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Installation of Underground Services Crossing ARTC Railway Tracks

ETS-13-01

Applicability

ARTC Network Wide

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1.0	17 July 05		First Issue
1.1	12 Aug 25	4.1	Wording clarification

Table of Contents

1 Scope and Application

This Standard outlines the technical requirements and recommendations for designing and constructing underground services that cross ARTC railway tracks, as well as for monitoring these railway tracks during and after the installation of these services.

The requirements and recommendations apply to all underground services constructed under ARTC railway tracks, including but not limited to electric power, signalling, telecommunications, water (both mains and domestic), gas, sewerage, drainage, and other services that are flammable, toxic, corrosive, and combustible.

Applications for third parties to access ARTC railway corridors shall be submitted through https://www.artc.com.au/work/external-parties/ (Accessing the Rail Corridor - ARTC)

It is recommended that third parties submit their applications to ARTC a minimum of 90 days before the intended start date of the construction.

Access for third parties to ARTC railway corridors for the construction of underground service crossings is supported by a Property Agreement or an Infrastructure License and/or Agreement issued by the Property Division, which is entered into with ARTC.

Trenches or excavations that do not cross ARTC railway tracks are excluded from this Standard.

1.1 References

AS 4799	Installation of underground utility services and pipelines within railway boundaries
AS 2566.1	Buried flexible pipelines, Part 1: Structural design
AS 3725	Design for installation of buried concrete pipes
AS 5100.2	Bridge Design, Part 2: Design load
AS 7634	Railway Infrastructure – Survey
AS 1726	Geotechnical Site Investigations
AS 1289	Methods of testing soils for engineering purposes
AS 1379	Specification and supply of concrete
AS 1554	Structural steel welding
AS 4058	Precast concrete pipes (pressure and non-pressure)
AS 2885	Pipelines—Gas and liquid petroleum
AS 4822	External field joint coatings for steel pipelines
AS 4130	Polyethylene (PE) pipes for pressure applications
AS 1477	PVC pipes and fittings for pressure applications
AS 1254	PVC-U pipes and fittings for stormwater and surface water applications
AS 1260	PVC-U pipes and fittings for drain, waste and vent application
AS 4765	Modified PVC (PVC-M) pipes for pressure applications
AS 2832.1	Cathodic protection of metals, Part 1: Pipes and cables
AS 5488.1	Classification of Subsurface Utility Information (SUI) Subsurface Utility Information
AS 3571	Glass filament reinforced thermosetting plastics (GRP) pipes—Polyester based—Water supply, sewerage and drainage applications

1.2 Document Owner

The Manager Engineering Services is the Document Owner. Queries should be directed to standards@artc.com.au in the first instance.

1.3 Definitions

Requirements are mandatory to follow to claim full compliance with this Standard. Requirements are identified within the text by the term "shall".

Recommendations do not mention or exclude other possibilities but do offer the one that is preferred. Recommendations are identified within the text by the term "should".

Permissions are neither requirements nor recommendations but give options. Permissions are identified within the text by the term "may".

Geotechnical Site Engineer (GSE) refers to the geotechnical engineering representative appointed by the third party, who should be present at construction sites where required or recommended in this Standard. The GSE works directly with the appointed Principal Geotechnical Engineer (PGE) from the third party to ensure that sound construction is progressed and the construction impact on ARTC railway tracks is minimised. In some projects, GSE and PGE may be the same person.

The following terms and acronyms are used within this document:

Term of acronym	Description
A/TB	Auger/Thrust boring
BYDA	Before You Dig Australia
DLA	Dynamic Load Allowance
FE	Finite Element
GNSS	Global Navigation Satellite System
GRP	Glass Reinforced Plastic
GSE	Geotechnical Site Engineer
HDD	Horizontal Directional Drilling
JSEA	Job Safety Environmental Analysis
MT/PJ	Micro-tunnelling/Pipe Jacking
NATA	National Association of Testing Authorities
PE	Polyethylene
PGE	Principal Geotechnical Engineer
PVC	Polyvinyl Chloride
RC	Reinforced concrete
SLS	Serviceability Limit State
SWMS	Safe Work Method Statement
TC	Track Certifier (as per ARTC Track and Civil Matrix)
ToR	Top of Rail
ULS	Ultimate Limit State

2 General Requirements

All underground service crossings under ARTC railway tracks shall be designed and installed in accordance with AS 4799 and the requirements of this Standard.

