the Tunnels meets all applicable Design Life requirements, and includes consideration of the following elements (as applicable):

i) the micro-environment, including ground conditions, groundwater conditions, contamination and exposure conditions including temperature, humidity, atmospheric conditions, pH and carbon dioxide levels;

ii) operational conditions including drying and wetting, vibration and heat;

iii) potential deterioration mechanisms in the micro-environment including penetration of aggressive substances into structural elements through cracks, joints or by wick action;

iv) the feasibility and cost of in-situ monitoring, maintenance or repair and replacement;

v) fire resistance; and

vi) the significance of failure.

c) The following exposure categories must be used for the durability design of the Works as a minimum:

i) for concrete elements of Tunnels: minimum exposure classification B1 in accordance with AS 5100.5 Bridge design, Part 5: Concrete; and

ii) for steel elements of Tunnels exposed to traffic emissions: atmospheric corrosivity category C4 (high) in accordance with AS 4312 Atmospheric corrosivity zones in Australia.

d) Steel sheet piles must not be used as part of the permanent Works.

7 Design Life

7.1 General

Tunnels must have a Design Life in accordance with Table TUN-CIV-DC1 7-1.

Table TUN-CIV-DC1 7-1 Design Life requirements

Element	Design Life
For all Tunnel assets except those listed below	100
Roadway support structures	100
Tunnels and associated waterproofing systems	100
Passive flood mitigation assets	100
Assets that are not Readily Accessible, including fire protection and drainage elements	100
Assets that are Readily Accessible, including drainage elements - assets excluding the passive fire protection system	50
Assets that are Readily Accessible, including drainage elements - passive fire protection system	35
Architectural Panels, architectural features and cladding (including support structures)	50
Surface coatings including paint finishes	25
All other structural elements addressed by ST-SD-D1 “Design of Structures”	Refer to ST-SD-D1 “Design of Structures”

7.2 Warranty

Architectural Panels (including support structures) and other architectural features and cladding including must have a minimum warranty of at least 25 years in accordance with the requirements of PC-CN3 “Construction Management”.

8 Excavation and support

8.1 General

a) The Contractor must ensure that Tunnels meet the following excavation and support requirements:

i) Tunnels must not encroach within the volumetric zones or exceed the loading / unloading limits of existing adjacent assets and infrastructure;

ii) where the Tunnels alter, connect to, or are adjacent to an excavation or underground infrastructure, the structural capacity, stability, durability and watertightness of the existing structure must not be adversely affected and the impacts to the existing structure must be analysed as part of the design;

iii) all Temporary Works relating to Tunnels, including retention systems and ground anchors, must be removed to a minimum depth of 1.5 m below the finished surface level;

iv) Temporary Works that are broken down to satisfy the requirements of section 8.1a)iii) for cut and cover Tunnels must be undertaken to below the top of any screed protecting the waterproof membrane, in order to avoid pockets or depressions that may create water ponding;

v) permanent Tunnels, including the protective screed layer on top of any cut and cover Tunnels, must be a minimum of 1.5 m below finished ground level for space provision to accommodate drainage and street lighting and furniture, tree and landscaping requirements and provision for future Utility Services, except for shaft interfaces with the surface;

vi) the requirement for no sag deflection under permanent load from AS 5100.2 Bridge design, Part 2: Design loads, does not apply to cut and cover Tunnels;

vii) any beneficial long-term contribution or load distribution from Temporary Works left in the ground must not contribute to the design of the permanent Works, unless the Temporary Works components are incorporated into the permanent Works and meet the nominated Design Life performance requirements and all other requirements of the Contract Documents;

viii) both temporary and permanent support systems for ground supporting structures must be designed to prevent progressive collapse;

ix) in addition to the requirements of AS 5100 Bridge design, in-ground support systems for earth retaining structures must be designed in accordance with:

A. the principles contained in TR26 (ICS 93.020) Technical Reference for Deep Excavation; and

B. for redundancy, robustness, progressive collapse and damage to adjacent infrastructure, CIRIA C760 Guidance on embedded retaining wall design;

x) cut and cover Tunnels must be structurally continuous and without movement joints; and

xi) reinforcement crossing construction joints must be galvanised where the construction joint is:

A. subject to constant exposure to weather;

B. located in a highly visible area; or

C. in a location where it is possible that water is able to enter through a crack or opening at the construction joint and cause corrosion of the reinforcement in the life of the structure.

8.2 Structural linings

a) The Contractor must ensure that structural linings meet the following requirements:

i) all driven Tunnels and shafts must have permanent and durable structural linings consisting of permanent cast insitu concrete or precast concrete segments;

ii) where unreinforced permanent structural linings are proposed for Tunnels, the Contractor must demonstrate as part of the Design Documentation how the design of the concrete arch will remain in a serviceable state and in compression throughout the Design Life of the Tunnel;

iii) rockbolts or similar must not be used as a permanent support in lieu of a structural lining for any driven Tunnels and shafts, or as a measure to partially relieve loads on a structural lining; and

iv) formed surfaces of permanent structural linings, except for precast segmental linings, must be finished to a minimum Class 3 in accordance with AS 3610 Formwork for concrete.

b) Where precast concrete segments are used, the Contractor must meet the following requirements:

i) the manufacture of the precast concrete segments must be carried out within a suitable AS/NZS ISO 9001 Quality management systems - Requirements, certified production facility;

ii) the control of production procedures must be undertaken by experienced specialist personnel familiar with the manufacture of high strength, durable, dimensionally accurate precast concrete elements;

iii) formed surfaces of precast segmental linings must be finished to a minimum Class 2 in accordance with AS 3610 Formwork for concrete, except for the extrados surface which, if not formed, must be finished with a steel trowel;

iv) precast concrete segments must use tapered rings, instead of packing, to negotiate curves and to correct alignment;

v) precast concrete segment radial joints in adjacent rings must be staggered to avoid continuous joints, except at cross passages and sump locations agreed with the Principal;

vi) for precast concrete segments with bar reinforcement, dimples must be spherical with a minimum radius of 16 mm and minimum depth of 3 mm, and must be formed on the intrados of the segments to indicate where drilling of fixings will not encounter reinforcement; and

vii) cast in ferrules and fixings must be used for all permanent equipment and cables to minimise ad hoc drilling into precast concrete segments.

8.3 Crack width requirements

a) In addition to the stress limit requirements of AS 5100 Bridge design:

i) serviceability state crack widths for Tunnels (excluding segmentally lined Tunnels) must be calculated using the methodology set out in Eurocode 2: Design of concrete structures - Part 1-1: General rules and rules for buildings; and

ii) serviceability state crack widths for the segmental Tunnel lining must be calculated using the methodology set out in fib Model Code for Concrete Structures, or Eurocode 2: Design of concrete structures - Part 1-1: General rules and rules for buildings.

b) Early age thermal cracking for structures forming part of the permanent Works must be calculated in accordance with the methodology set out within CIRIA C766 Control of cracking caused by restrained deformation in concrete.

c) The maximum design crack widths at Durability Cover must be the lesser of:

i) the crack width, as determined by a durability assessment which considers site specific water quality and soil contamination, in combination with hydrostatic pressure head, with such assessment to be conducted using a probabilistic approach consistent with the fib Model Code for Concrete Structures and related fib papers; and

ii) the corresponding exposure classification, including:

A. 0.25 mm for exposure classification B2, C1, C2 or U; and

B. 0.30 mm for exposure classification B1.

d) The Durability Cover referred to in section 8.3c) may omit additional cover that is provided for purposes such as:

i) when ‘cast against ground’;

ii) where a curing compound is applied;

iii) tolerances in addition to those required by the Reference Documents; and

iv) other geometric reasons.

e) For the purposes of crack width calculations, Durability Cover must be applied to the outermost bar and not only the ‘main’, ‘longitudinal’, ‘bar resisting the stress or crack in consideration’, or similar.

f) The maximum design crack widths at Durability Cover must be applied for concrete elements irrespective of whether additional protection is adopted.

g) The requirements for calculation and control of cracking must be applied in addition to detailing and crack control requirements set out in AS 5100 Bridge design.

8.4 Ground anchors

The Contractor must ensure that ground anchors meet the following requirements:

a) all ground anchors must not extend beyond the Site (excluding any temporary land parcels);

b) permanent ground anchors including rock bolting which require ongoing tensioning or adjustments must not be used;

c) ground anchors used for permanent uplift / buoyancy restraint must:

   i) be passive anchors;

   ii) have a maximum yield stress of 500 MPa; and

   iii) comply with AS/NZS 4671 Steel for the reinforcement of concrete;

d) where permanent hold-down anchorages or tension piles are proposed to resist uplift of the cut and cover Tunnels, the Contractor must demonstrate in the Construction Methodology how construction methods and quality assurance systems will ensure the anchorages meet the durability and Design Life requirements specified in the Contract Documents; and

e) temporary ground anchors must be designed to be destressed and decommissioned safely and effectively.

9 Design loadings

9.1 General

The following requirements apply to the design loadings for Tunnels:

a) all loads and consequential effects, including those due to manufacturing, fabrication, lifting and handling, transportation, construction, maintenance, in service conditions and future proofing, must be allowed for in the design and construction of the structural elements;

b) Tunnels must be designed for the envelope of the stress resultants (moments, shear, axial force) due to the various combinations of load cases that are combined so as to induce the most severe effect for both the ultimate and serviceability limit states for the stress under consideration;

c) strutting, propping and ground anchor systems forming part of an earth retaining structure must form part of the same structural / geotechnical assessment when determining design actions resulting from all loading conditions including staging, redundancy, robustness and thermal effects;

d) the structural design of all Tunnel elements must accommodate the hydrostatic pressures that arise from compliance with the groundwater control requirements and groundwater seepage limits given in section 10;

e) groundwater and surface water pressures used in the design must be based on the applicable ULS and SLS high and low water levels both during and after construction;

f) Tunnels must be designed to resist foreseeable differences in groundwater table level between opposite sides of the completed Tunnels for the applicable Design Life;

g) the roof of Tunnels beneath a road corridor must be designed to support SM1600 road traffic loading plus an allowance for pavement to be a minimum 0.3 m higher than design pavement level;

h) the roof of Tunnels beneath pedestrianised plazas or similar, and emergency vehicle access paths, must be designed for SM1600 road traffic loading plus an allowance for pavement to be a minimum 0.3 m higher than the design surface level;

i) the roof of Tunnels beneath landscaped areas, must be designed for SM1600 road traffic loading plus the depth of soil for landscaping and an allowance for soil to be a minimum 0.3 m higher than the design surface level;

j) permanent supports that are within the road reservation must be designed for a collision load in accordance with the pier requirements set out in ST-SD-D1 “Design of Structures”;

k) Tunnels must be designed to resist accidental explosion, with a blast load of 10 kg equivalent TNT at 1.0 m from the intrados of lining or wall with no structural collapse, loss of watertightness and operational failure of existing buildings or any infrastructure above;

l) Tunnels must be designed to support equipment loads at any reasonable position likely to be experienced, including access routes for installation, maintenance or replacement;

m) the dynamic effects due to the operation of equipment including pipework must be included when determining equipment loads;

n) air and hydraulic pressure acting on the structural elements and fixtures resulting from the operation of mechanical and fire safety systems, and aerodynamic forces from vehicular traffic must be applied; and

o) annular backfill grout must achieve sufficient compressive strength (via grout mix design or adequate curing time) prior to the application of gantry wheel loads to fresh grout during tunnelling, and must take into account the anticipated range of the TBM advance rate.

9.2 Uplift / buoyancy

The following requirements apply to the design of uplift and buoyancy for Tunnels:

a) Tunnels must be designed to resist buoyancy at all stages of construction of the Works and throughout the Design Life of the Tunnel, including accounting for the effects of climate change;

b) groundwater levels used for buoyancy assessment must be based on the applicable ULS Design Groundwater Levels and SLS Design Groundwater Levels;

c) where the Tunnel is resisting buoyancy, the minimum structural mass of that part of the relevant Tunnel must remain in place for its Design Life;

d) resistance to uplift / buoyancy must be designed for each overall Tunnel, and for each cross-section of each Tunnel as applicable. Where the resistance to buoyancy is not coincident with the restraining force, the Tunnel must be designed for the resulting internal forces;

e) any loads from over site developments or installations or from elements that could be altered or removed within or above the Works must not be considered in buoyancy assessments;

f) backfill, soil and water over Tunnels must not be considered in buoyancy assessments for the future development unloading conditions identified in section 9.4 to allow for future excavations;

g) frictional resistance between elements of each Tunnel and the surrounding soil may only be considered where evidence, based on in situ tests, is available to justify the value being used. The value adopted must be less than the mass of soil, mobilised by the friction forces and must be set out in the relevant Design Documentation;

h) the structural mass resisting buoyancy must be reduced or increased by a factor calculated in accordance with AS 5100.2 Bridge design, Part 2: Design loads;

i) the geotechnical strength reduction factor multiplied by the ultimate geotechnical strength resisting buoyancy must be calculated in accordance with AS 5100.3 Bridge design, Part 3: Foundation and soil-supporting structures;

j) buoyancy assessments for segmentally lined Tunnels must be carried out in accordance with PAS 8810 Tunnel design - Design of concrete segmental tunnel linings - Code of practice using the factors listed in sections 9.2h) and 9.2i); and

k) buoyancy assessments for Tunnels which are not segmentally lined must satisfy the following:

    i) the combination of the factored structural mass and geotechnical strength resisting buoyancy, using the factors listed in sections 9.2h) and 9.2i), must be greater than the

uplift force due to buoyancy in accordance with AS 5100 Bridge design for the ULS and SLS Design Groundwater Levels;

ii) the combination of the unfactored structural mass and geotechnical strength resisting buoyancy must be greater than 1.05 times the uplift force due to buoyancy for the ULS Design Groundwater Level; and

iii) the combination of the unfactored structural mass plus geotechnical strength resisting buoyancy must be greater than 1.2 times the uplift force due to buoyancy for the SLS Design Groundwater Level.

9.3 Seismic design

The requirements of this section 9.3 in relation to Tunnel earthquake design must be used in place of the requirements set out in ST-SD-D1 “Design of Structures” and ST-RE-D2 “Design of Retaining Walls”:

a) seismic design of Tunnels must be based on an appropriate risk-based assessment of ground hazards in accordance with National Seismic Hazard Assessment NSHA-18 and AS/NZS 1170.0 Structural design actions, Part 0: General principles;

b) the design earthquake acceleration coefficient must be obtained from AS/NZS 1170.4 Structural design actions, Part 4: Earthquake actions in Australia, as the product of the relevant probability factor (kp) and the hazard factor (Z);

c) earthquake design loads for the design of Tunnels must be determined using equivalent static analysis in accordance with AS/NZS 1170.4 Structural design actions, Part 4: Earthquake actions in Australia, and the methodologies described in Hashash Y.M.A., Hook J.J., Schmidt B. & Yao J.I. (2001), “Seismic design and analysis of underground structures”, Tunnelling and Underground Space Technology, Vol. 16, no. 4;

d) the performance of Tunnels subject to seismic loading must meet the seismic performance criteria described in AGRT Part 2: Planning, Design and Commissioning, for the following design loadings:

i) the operating design earthquake, using an annual probability of exceedance of 1/200;

ii) maximum design earthquake using an annual probability of exceedance of 1/2500; and

iii) maximum considered earthquake;

e) the design of the Tunnels for seismic loading must be based on deformation / displacement compatibility with the surrounding ground undergoing cyclic displacement under the design earthquake event specified in section 9.3d); and

f) for plant room buildings within the Tunnels (including all Primary Plant Rooms and Secondary Plant Rooms), earthquake structural detailing for reinforcements and connections must be in accordance with AS 3600 Concrete structures, and AS 4100 Steel structures.