In case of contradictions between the requirements of this Standard and other Australian Standards, including AS 4799, the requirements of this Standard shall prevail.

Within ARTC railway corridors, no third party shall begin the inspection, installation, repair, maintenance, or removal of any underground services without the approval from ARTC.

No services shall be attached to bridges, tunnels, or other ARTC structures or assets without the approval from ARTC and the Structures Specialist responsible for that line section. Fire, vehicle collision, and connection failure risk assessment shall be conducted for combustible and flammable services attached to bridges or structures.

Before proceeding with the third-party services that involve toxic and corrosive underground crossings, the third party shall conduct a comprehensive risk assessment, along with the presence of the relevant ARTC representatives. This risk assessment shall explicitly include all associated risks and controls during the construction and operation of such services within ARTC railway corridors. To proceed, the third party shall collect all necessary certificates and other documentation as required in this Standard and submit these to ARTC.

The third party shall assess the stability of the existing ARTC railway earthworks, such as cuttings or embankments, and shall accept all risks associated with any instability of ARTC earthworks that may impact their constructed services at any time.

The third party shall indemnify ARTC against any losses or expenses incurred as a result of instability in the cuttings or embankments due to the constructed services at any time.

All restrictions and requirements for future ARTC works near the constructed pipeline shall be specified or referenced on the “As-built” drawings.

At all locations within ARTC rail corridors, the constructed pipeline shall be trafficable by plant or equipment, which may also include low-loaders, articulated dump trucks, etc.

3 Route Locating, Design, and Construction

Before You Dig Australia (BYDA) may be used to identify the presence of any third-party services after consulting with ARTC. However, BYDA should not be relied on to locate ARTC-owned services, such as signalling and communication cables. Consult with ARTC when applying for the corridor access.

4 Structural Design

4.1 Railway Loading

The railway design traffic loading shall be 300LA as per AS 5100.2. The railway design traffic loading for the NSW Hunter Valley heavy haulage lines shall be 350LA (1.17 × 300LA).

The pressure intensities of the trains are underestimated in AS 4799 and shall not be used. Additionally, the impact factor and its application stated in AS 4799 differ from the Dynamic Load Allowance (DLA) stated in AS 5100.2 or the impact factor stated in other Standards such as AS 3725. For the design of pipes under ARTC railway tracks using trenchless methods mentioned in this Standard, DLA shall be taken as 0.45, linearly reduced from the underside of sleepers to the top of the pipe. The DLA shall be taken as zero at a depth of 3 m from the Top of Rail (ToR).

For the structural design of the pipe, the live load factor or design safety factor shall conform to the relevant Standards (allowable stress or limit state design principles).

The unfactored live load design action is equal to (1 + DLA) × (300LA or 350LA, depending on the line).

Table 1 below shall be used when designing pipelines under ARTC railway tracks.

Table 1-Average Intensity of the Unfactored Live Load (Including DLA)-Standard Track Gauge with 2.5 m Long Sleepers

Cover (m)	Average Intensity (kPa) Single or Multiple Track		Cover (m)	Average Intensity (kPa) Single or Multiple Track	
	300LA	350LA		300LA	350LA
1.6 (minimum)	63	74	3.2	41	48
1.7	60	70	3.3	41	48
1.8	58	68	3.4	41	48
1.9	55	65	3.5	41	48
2.0	53	62	3.6	40	47
2.1	52	60	3.7	40	47
2.2	50	59	3.8	39	46
2.3	50	59	3.9	39	46
2.4	49	57	4.0	38	44
2.5	48	56	5.0	35	41
2.6	47	55	6.0	33	39
2.7	45	53	7.0	31	36
2.8	44	52	8.0	29	34
2.9	43	50	9.0	29	34
3.0	42	49	10.0	28	33
3.1	42	49			

Note: When designing pipes under ARTC railway tracks using available software packages, the designer shall ensure that the factored live load effects listed above are correctly applied in the design inputs. It is important not to rely solely on the software's inputs.

The superimposed dead load from the track (rails, sleepers, and ballast), embankment fill, trench fill, hydrostatic and internal pressures, construction live load, etc., shall be considered alongside the live load. Any future works that have the likelihood of increasing the loads over the pipe shall also be included in the design.

The superimposed dead loads of soil, groundwater, ballast, track, embankments, etc., shall include appropriate load factors in accordance with AS 5100.2.

4.2 Design Life

All parts of under- or overground third-party pipelines within ARTC railway corridors, including, but not limited to, the enveloping pipes, non-encased carrier pipes, or conduits, shall be specified with a minimum design life of 50 years.

4.3 Maximum Allowable Track Settlement

For analysis purposes, the maximum allowable baseline settlement of track shall be taken as 12 mm (not under special trackwork such as turnouts or diamond crossings). Refer to Section 7.

4.4 Roadway Loading

Where a precast concrete pit is installed within ARTC railway corridors in areas with existing access roads or where maintenance vehicles may cross, the pit shall be designed to support a minimum wheel load of 40 kN. The load factors for the Ultimate Limit State (ULS) and Serviceability Limit State (SLS) designs shall be set at 1.8 and 1.0, respectively, with no DLA applied. The minimum design life of precast concrete pits shall follow Clause 4.2.

4.5 Required Documents

For constructions (overall, i.e., boreholes) with a diameter of 150 mm or less at any depth below ARTC railway tracks, detailed sketches on aerial images, including all measurements, cross section, and elevation, may be sufficient to show all the relevant information when the documents listed under "Design Drawings" (1) are missing. These sketches should include ARTC railway corridors and locations, rail kilometres, pipe or duct alignments, access points, and any other required information.

For constructions exceeding 150 mm in diameter, the following documents (1 to 4) should be submitted to ARTC.

For all constructions, regardless of diameter, a detailed sketch (above) or Design Drawings (1), pipe design capacity calculations, design information, or datasheet (see 2), and the “Detailed Method Statement” (3) should be submitted to ARTC.

A geotechnical investigation report for under-track constructions with a diameter larger than 150 mm should be submitted to ARTC. The contractor responsible for drilling works should ensure that the site is safe for construction activities and engage experienced personnel to conduct any additional necessary investigations, considering the risks associated with each construction method (Section 5), to ensure a safe construction process.

1. Design Drawings

Including below:

- Project description including the client or service owner, the consulting company, and the contractor(s).
- Design information, including design loading, site layout, rail kilometrage, longitudinal profiles, cross-sections of the construction, along with any newly designed services, such as valves. These Design Drawings shall clearly show the alignment dimensions, lengths, distances, and elevations of any new designs in relation to ARTC rails, ground level, railway corridors, and any existing assets or structures. Additionally, the drawings shall include detailed measurements, dimensions, elevations, and GPS coordinates for trenches and entry and exit pits.
- Aerial images showing the service or pipeline alignment and names of roads where entry and exit pits are constructed, including full measurements. Services should cross ARTC railway tracks as close to 90° unless approved by ARTC. Pipes shall not have bends within ARTC rail corridor. Valves or pumping stations shall not be located within ARTC railway corridors. All the above-mentioned information may be merged with the relevant aerial images.
- “For Construction” Design Drawings in PDF, and, where applicable, “For Review” (e.g., 15%, 85%) Design Drawings in PDF.
- As-built drawings in PDF and CAD formats within 10 business days of the actual project completion date or as stipulated in the Property Agreement.