9.4 Future development

a) All Tunnels must allow for additional loadings and unloading from Approved Developments by considering:

i) information from various sources including changes of buildings, land use and surface levels;

ii) dewatering required during such developments;

iii) appropriate integration with staging; and

iv) coordination with urban and landscape design requirements.

b) The Works must allow for the future development of the land above and adjacent to the Tunnels by designing and constructing for the loading and unloading requirements specified in Table TUN-CIV-DC1 9-1 and Table TUN-CIV-DC1 9-2 (as applicable) in addition to the design loads applicable to the support of the Tunnel excavation.

c) A minimum ultimate limit state load factor of 1.5 must be applied to all future development loads used in the design of Tunnels.

d) For each future development scenario in Table TUN-CIV-DC1 9-1 and Table TUN-CIV-DC1 9-2, the Tunnel design must allow for the additional loading unloading and distortion requirements to be applied separately and together in any order, including asymmetrical arrangements, to yield the most onerous conditions.

Table TUN-CIV-DC1 9-1 Future development allowances for Tunnels (excluding cut and cover Tunnels)

Element	Future development allowance
Additional loading	The following additional loadings must be accommodated: a) 50 kPa (working load) increase in vertical stress acting on a plane 1 m above the Tunnel crown must be accommodated. This stress must be assumed to be applied in uniform and patterned (including symmetric and unsymmetrical) arrangements which yield the most onerous loading / distortion condition on the Tunnel; and b) 20 kPa (unfactored) for build-up of surface level.
Unloading from excavation	The following unloading from excavation requirements apply: a) allowance must be made for an excavation of up to 7 m below the Natural Surface, at a minimum separation distance of 7 m from the extrados of the Tunnel; and b) an additional deformation of the diameter of the Tunnel lining of up to 15 mm due to any adjacent excavation must be considered.

Table TUN-CIV-DC1 9-2 Future development allowances for cut and cover Tunnels

Element	Future development allowance
Additional loading	The following additional loadings must be accommodated: a) 25 kPa (working load) increase in vertical stress acting on the level of the top of cut and cover Tunnels above and/or beside the cut and cover Tunnels in uniform and patterned (including symmetric and unsymmetrical) arrangements which give the most onerous loading condition on the cut and cover Tunnels; and b) 20 kPa (unfactored) for build-up of surface level.
Horizontal stress	Allowance must be made for the following horizontal stresses: a) a 25 kPa (working) increase in horizontal stress acting on the face of the retained excavation. This stress will be assumed to be applied with a trapezoidal distribution having a magnitude of 0 kPa at the top of the wall increasing linearly to a maximum of 25 kPa at a depth equal to 0.25 times the height (H) of loading, remaining constant at 25 kPa to a depth of 0.75H, then reducing linearly to 0 kPa at the base of the excavation; and b) a 25 kPa (working) decrease in horizontal stress due to excavation at ground level, applied to the face of the retained excavation. This stress will be assumed to be applied with a trapezoidal distribution having a magnitude of 0 kPa at the top of the wall decreasing linearly to -25 kPa at a depth equal to 0.25 times the height (H) of loading, remaining constant at -25 kPa to a depth of 0.75H, then increasing linearly to 0 kPa at the base of the excavation.

10 Groundwater control and seepage requirements

10.1 Groundwater control

In relation to groundwater control for Tunnels, the Contractor must ensure that:

a) permanent Tunnels are designed and constructed as Undrained;

b) lowering of groundwater levels using permanent dewatering systems, by pumping or any other means, is not practised;

c) any groundwater recharge program is:

   i) not a long-term recharge program using recharge wells;

   ii) designed and implemented to the satisfaction of relevant Authorities and the Principal; and

   iii) detailed in a report and submitted as part of the Design Documentation prior to implementation;

d) a detailed hydrogeological impact assessment is:

   i) prepared which demonstrates that the potential impacts from construction and operation of the Tunnels, including short and long-term settlement due to the effects of groundwater drawdown, comply with the requirements of the Contract Documents; and

   ii) submitted as part of the relevant Design Documentation; and

e) the Contractor's Activities during construction and operations comply with all environmental requirements and all applicable Approvals and Laws in relation to the management of groundwater, including:

   i) avoiding migration of groundwater contamination which may cause harm to human health and the environment, including any potential for drawing contaminated groundwater into existing uncontaminated groundwater within or adjacent to the Site;

   ii) mitigating adverse impacts associated with volatile contaminant ingress or other vapour intrusion into the Tunnels due to the movement of contaminated groundwater; and

   iii) mitigating adverse impacts on groundwater and surface water systems and sensitive receptors in compliance with the requirements of the Environment Protection (Water Quality) Policy 2015 and 'General Environmental Duty' under the *Environmental Protection Act 1993* (SA).

10.2 Waterproofing

The Contractor must ensure that waterproofing for Tunnels meets the following requirements:

a) well detailed high quality permanent durable concrete linings must be provided for all Tunnels which are designed to limit crack widths in accordance with the requirements of the Contract Documents, including section 8.3;

b) cut and cover Tunnels, mined Tunnels and other cast insitu Tunnels must adopt a waterproofing system in accordance with BS 8102 Protection of below ground structures against water ingress - Code of practice, combining the following:

   i) waterproof membrane barrier protection for the full perimeter of the structure; and

   ii) structurally integral protection (crack width controlled);

c) waterproof membrane systems must meet the following requirements:

   i) the membrane system must be bonded and / or compartmentalised sheet membranes designed and constructed in accordance with British Tunnelling Society and The Institution of Civil Engineers, Specification for Tunnelling;

   ii) where sheet membrane systems are adopted, rearguard water stops which are composed of a compatible material must be used to isolate construction joints; and

   iii) for unbonded sheet membrane systems, the sheet membrane must be welded to the rearguard water stops as per the manufacturer's recommendations and instructions;

d) for cut and cover Tunnels or similar structures, the Contractor must provide:

i) where possible, a waterproof membrane over the roof slab extending down to below the joint between the roof slab and the walls;

ii) a continuous waterproof joint at any construction joint between the wall and roof / intermediate / base slabs, between adjacent slabs and between adjacent wall panels;

iii) a protective layer consisting of a reinforced concrete screed over the waterproof membrane to prevent rupture in the event of excavation over the top of cut and cover Tunnels;

iv) a minimum grade of 1:100 after permanent effects for the waterproof membrane and the permanent protective screed layer as appropriate drainage to minimise the presence of water adjacent to the membrane; and

v) where it is not possible to install an external waterproof membrane for cut and cover Tunnels (including diaphragm walls), a waterproofing system for the walls in accordance with BS 8102 Protection of below ground structures against water ingress - Code of practice, combining the following:

A. structurally integral protection (crack width controlled); and

B. internal drained seepage cavity protection (connected and channelled to the drainage system);

e) diaphragm wall panel joints must implement post grouting where required in order to meet the watertightness requirements of the Contract Documents;

f) for Tunnels that incorporate permanent cast insitu linings, the Contractor must provide:

i) a waterproof membrane and geotextile drainage layer in accordance with the British Tunnelling Society and The Institution of Civil Engineers, Specification for Tunnelling, or equivalent international standard;

ii) a waterproof membrane type with compartmentalisation to enable leak identification and having a proven history and reputation for satisfactory performance with minimal maintenance requirements in Tunnels with similar groundwater conditions;

iii) a waterproof membrane and geotextile that is self-extinguishing;

iv) evidence obtained from the manufacturer that no components of the membrane will leach out and deleteriously affect the durability of the elements of the groundwater control system, ground support or structural lining; and

v) where a waterproof membrane is to be installed in the Tunnel invert, a protective layer over the waterproof membrane immediately after testing is completed to prevent rupture or damage during subsequent Contractor's Activities;

g) for Tunnels that incorporate a permanent pre-cast concrete segmental lining, the Contractor must provide, in accordance with the British Tunnelling Society and The Institution of Civil Engineers, Specification for Tunnelling:

i) a water sealing system which includes an elastomeric gasket; and

ii) the water sealing system must have an extensive history and proven reputation for satisfactory performance in tunnels with similar groundwater conditions; and

h) any waterproof membrane and associated seals must allow for wet and dry cycles of groundwater exposure.

10.3 Groundwater seepage

a) In relation to groundwater seepage in Tunnels, the Contractor must ensure that:

i) Tunnel linings and other retaining structures are not visibly wet from groundwater seepage;

ii) groundwater does not drip or flow onto or over road pavements, walkways, egress passages, traffic barriers and areas that contain mechanical or electrical equipment;

iii) there are no adverse effects as a result of groundwater chemistry on the overall structural integrity of the Tunnels; and

iv) there are no material groundwater chemistry impacts on drainage systems for Tunnels, including the potential for the precipitation of insoluble salts to reduce the effectiveness of the relevant drainage system.

b) In addition to the requirements of section 10.3a), the Contractor must ensure that the following groundwater ingress requirements are met for Tunnels throughout the Design Life:

i) Tunnels must meet Haack Tightness Class 3 and satisfy the crack width requirements of section 8.3; and

ii) there must be no groundwater seepage through the Tunnel pavements and floors (i.e. 0 l/s).

c) The degree of watertightness for Tunnels must be increased above that specified in the Contract Documents where required to satisfy occupation, health and safety standards in relation to contaminated ground or groundwater and the usage of the internal space.

d) Access covers that achieve the specified watertightness requirement of the Tunnels in which they are installed must be provided.

e) The Contractor must provide documented evidence that the specified limits for groundwater ingress in respect of the Works are not exceeded in accordance with a measurement methodology agreed with the Principal at the following time periods:

i) within 3 months prior to Completion and as a condition precedent to Completion; and

ii) within 3 months prior to the end of the relevant Defects Liability Period.

11 Tunnel finishes and barriers

a) Barrier openings at cross passage locations must be flared to prevent end-on collision, in accordance with Australian precedent and subject to the requirements of RD-GM-D2 “Road Safety Audits”.

b) Tunnel finishes must comply with the urban design requirements set out in the Contract Documents.

c) Architectural Panels must be provided in the Tunnels carrying vehicular traffic, excluding cross passage openings.

d) The Architectural Panels must:

i) be continuous above the barrier to a height of at least 4.0 m above the roadway;

ii) be of the same appearance on both sides of the carriageway;

iii) present a constant smooth, continuous and consistently detailed line for the top edge parallel to the road surface and for the bottom edge parallel to the top of the concrete traffic barrier;

iv) present a continuous smooth profile between adjacent panels without steps between the faces of adjacent panels, or between the joints of adjacent panels;

v) be located outside of the vehicle roll allowance;

vi) not be supported from roadside safety barriers

vii) not have services fixed to the face of the Architectural Panels;

viii) be durable, non-distorting and enamel coated with self-cleaning property;

ix) provide surface reflectance greater than 60% and less than 85% for the required Design Life without glare issues to Tunnel users;

x) be non-combustible and stable when exposed to conditions of 450°C for 2 hours;

xi) be manufactured and constructed of materials that do not allow:

A. the spread of fire; and

B. the release of toxic fumes,

during a fire in the Tunnel;

xii) except where protective coatings are used, be non-corrodible;

xiii) where protective coatings are used, be in accordance with:

A. ST-SS-S2 “Protective Treatment of Structural Steelwork” which may include:

I. epoxy based coatings; or

II. paint systems; or

B. ST-SS-S3 “Galvanizing” for hot dip galvanising;

xiv) be resistant to impact and abrasion from an errant vehicle to the extent that any resultant debris is unlikely to endanger occupants of other vehicles;

xv) be resistant to applied traffic gust loading, fatigue and vibration;

xvi) be resistant to adherence of dirt and vehicle emissions;

xvii) be easily mechanically cleanable and resistant to loads applied by cleaning apparatus;

xviii) be resistant to the Tunnel environment, graffiti and cleaning fluids;

xix) provide an attractive environment and intuitive assistance in wayfinding and be coloured to highlight safety facilities, including identification of entrances to emergency egress passages;

xx) extend down to 280 mm above the top of the roadside safety barrier on the side of Tunnels, or extend down to 280 mm above the floor where the cladding is visible behind the roadside safety barrier;

xxi) provide access to drainage systems located on or behind the barrier for cleaning and maintenance without removal of the Architectural Panels;

xxii) be capable of receiving an applied surface feature of light projection with no visible distortion;

xxiii) not have any vertical framing members and associated base plates and any grouting to these base plates within the longitudinal drains located behind the roadside safety barriers; and

xxiv) contain no indentations along the top or bottom edges.

e) Individual panels that form part of the Architectural Panels must be designed and constructed such that:

i) panels are of equal width for continuity and aesthetics except at locations constrained by openings such as cross passages where the panel width may be adjusted such that:

A. panel width dimensional adjustments occur at one location;

B. panel width adjustments occur over a maximum of 4 adjacent wall lining panels;

C. the panel width adjustment location is selected to minimise their visibility and impact on the Tunnel users; and

D. the width of individual panels is no less than 75% or no more than 125% of the width of a typical standard panel;

ii) joints between adjacent panels are of uniform dimension and consistent throughout;

iii) vertical joints between adjacent panels are perpendicular to the road control line (90° to finished road surface level);

iv) vertical and horizontal edges of panels are consistent and uniform;

v) panels use a 'hook-on' or similar system (e.g. prefabricated keyhole slots for hanging panels on the support frame system) to facilitate removal and reattachment of individual panels to the framing system over the Design Life of the panels. For the avoidance of doubt, screws or glue are not acceptable; and

vi) panels have an in-built lifting point or lifting eye, with the Design Documentation demonstrating how the panels can be removed safely for maintenance and inspection reasons.

f) The framing of Architectural Panels must achieve the following requirements:

i) sheeting, sub-framing and main framing for the Architectural Panels must be modular to provide easy, quick, safe and efficient removal, inspection, repair or replacement;

ii) effective and efficient maintenance access and maintainability provisions of the Architectural Panels and all assets located in or behind the Architectural Panels, which must be demonstrated in the relevant Design Documentation;

iii) sub-frames that support Architectural Panels and utilise continuous and spliced horizontal girt systems must not be used; and

iv) the framing system and individual panel fixings for Architectural Panels must be comprised of a prefabricated system which is fixed together using captive nuts. On-site drilling, self-tapping screws and cutting of panels to install the framing system and panels is not permitted.

g) All Tunnel surfaces higher than 4.0 m above the carriageway and between the base of the architectural cladding and the top of the concrete roadside safety barrier must be coloured black. Any equipment, pipework, support system or framing system installed in this area must also be dark coloured to match.