2. Comprehensive Design Report

Including below:

- The Comprehensive Design Report should include a geotechnical site investigation in accordance with AS 1726, including all relevant photographs, laboratory tests, borehole logs, and soil profiles’ shear and compressive strengths, etc.
- The Comprehensive Design Report may include numerical Finite Element (FE) modelling for both static and dynamic loadings (including railway, jacking, frictional, tensile, etc.). It may also contain calculations that predict track settlements before the application of annulus grouting, as well as the anticipated long-term settlement. The Comprehensive Design Report shall include pipe/encasement stress analysis under loading or their design capacity calculations, design information, or datasheet in accordance with the relevant Australian Standards for buried rigid, semi-rigid, or flexible pipes. Other analyses or calculations, such as the stability design of any excavation that may be temporarily constructed close to and parallel to the railway, should be included in the design report. In addition, all the documents and datasheets, including pipe specifications, weld procedures, and welder qualifications and certificates, may be submitted within the Comprehensive Design Report, if applicable. The attachments to this report should also include the site access and BYDA information.

3. Detailed Method Statement

Including below:

- The Detailed Method Statement shall include the brief construction methodology and stages (refer to Section 5), Safe Work Method Statement (SWMS), Job Safety Environmental Analysis (JSEA), and, where applicable, the relevant risk assessments (that may include, but not be limited to, access, excavations, the potential for damage to ARTC assets, control settlements, etc.).

- In addition, the Detailed Method Statement may include the documents of the equipment to be used, the annulus grouting procedure, the procedure of welding or jointing of pipes, corridor and/or level crossing vehicle movement, contamination, noise, dust, erosion, and sediment control, and the contingency and recovery management plans.

4. Detailed Track Monitoring Report

   Including below:

- The Detailed Track Monitoring Report shall include track monitoring information to ensure full detection of possible track movements (refer to Section 7).

4.6 Minimum Design Requirements Under ARTC Railway Tracks

Table 2 lists the pipe/encasement materials, ARTC (under-track) minimum design requirements, and the relevant Australian Standards for the designs.

Table 2-Pipe/Encasement Material and ARTC (Under-Track) Minimum Design Requirements

Pipe/Encasement Material	Minimum Design Requirements	Relevant Australian Standard
Polyethylene (PE)	PN16 (pressure only)	AS 2566.1, AS 4130
Polyvinyl chloride (PVC)	SN16 PN20 (pressure only)	AS 2566.1, AS 1254, AS 1260, AS 1477, AS 4765
Glass Reinforced Plastic (GRP)	PN20	AS 2566.1, AS 3571
Steel	* fy=250 MPa	AS 2566.1, AS 2885, AS 4822, AS 1554
Reinforced concrete (RC)	Class 4	AS 3725, AS 4058
Other materials	Only standard materials as stated in the relevant Australian Standards when they are site-specifically designed or in accordance with ARTC type-approved systems	
* fy=Yield strength of steel material		

If jointing of pipes under ARTC railway tracks is required, butt welds (full penetration for metallic pipelines) shall be utilised to joint all pipe materials other than concrete pipes. Other methods of pipe-jointing, such as electrofusion, clamped, or bell and spigot-type joints, should not be permitted directly under ARTC railway tracks. If possible, any pipe joints should be at least 1 meter away from the end of the sleepers on either side of the track to reduce future track issues due to the connection failure. Jointing of concrete pipes under multiple tracks may be unavoidable, as they are often available in shorter lengths. In this situation, concrete pipes should be rubber ring jointed.

Under ARTC railway tracks, PVC or GRP should not be used for the new pipelines containing fire service, toxic, or corrosive material, or any combustible and flammable liquid.

Pipe material selection shall consider the risk of fire or explosion, as well as the risk of construction of combustible and flammable services in proximity to the existing assets, such as railway stations or bridges.

Cathodic protection, electrical isolation, and corrosion protection requirements of the metallic pipelines shall be designed and maintained in accordance with AS 2832.1.

Corrugated metal or ceramic pipelines shall not be installed under the existing ARTC railway tracks using any pipe installation methods described in this Standard.

5 Construction

5.1 Depth of Cover

Table 3 lists the required and preferred depth of cover from the ToR to the top of the construction, and for the embankment tracks, from the level of the embankment toe to the top of the construction.

Table 3-Depth of Cover

Pipe	Required Depth of Cover (m)	Preferred Depth of Cover (m)
Fire service, toxic, or corrosive material, petroleum, or any combustible and flammable liquid, oil, or gas services	≥2 from ToR	≥3 from ToR
Other services (not included above)	≥1.6 from ToR	≥2 from ToR
Any pipe (under embankment track)	≥2 from the level of the embankment toe	

5.2 Pipe Installation Methods

Depending on the site conditions, required services, and other project considerations, the contractor responsible for drilling works should choose to install the services under ARTC railway tracks using the following standard trenchless methods.

5.2.1 Horizontal Directional Drilling (HDD)

The HDD method should be limited to bore diameters not exceeding 500 mm.

In brief, this method includes the following stages:

- Drilling a pilot hole using a steerable/trackable drill.
- Enlarging the borehole to the required diameter through multiple passes.
- Stabilising and protecting the borehole using drilling fluid or mud.
- Where there is an encasement, pulling the encasement and then the pipe into the enlarged borehole.

For this construction method, the contractor shall ensure that a suitable contingency and recovery management plan is in place. The plan shall ensure that equipment and materials are on standby to mitigate risks, such as:

- Loss of drilling fluid
- Hydraulic fracture (frac-out)
- Hydrolock
- Shear failure of soil and collapse of the borehole
- Fluid pit overflow
- Hydrocarbon spill
- Encountering an unforeseen obstruction, boulders or pockets of groundwater
- Drill pipe or bottom hole assembly failure

- Excessive settlement or heave
- Safety or environmental incidents

The drilling fluid shall not be used as a long-lasting or impermeable seal instead of grouting between the borehole and the pipe to stabilise the gap permanently (refer to Clause 5.3). If the drilling fluid is applied through the process, it shall be environmentally friendly and conform to the relevant Standards. The contractor shall select the appropriate drilling fluid separation system to remove solids from the drilling fluid and properly manage the volume and pressure of the drilling fluid through the borehole to minimise any risk, such as frac-out, ground settlement, or heave. The contractor shall implement a regular testing plan for the drilling fluid during construction shifts to ensure optimal performance.

5.2.2 Micro-tunnelling/Pipe Jacking (MT/PJ)

This method may be used for constructing larger diameters than 500 mm. This method involves earth pressure balance, slurry, a pilot tube, and vacuum MT/PJ boring machines. In brief, this construction method includes the following stages:

- Setting up the MT/PJ boring machine and the cutting shaft head unit.
- Utilising a combination of high-pressure water and a cutting head unit to accurately excavate the design alignment. The head unit is designed to counterbalance external earth pressures, ground movements, and variable material density to ensure an accurate alignment.
- Crushing the excavated material into fine particles and vacuuming them out along with the water, resulting in a slurry by-product.
- Halting excavation once the cutting unit is set up and lodged into the earth to allow for the pipeline to be installed to the end of the unit and is jacked forward as the head unit continues to excavate.

For pipes carrying storm water or gravity sewer services, the jacked pipe may be the same as the carrier pipe. However, the pressure pipelines should have a carrier pipe inside an encasement to further protect the pipeline in the event of pipe failure.

For this construction method, the contractor shall ensure that a suitable contingency and recovery management plan is in place. The plan shall ensure that equipment and materials are on standby to mitigate risks, such as:

- Shaft/pit collapse
- Tunnel collapse
- Shaft/pit flooding
- Tunnel flooding
- Hydrocarbon spill
- Mechanical/electrical boring machine failure
- Excessive settlement or heave
- Safety incidents
- High water inflows at the face of the boring machine, which prevent access to the pressure chamber for cutter inspection and replacement
- higher jacking forces than expected

- Safety or environmental incidents

For this method, the contractor shall effectively control the maximum progression of excavation ahead of the leading end of the pipe to minimise the risk of affecting ARTC railway track stability.