12 Drainage system

a) The Contractor must provide a drainage system for the Tunnels which complies with all relevant environmental requirements set out in the Contract Documents.

b) The Contractor must comply with the Tunnel flood immunity requirements as set out in the Contract Documents.

c) Where lowered carriageways and ramps run downhill towards the day-light portal, a collection and drainage system leading to a portal sump and pump system capable of managing a 1% AEP event must be provided to intercept the approaching stormwater runoff upstream of the Tunnel entrances.

d) Drainage systems for Tunnels must accommodate the full range of credible combinations of stormwater, incident, groundwater, maintenance, firefighting, and other water ingress events including:

i) surface stormwater run-off from portal areas;

ii) stormwater carried into Tunnels by vehicles;

iii) wastewater effluent from Tunnel cleaning;

iv) subsurface water seepage;

v) fire system operation, including that of sump foam suppression systems;

vi) accidental rupture of pumped drainage, fire main or hydrant; and

vii) accidental spillage of fuel and chemicals from damaged tankers and other vehicles and the wash-down of such products.

e) Drainage systems for Tunnels must ensure plant rooms, cabinets, cable pits, cross passages and other egress paths from the Tunnels are kept dry at all times including after any operation of the deluge system in the main Tunnel carriageways.

f) As a minimum, drainage systems for Tunnels must:

i) provide a collection and drainage system that can be easily maintained and flushed to remove blockages and siltation or sludge. Any open drainage systems which may receive bacteria or oxide sludge deposits must be self-cleaning;

ii) not have access impeded by any sub-framing, structural supports, services or Architectural Panels;

iii) capture surface waters in Tunnels between the day-light portals, which must be via gullies at 40 m or closer intervals, with longitudinal pipework to sumps. In relation to gullies, the Contractor must ensure that:

A. gullies have fire/flame trap features and are designed to withstand explosion without hazardous flying parts. The fire/flame trap configuration in the gullies must be designed as self-cleansing based on design flow of fire-fighting component alone;

B. gully grates (size, type, orientation, debris blockage) must be designed to achieve the gutter-flow-width design such that:

I. under normal operating conditions, the surface flow does not encroach onto the adjacent traffic lane by more than 1.0 m when taking into account the combined effects of the events listed in sections 12d)i), 12d)ii) and 12d)iv) with 0.2 EY stormwater components;

II. during a fire incident, at least one traffic lane is kept free of surface flow when taking into account the combined effects of the events listed in sections 12d)i), 12d)ii), 12d)iv) and 12d)v) with 1% AEP stormwater components; and

III. at least one traffic lane is kept free of surface flow when taking into account the full range of credible combinations of the events listed in section 12d) with 0.2 EY stormwater components (for the purposes of section 12d)vi) includes one full-flowing ruptured hydrant and for section 12d)vii) includes one damaged tanker spilling at a credible flow rate until the full tank is emptied); and

C. the geometry of the gullies and the roadway levels in the vicinity of the gullies are such that the water flow from the activation of the design maximum number of deluge system zones is all captured within 120 m of the end of the last active deluge zone;

iv) not used

v) ensure the designed hydraulic conveyance is maintained for the Design Life of the drainage system. A pipe size that is larger than the designed size must be selected to account for un-intended gradual built-up on the inside wall of drain pipes. The absolute minimum long-term internal clear opening space is 225 mm diameter for pavement runoff and 150 mm diameter for non-pavement runoff;

vi) locate drainage pit access lids and grates outside of motorway lanes unless approved by the Principal, and where approved must not be positioned within the wheel paths of motorway lanes;

vii) provide sumps and holding tanks in accordance with TUN-ME-DC1 “Tunnel Hydraulics Treatment and Pumping”;

viii) provide management and discharge of combined inflows in accordance with TUN-ME-DC1 “Tunnel Hydraulics Treatment and Pumping”;

ix) provide access hatches to sumps which must be:

A. not located within motorway lanes unless approved by the Principal, and where approved must not be positioned within the wheel paths of motorway lanes;

B. located directly above pumps to provide a clear vertical lifting path for pump extraction via the vertical slide rail and in accordance with the requirements of TUN-ME-DC1 “Tunnel Hydraulics Treatment and Pumping”;

C. located away from the Tunnel sag to reduce potential of submergence, and assist easy finding in the event of Tunnel sag flooding; and

D. located to ensure lane closure requirements of the Contract Documents are met; and

x) provide adequate space in road gullies, pits, and sumps to allow cleaning and maintenance of pipes, pumps and all associated equipment. The spatial dimensions for human accessibility must be designed to meet human factor consideration in accordance with AS/NZS 4024.1703 Safety of machinery, Part 1703: Human body measurements - Principles for determining the dimensions required for access openings, and WHS requirements.

g) For a distance of at least 50 m outside of the daylight portals, the maximum aquaplaning film depth in AGRD Part 5A: Drainage: Road Surface, Networks, Basins and Subsurface, must be lowered to a desirable depth of 2.5 mm.

h) Where non-return valves or similar devices are used to prevent backflow into the Tunnels or Tunnel portal areas for gravity drainage systems, they must consist of dual redundancy valves and additional provisions to prevent build-up of debris.

i) As part of the relevant Maintenance Plan, the Contractor must provide estimated sludge and built-up for Tunnel drainage systems and propose a corresponding effective maintenance regime.

j) Subsoil drainage must comply with the groundwater control requirements of section 10.1.

13 Fire resistance of Tunnel infrastructure

The Contractor must ensure that the Tunnels and associated Tunnel infrastructure meets the fire resistance requirements of TUN-FIRE-DC3 “Tunnel Fire Engineering”.

14 Tunnel pavements

Tunnel pavements must be in accordance with the requirements of RD-PV-D3 “Concrete Road Pavements”.

15 Construction requirements

15.1 General

The Contractor must submit detailed construction specifications and procedures for underground works as part of the Construction Documentation. This must include specifications and procedures relating to monitoring, recording and control processes, in accordance with the following documents:

a) British Tunnelling Society and The Institution of Civil Engineers, Specification for Tunnelling;

b) SafeWork Australia - Guide for tunnelling work;

c) WorkCover NSW - Tunnel Under Construction Code of Practice; and

d) SafeWork SA - Excavation Work Code of Practice.

15.2 Groundwater control

a) Without limiting any obligations imposed on the Contractor by the requirements of the Contract Documents, the Contractor must employ appropriate groundwater inflow mitigation measures during construction in accordance with the environmental requirements set out in the Contract Documents.

b) The Contractor must satisfy all requirements and obtain all Approvals for any groundwater dewatering or recharge systems during construction in accordance with the environmental requirements set out in the Contract Documents.

15.3 Tunnelling methods

Without limiting all other obligations of the Contract Documents, the Contractor must select appropriate tunnelling methods that considers:

a) the ground conditions (including groundwater), Tunnel dimensions, stability of the face opening during excavation and prior to placement of any Tunnel excavation support, and limiting deformation of the lining or wall around the locations of cross passages, junctions, break-outs or similar openings during and after such works;

b) avoiding hazards and mitigating foreseeable risks; and

c) compliance with the relevant environmental requirements set out in the Contract Documents.

15.4 TBM tunnelling

15.4.1 Tunnel boring machines

a) Where a TBM is used for the purpose of excavating and constructing the Tunnels, the TBM must:

i) be supplied by a TBM manufacturer with successful experience in the design and manufacture of large diameter TBMs (>12 m) of the type required by this Master Specification Part;

ii) make adequate provision for the safety of workers and the application of safe methods of tunnelling;

iii) be a closed face machine with the ability to apply, when required, sustained and controlled pressurisation of the Tunnel face, shield annulus and segment grout pressure to minimise ground movements and movement of contamination;

iv) be designed with external diameters of the cutterhead and shield producing the least necessary clearance required for tunnelling;

v) have a bentonite circuit that enables active face support through automatic pressurisation of the face and shield annulus, a shield annulus gap injection system and the facility to monitor volume and pressure at each port;

vi) have a foam and polymer injection system;

vii) have the capability to drill probe holes for a minimum 50 m ahead of the Tunnel drive from the cutterhead and the shield in order to determine the likely nature and water-bearing characteristics of the ground;

viii) have systems that will enable the Contractor to meet its monitoring obligations required by the Contract Documents including:

A. systems for monitoring, testing and alarming of environments that are hazardous to human health including respirable hazards;

B. systems for monitoring, testing and alarming of environments for oxygen levels and noxious gases, including carbon dioxide (CO_2), methane (CH_4), carbon monoxide (CO), nitrogen monoxide (NO), nitrogen dioxide (NO_2), and hydrogen sulphide (H_2S);

C. systems to ensure that the presence of methane above 0.5% beyond the shield isolates the tunnelling electrical equipment immediately whilst maintaining ventilation and emergency lighting. All other abnormalities must alarm only with a clear indication on the TBM console that the anomaly exists. All gas anomalies must be recorded and must also alarm at the surface to alert the supervision management of the situation; and

D. systems to provide real-time monitoring of groundwater monitoring piezometers provided for the purposes of monitoring TBM performance and effects on contamination migration;

ix) where the TBM uses a conveyor belt for spoil removal, have at least 2 calibrated belt weighers to automatically measure and record the amount of material excavated per unit of advance and compare it with the theoretical excavation weight. Over-excavation must cause an alarm to activate in the subsurface TBM control cabin and initiate appropriate investigation processes and procedures;

x) have systems which determine the actual weight and volume of spoil excavated per advance including measurement of all added fluids;

xi) have a tailskin grouting system that monitors both grout flow (volume) and pressure at every grout port so that the total volume of grout injected per ring and the pressure profile can be accurately determined;

xii) have a data capture system through which TBM instrumentation and monitoring results can be accessed in real time to enable correlation of the measured responses of the ground, groundwater and existing structures with TBM operating parameters;

xiii) have separate TBM cooling water and industrial water lines to avoid the health risk of Legionella bacteria;

xiv) have a refuge chamber on the back up system for a minimum of 1.5 times the TBM operation crew;

xv) have a segment erector of vacuum type which is designed such that a safety factor of 3 is applied at 80% vacuum and capable of retaining vacuum for a minimum period in line with the TBM emergency response plan in the event of power failure; and

xvi) have an emergency generator with automatic transfer switch (ATS) installed at the surface with sufficient capacity for selected services in the event of power failure.

b) For TBMs, a TBM Hazard and Risk Assessment must be submitted to the Principal as part of the Preliminary Design Documentation. The TBM Hazard and Risk Assessment must cover each of the following as a minimum:

i) the TBM electrical system, including risk of electrical shock and fire, electrical equipment fault and damage, loss of power supplies and fire suppression systems;

ii) the TBM back-up system, including risk of leakage of high-pressure fluids, close location to heat and electrical sources, occurrence of naked flame, and danger of moving machinery;

iii) the entry and exit points from the TBM and back-up systems, including:

A. means of escape during an emergency and re-entry;

B. moving of Tunnel lining segments through the TBM back-up on to the segment erector, moving of Tunnel lining segment on the segment erector; and

C. dangers to personnel arising from the segment erector, and operation of cutter head etc.);

iv) access for operation and maintenance for the TBM, including for surveying;

v) the grouting system; and

vi) TBM assembly and dismantling.

c) Secondary grouting equipment for TBMs must be capable of monitoring pressures and grout volumes injected.

d) Monitoring systems in TBMs must provide the following information to allow correlation of measured ground movements and ground-borne vibration with TBM operating parameters:

i) excavated volumes and constructed/injected volumes;

ii) data that demonstrates magnitudes of TBM operation/wear in order to ensure maintenance can be scheduled effectively and avoid sudden loss of functionality of critical TBM systems that may results in adverse impacts to construction works, program, community or the environment; and

iii) construction records that demonstrate that no voids have been left in the ground by the TBM Tunnel construction. A continuous record of weight and volume of excavated material must be compared to the estimated design volume and the volume of grout injected from parameters automatically recorded including belt weight, laser scanning volume, advance length, estimated design volume and volume of grout injected to ensure voids are appropriately filled.

e) Alignment survey equipment must be provided for TBMs and operated such that they provide information of the TBM position, inclination, and roll. This information must be used to determine rates of TBM advance, and the position of the TBM in relation to the alignment. In addition to the position of the TBM, the following geometric information must be monitored by the alignment survey equipment:

i) accuracy of lining erection, which must include vertical, horizontal, and diagonal measured/surveyed diameters, steps and lips out of tolerance, and deviation of the ring from plane;

ii) position of lining relative to shield;

iii) gap between extrados of lining and tail shield; and

iv) concrete lining roll.

f) The Contractor must provide a written certification from the TBM manufacturer of full and complete design coordination, ensuring compatibility with the backup equipment, segment erector and lining systems. The certification must be provided as part of the Quality Management Records.

g) The TBM must be assembled at the manufacturer's premises on completion of fabrication or modification, and tested to demonstrate that all components operate correctly.

h) The Contractor must provide 30 days' notice prior to Factory Acceptance Testing of the assembled TBM, which will constitute a **Hold Point**. Factory Acceptance Testing of the TBM must not occur until this Hold Point has been released.

i) The Principal must be permitted to visit the manufacturer's facility for the purposes of inspection during the course of manufacturing or testing of the TBM prior to shipping to Australia.

j) The Contractor must provide 30 days' notice prior to shipping of the TBM which will constitute a **Witness Point**. The Contractor must not ship the TBM until the Contractor has progressed past the Witness Point.

15.4.2 TBM reporting

a) The Contractor must prepare reporting in relation to all TBM activities in accordance with the requirements of Table TUN-CIV-DC1 15-1, which must be submitted to the Principal within 5 Business Days of the relevant activity as part of the Quality Management Records.

b) Data and reports produced for TBM activities must be managed in the Common Data Environment (CDE) (refer PC-EDM5 "Digital Engineering") which covers ground information, instrumentation and monitoring data, segment management information, TBM navigation and operating parameters as a minimum.

c) TBM monitoring data must be managed in the CDE (refer PC-EDM5 “Digital Engineering”) and be accessible in real time in the TBM operator’s cabin. Where data is not collected in real time, the operator must be able to view the most up to date information, if applicable.

d) TBM real-time data for each ring must be provided as part of the CDE (refer PC-EDM5 “Digital Engineering”) on a graph against time or TBM advance.

e) Access to the CDE must be provided in accordance with PC-EDM5 “Digital Engineering”, and without limiting the requirements of PC-EDM5 “Digital Engineering”, must be provided at a minimum from 4 weeks prior to the commencement of TBM tunnelling until Completion of the relevant Tunnel.

Table TUN-CIV-DC1 15-1 TBM reporting requirements

Report	Frequency	Minimum data to be provided
TBM	One report per ring	a) Chainage of ring build; b) unique ring identification and installation date; c) unique identification of each segment in ring; d) ring build position; e) position of TBM, control line, chainage, horizontal displacement, vertical displacement (line and level), left or right lead, overhand or look-up, pitch and roll, with data points updated at least every 60 seconds; f) total weight and volume of excavated material; g) accuracy of lining build: diameter, stepping, lipping, ring plane, horizontal displacement, vertical displacement; h) total length of TBM advance to date and for the current shift; i) plots of various measures against TBM advance for each ring. Measures to include the following, as a minimum: i) face pressure, either individually for each sensor or as an average of all sensors; ii) cutterhead rotation speed (RPM); iii) instantaneous penetration rate (in mm/rev); iv) torque and thrust force at cutterhead; v) TBM penetration rate (in mm/min); vi) ram thrusts per shoe, expressed as an average and a maximum, or individually; vii) cumulative weight of excavated spoil, and cumulative volume of excavated spoil; viii) annulus injection pressure and cumulative flow; ix) grout pressure and cumulative flow; x) slurry flows, density and pressure (for slurry machines); and xi) screw rotation speeds and pressure drop (for EPBM machines); j) details of any trigger alerts or alarms activated and actions taken; k) details of any incidents or events that may affect monitoring data or results and reporting including any actions or mitigation measures taken; l) ground and groundwater conditions (inflow and drawdown); m) volume and ratio of soil conditioning constituent materials including air, water, foaming agents and polymers; and n) unique structure identification number, where applicable in reporting.