5.2.3 Auger/Thrust Boring (A/TB)

This open-face method, also known as “jack and bore”, is a precise method of placing an auger with a casing pipe together to create a bore to facilitate trenchless excavation. This method includes the following stages in brief:

- Forming a borehole from a launch or driving pit/shaft to a reception pit /shaft using a rotating cutter head or auger.
- Continuously supporting the borehole with a temporary casing.
- Removing the spoil back to the drive shaft using helically wound A/TB flights that rotate within a casing.

For this construction method, the contractor shall ensure that a suitable contingency and recovery management plan is in place. The plan shall ensure that equipment and materials are on standby to mitigate risks, such as:

- Shaft/pit collapse
- Casing pipe failure
- Pit flooding
- Mechanical/electrical boring machine failure
- Excessive settlement or heave
- Safety or environmental incidents
- High water inflows at the face of the thrust boring
- Higher jacking forces than expected
- Safety or environmental incidents

In any of the above construction methods subject to Clauses 5.2.1 to 5.2.3, the contingency and recovery management plan should consider the following:

- Names, roles, responsibilities, and contact numbers of all contractor employees carrying out the installation at the site and other appointed engineering representatives (desktop or site)
- Emergency response procedures, thresholds, and immediate actions
- Equipment available for containment control and site clean-up
- Time schedules of remedial stages
- Proposed methods for clean-up

In addition to the requirements or recommendations specified in this Standard, for the pipes containing any type of liquids or gases, the contractor should consider a specific emergency plan to deal with any potential leakage/seepage during construction and thereafter.

Details regarding the selected disposal location for drilling fluids, spoils, excavated and moistened soils, etc., should be considered and shall be situated outside ARTC railway corridors.

5.3 Annulus Grouting

The borehole diameter should not exceed 30 mm beyond the outside diameter of the pipes permanently. If there is a cavity of greater than 30 mm between the borehole and the service, it shall be properly backfilled with approved materials, such as an approved cementitious grout, which has a minimum compressive strength of 1 MPa at 48 hours. Grouting any cavity is essential for controlling settlements and the long-term protection and maintenance of underground services. During construction, pumping of the grout should be stopped until the pumped grout volume has equalled the theoretical annulus volume between grout ports, and the installed grout pressure exceeds the theoretical hydrostatic ground pressure plus a pressure of 0.25 bar.

During construction, the cutter head shall never be more than 600 mm ahead of the casing pipe.

5.4 Alignment Horizontal Clearance

Table 4 lists the required horizontal clearance between the new under-track alignments and existing assets.

Table 4-Required Horizontal Distance Between the New Under-Track Alignment and Existing Assets

Asset	Required Horizontal Clearance (m)
Transmission or communication towers, overhead structures, or any elevated structures with live wires	≥20
Railway stations, bridge substructures, or bridge approaches	Fire service, toxic, or corrosive material, petroleum, or any combustible and flammable liquid, oil, or gas ≥15
	Other services (not included above) ≥3
Special trackwork, like turnouts or diamond crossings	≥10
Buildings, retaining walls, culverts, or other structures	Fire service, toxic, or corrosive material, petroleum, or any combustible and flammable liquid, oil, or gas ≥10
	Other services (not included above) ≥3
Any telecommunication, communication, or instrumentation systems/facilities/equipment not listed above	≥3
Cattle pits, grids, or drains	≥2
Existing underground services (any type)	≥2
Existing level crossings	≥2
Any other minor foundations, slabs, or boundary fences	≥1

Where multiple new boreholes should be constructed under tracks, a minimum edge-to-edge spacing of 10D (where D is the diameter of the largest borehole) between each bore should be maintained.

5.5 Construction Tolerances

The actual under-track bore alignment should follow the For Construction Design Drawings and conform to the allowable construction tolerances listed in Table 5, where the alignment is within ARTC railway corridors. It should be noted that the construction tolerance listed in Table 5 is mostly for the ease of locating the underground services in the future. The contractor responsible for drilling works may specify further tolerances on top of Table 5, considering the specific installation conditions and outcomes required; however, under no circumstances shall the actual as-built alignment or cover infringe the minimum required depths of cover or horizontal clearances specified in Tables 3 and 4.