Report	Frequency	Minimum data to be provided
Rings and openings deformation measurement	As determined by design - monitoring results reviewed as part of the daily review meetings conducted for the permit to excavate	a) Unique structure identification number, where applicable in reporting; b) measured values, changes from start of monitoring (including baseline data) and changes since last measurement (in table and graph format); c) construction activity since previous data measured; d) details of any trigger alerts or alarms activated and actions taken; and e) details of any incidents or events that may affect monitoring data and or results and reporting including any actions or mitigation measures taken.

15.4.3 Ring build tolerances

a) The Contractor must undertake ring surveys and ring build tolerance measurements for rings in accordance with Table TUN-CIV-DC1 15-2.

b) At the commencement of each TBM Tunnel drive, the Contractor must measure the plane of each ring for the first 10 rings and confirm that the rings are built within tolerance. Thereafter, the Contractor must measure every 25th ring, or more frequently as agreed with, or directed by the Principal, if the ring build quality is out of tolerance or regular cracking is occurring.

c) Ring build tolerance data must be managed in the CDE (refer PC-EDM5 “Digital Engineering”) and provided as part of the Quality Management Records.

Table TUN-CIV-DC1 15-2 Ring build tolerance measurements

Location / position and timing	Description / checks
Immediately after completion of the ring build and a position at least 10 rings behind the TBM	Steps, lips, gaps (bird mouthing), ring roll.
As soon as practicable after ring build completed	a) Diameter of ring at axis level; and b) ring plane.
As soon as practicable after ring build completed	Survey of the lower ring area (below axis) to confirm the relative positions of: a) invert; b) points at left hand and right-hand axis; and c) points at the knee (45° from invert level).
As soon as practicable after the end of the TBM gantry	A survey of the upper half of the ring comprising the relative positions of: a) crown; b) the same points at left hand and right-hand axis as used for the lower ring survey; and c) points at the Tunnel shoulder (45° from crown)(1).

Table notes:
(1) This information must be used to determine diametric deformations horizontally, vertically, and diagonally where required.

15.4.4 Secondary grouting

a) The Contractor must record and monitor for every secondary grouting operation:

i) the date and time of grouting operation;

ii) the location of rings drilled;

iii) the location of rings grouted and location around rings where grout was injected;

iv) grout types;

v) grout pressure;

vi) grout volumes and the locations where these were injected; and

vii) any leakage, with estimated volumes.

b) The secondary grouting record data must be provided as part of the Quality Management Records by the end of each shift. A comprehensive reconciliation of the excavation volumes against the volume injected through the tailskin grouting and the secondary grouting system must be undertaken to identify the reason for any shortfall in volume.

15.4.5 Monitoring rings and openings in the Tunnel

a) The Contractor must provide monitoring rings for the purposes of validation of the design, and where:

i) there is potential for lining deformation or a change in loading after lining installation; and

ii) it is necessary to understand loads in the lining post installation.

b) The Contractor must monitor in each monitoring ring and opening section:

i) ring deformation;

ii) loads in linings;

iii) deformation in opening supports (both temporary and permanent);

iv) 3D movement of the temporary support at the junction with the lining; and

v) loads in opening supports (both temporary and permanent).

15.4.6 TBM operations monitoring

a) The Contractor must comprehensively review the TBM performance in relation to ground movements and the operational parameters of the TBM at least daily, and at least twice daily for any critical areas. As a minimum the review must include:

i) the TBM operational parameters including face pressure and grout pressure (TBM drive parameters);

ii) the measured ground movement profiles from subsurface and surface monitoring data;

iii) the expected ground conditions from all geotechnical information, including any ground probing ahead of the TBM;

iv) volumes of primary and secondary grouting; and

v) any infrastructure identified in ground movement and ground-borne vibration impact assessments which require mitigation of impacts induced by TBM operations.

b) If any review indicates that the TBM performance is not sufficient, the Contractor must revise the TBM operational parameters to mitigate the potential adverse impacts to any property or infrastructure and control TBM performance within acceptable levels.

15.5 Daily review meeting

a) A daily review meeting must be held during the excavation of Tunnels to evaluate the excavation and support measures in use for both TBM tunnelling and mined tunnelling.

b) A permit to excavate over a defined section of the Works will be jointly issued by the Contractor and the Designer in accordance with the agreed outcome of the meeting. The subsequent daily review meeting will confirm that the planned continuation of tunnelling for the next day complies with the requirements under the existing permit to excavate or whether changes are necessary.

c) The following personnel must attend each daily review meeting (to the extent those personnel are required by the Contract Documents):

i) Tunnel Manager;

ii) Designer;

iii) Lead Geologist or Lead Geotechnical Engineer;

iv) Instrumentation and Monitoring Engineer;

v) the Principal; and

vi) Construction Verifier.

d) The following will be reviewed at each daily review meeting:

i) general performance, including observations and findings from relevant inspections and issues/incidents;

ii) information from TBM reporting, as per Table TUN-CIV-DC1 15-1;

iii) monitoring results and trends of the responses of the ground, groundwater and existing assets and infrastructure;

iv) convergence monitoring results;

v) lining quality - as-built profiles, thickness and shotcrete strength results;

vi) geological mapping or probing results;

vii) requirements for any planned/emergency intervention (for TBM tunnelling);

viii) identification of any critical areas which may require modification of construction method statements, operating parameters, inspection and test plans, instrumentation and monitoring plans, emergency response plans or relevant risk assessments; and

ix) confirmation that the permit to excavate aligns with the planned continuation of tunnelling for the next day.

e) Procedures for the daily review meetings and the development, issuance and updating of the permits to excavate must be documented and provided to the Principal as part of the Construction Management Plan.

f) The Contractor must allow sufficient time for briefing at each shift change so that relevant information and decisions from daily review meetings are conveyed to the TBM operation crew.

15.6 Geological mapping and probing

a) The Contractor must map all exposed ground faces using an Engineering Geologist who satisfies the requirements of Table TUN-CIV-DC1 3-1 prior to any application of support.

b) Where Tunnel excavation support is constructed such that the ground conditions are not exposed (such as TBM installing segments), the Contractor must record the ground conditions inferred from probe holes, machine head torque, spoil cuttings and other relevant methods.

c) The Contractor must carry out probing and compile an accurate and systematic record of probe hole positions, drill penetration rate and water ingress as a minimum for evaluation of the ground conditions encountered.

d) As a minimum, all anticipated major geological features identified in the relevant Design Documentation must be located during construction via forward probing or a reliable investigation method agreed by the Principal.

e) The number of probe holes, probing frequency, drilling angles and positions in the face, as governed by the actual type of ground encountered taking into account the excavation sequence and tunnel size, must be agreed with the Principal.

f) All soil and rock samples collected during Tunnel excavation must be kept in suitable containers, properly labelled and stored temporarily at a suitable location for inspection prior to delivery to the Principal's nominated facility, at a minimum of monthly intervals or as requested by the Principal.

g) The Contractor must compile all geological mapping records and inferred ground conditions into reports, which must be submitted to the Principal and provided as part of the CDE (refer PC-EDM5 "Digital Engineering") within 24 hours of data acquisition as Tunnel operations advance as part of the Quality Management Records.

15.7 Tunnel excavation support

In relation to Tunnel excavation support, the Contractor must:

a) undertake excavation and installation of ground support with due care and strict precautions necessary to ensure that ground movement or subsidence is minimised, and to ensure that the excavated surfaces are stable and that overbreak is minimised;

b) regularly examine all excavated surfaces and make the Tunnel excavation safe by removing all loose materials or by other appropriate methods as necessary;

c) promptly and safely support excavated surfaces;

d) survey all installed supports, including all rockbolts, steel sets, forward reinforcement and shotcrete / concrete thicknesses, using a suitably qualified and experienced surveyor or Tunnel engineer and submit all records as part of the Quality Management Records;

e) take measurements, undertake inspections, and keep records to provide data to verify the underground design based on the actual ground material behaviour. Monitoring procedures must be based on a thorough hazard analysis;

f) implement processes and controls and use tunnelling machines and tunnelling methods for excavation and installation of ground support and any other activities such that personnel never work beneath unsupported ground; and

g) provide 5 days' notice prior to opening the segmental lining for the construction of a cross passage, which will constitute a **Witness Point**. The segmental lining must not be opened until the Contractor has proceeded past the Witness Point.

15.8 Crack width monitoring

a) The Contractor must monitor for cracks within the Tunnel from the point of construction or installation until the expiry of the relevant Defects Liability Period.

b) For the purposes of construction Non-Conformances of the Tunnels, all active cracks must be monitored at the surface at each end and at intermittent spacings along the extent of the crack to allow ongoing monitoring of the crack.

c) Where the maximum crack widths, at any point along the length of the crack, exceed the lesser of the following:

   i) the design crack width limits set out in section 8.3c); and

   ii) those set out in ST-SC-C7 "Placement of Concrete",

   the entire crack will be deemed as a Non-Conformance and subject to the processes as detailed a in PC-QA1 "Quality Management Requirements" or PC-QA2 "Quality Management Requirements for Major Projects" (as applicable), and:

   iii) the Contractor must follow the cracking of concrete process set out in ST-SC-C7 "Placement of Concrete";

   iv) the associated Hold Point set out in PC-QA1 "Quality Management Requirements" or PC-QA2 "Quality Management Requirements for Major Projects" (as applicable) will apply; and

v) ongoing monitoring must be carried out until such time as that the crack has been repaired, sealed, or injected, depending on the crack nature, width, and design assessment and the crack is no longer propagating.

15.9 Waterproofing installation

a) The Contractor must ensure that all waterproof membranes are:

i) installed in accordance with the manufacturer's recommendations and instructions; and

ii) protected from damage at all times before and after installation.

b) Where the Contractor intends to construct sections of Tunnel using driven tunnel techniques that incorporate a permanent cast in situ concrete lining or similar, the Contractor must engage a supervisor who is suitably trained and experienced in the installation of waterproof membranes in driven Tunnels, with particular training, and experienced in the installation of waterproof membranes of a similar type and method.

c) Pre-production field trial and installation of each waterproofing membrane system will constitute a **Hold Point**. The Contractor must not continue any subsequent Works related to the waterproofing membrane system until the Hold Point has been released.

15.10 Temporary Tunnel ventilation

Without limiting the requirements of the Contract Documents including any environmental requirements, the Contractor must ensure all temporary Tunnel ventilation plant with connections to the atmosphere in any noise-sensitive location, are subject to mitigation measures appropriate to the local environment, including enclosures or screening.

15.11 Ground movement

15.11.1 Geotechnical model

a) The Contractor must prepare a geotechnical model of representative geological, geotechnical and groundwater conditions prior to excavation (that may pose a settlement risk) and tunnelling to identify geological structures and groundwater features. The model must:

i) include details of:

A. proposed excavations;

B. Tunnels and underground structures; and

C. construction staging; and

ii) identify surface and subsurface infrastructure, including any specific attributes, which may be impacted by the Contractor's Activities.

b) The Contractor must use the geotechnical model to assess the cumulative predicted ground movement, ground-borne vibration, stress redistribution and horizontal strain profiles caused by excavation and tunnelling, including groundwater drawdown and associated impacts, on adjacent surface and subsurface infrastructure.

c) The geotechnical model must be:

i) submitted as part of the Design Basis;

ii) updated as part of the Design Documentation submissions;

iii) maintained and reviewed as the ground conditions are further exposed by investigations, excavations, installations, grouting or other geotechnical works; and

iv) updated throughout the duration of the Works.

15.11.2 Acceptability criteria

a) The Contractor must undertake a review of surface and subsurface infrastructure at risk from damage to determine appropriate acceptability criteria to prevent damage, prior to excavation and tunnelling works that may pose a settlement risk, which must be in accordance with this section 15.11.2.

b) In the case of buildings, the acceptable criterion is the “Slight” category of damage as defined in the Australian Tunnelling Society, Tunnel Design Guideline.

c) Acceptability criteria for surface and subsurface infrastructure must:

i) for all subsurface infrastructure other than buildings, be determined in consultation with the owners of the surface and subsurface infrastructure;

ii) consider the guidance on typical acceptability criteria for settlement, angular distortion and tensile strain provided in the Australian Tunnelling Society, Tunnel Design Guideline; and

iii) have regard to the type, age, and condition of the surface and subsurface infrastructure.

d) The surface and subsurface infrastructure acceptability criteria must be determined prior to commencement of any excavation or tunnelling works potentially affecting the surface and subsurface infrastructure and documented in the Design Basis, and Ground Movement Plan.

e) The Contractor must design and construct permanent structures and temporary ground support measures to limit ground movements and ground-borne vibration to within the surface and subsurface infrastructure acceptability criteria during and after the construction of the Works.

15.11.3 Ground Movement Plan

The Ground Movement Plan must be developed, implemented, and maintained in accordance with section 5.10.

15.11.4 Protection of existing properties

a) The adopted surface and subsurface infrastructure criteria does not remove any responsibility of the Contractor for the protection of existing surface and subsurface assets or for rectifying any damage to surface and subsurface infrastructure resulting from the Contractor’s Activities.

b) For surface and subsurface infrastructure (including natural landscapes and parklands) impacted by ground movement and ground-borne vibration as a result of the Contractor’s Activities, the Contractor must undertake any required repair works, joint inspections or other actions as agreed with the owner, land manager, or asset manager in a prompt manner.

c) For places on the South Australian Heritage Register, consultation with South Australian Heritage Council and the relevant local council must occur (as applicable).

d) For places within a State Heritage Area, consultation with the relevant council must occur.

16 Hold Points and Witness Points

a) Table TUN-CIV-DC1 16-1 details the review period or notification period, and type (documentation or construction quality) for each Hold Point referenced in this Master Specification Part.

b) Table TUN-CIV-DC1 16-2 details the review period or notification period, and type (documentation or construction quality) for each Witness Point referenced in this Master Specification Part.

Table TUN-CIV-DC1 16-1 Hold Points

Section reference	Hold Point	Documentation or construction quality	Review period or notification period
5.1b)	Confirmation of the inner and outer diameters of the TBM Tunnels	Documentation	10 Business Days review

Section reference	Hold Point	Documentation or construction quality	Review period or notification period
15.4.1h)	Notification prior to TBM Factory Acceptance Testing	Construction quality	30 days notification
15.9c)	Pre-production field trial and installation of waterproof membrane system	Construction quality	5 days notification

Table TUN-CIV-DC1 16-2 Witness Points

Section reference	Witness Point	Documentation or construction quality	Review period or notification period
15.4.1j)	Notification prior to shipping of TBM	Construction quality	30 days notification
15.7g)	Notice prior to opening the segmental lining for the construction of a cross passage	Construction quality	5 days notification