Table 5-Construction Tolerances within ARTC Railway Corridors

Boring Method	Construction Tolerance (mm)	
	Horizontal (Plan)	Vertical (Elevation)
HDD	±500	±500
MT/PJ	±50	±50
A/TB	±50	±50

5.6 Construction Schedule

All boreholes larger than 150 mm in diameter at any depth below ARTC railway tracks and within 1.6 meters of the edge of the sleepers should be completed while trains are not operating.

Under no circumstances should an underground borehole exceeding the above limit remain unsupported, as this may increase the risk of collapse further ahead or deeper into the soil. For boreholes larger than 150 mm in diameter, where the installation is constructed below the water table, all the works shall be completed whilst trains are not operating.

If necessary, ARTC may approve rail vehicles to pass before the construction is fully completed. This may be subject to further risk assessment, speed or mass restrictions, contingency and recovery management plans, and increased inspections or track monitoring.

5.7 Temporary Trenches

Trenchless boring methods for installing the underground services aim to minimise or eliminate the need for temporary trenching or excavation; however, the following Clauses are included in this Standard in case constructing these temporary trenches or excavation in some locations within ARTC railway corridors is unavoidable.

The following Clauses exclude trenching or excavation requirements for signalling services that are not constructed directly under ARTC railway tracks, as stated in the relevant ARTC signalling Standards.

5.7.1 Entry and Exit Pits

The entry and exit pits of the third-party services should be located at least a minimum of 6 m from the toe of embankments or top of cuttings or 10 m from the nearest rail, whichever is greater, and positioned outside ARTC railway corridors. It should be noted that the fences do not necessarily indicate ARTC railway corridors. ARTC railway corridors should be confirmed before designing the location of new assets, such as entry and exit pits.

5.7.2 Design and Construction

Trenching directly under the track shall not be permitted unless approved by ARTC. This may be subject to an increase in the DLAs in Table 1 (to accommodate factors such as transitions or stiffness changes), and further work on earthworks design and construction, and risk assessment.

If a temporary trench or excavation is constructed adjacent and parallel to the rail while the train is in operation, the lateral pressure from trains shall be considered following the influence line at a slope of 1(H):1(V) from the bottom edge of the sleepers as indicated in AS 5100.2, including the appropriate DLAs. For 350LA, the pressures listed in AS5100.2 shall be factored by 1.17.

Every face of any excavation that exceeds a depth of 1.5 m should be supported or contained by appropriately designed shoring.

Within ARTC railway corridors, temporary trenches and access pits should be surrounded by temporary barriers and should not be left open outside the working shifts.

In trenches or excavations, the minimum horizontal clearance on each side of pipes should be 200 mm.

After the project completion, all trenches or excavations extending at least 5 meters beyond the outer rails should be backfilled if the excavation is within ARTC rail corridors.

Before the contractor issues the handover or project completion certificate, all backfilled trenches and excavations shall be examined, and any depressions caused by settlement or erosion of the backfilling shall be corrected, and the cause shall be rectified. All costs associated with potential remedial work on the third-party underground installations, required compaction, or any rectification shall be the contractor's responsibility, unless stated otherwise in the terms and conditions of the Property Agreement.

Within ARTC railway corridors, where in a trench or excavation, the design requires an RC protection cover to be put over the pipes/conduits, it should be 1 m wider than the enveloping and carrier pipes with a minimum thickness of 150 mm. The concrete should have a minimum compressive strength of 20 MPa at 28 days.

Internal concrete surfaces shall be free of voids and steel trowelled to a smooth finish. External concrete surfaces shall be finished to a non-slip wood trowelled finish.

Concrete edges and corners shall be chamfered to minimise chipping and breaking.

Concrete surfaces shall be level except where a slope is required to form a ramp or to disperse water away from a building or other structure.

The backfilling of the excavations should normally take up the majority of the spoil. However, any surplus spoil or unsuitable fill shall be treated in accordance with ARTC Earthworks Construction Specification ETC-08-04.

During the construction, at no time shall water be allowed to pool into the temporary trenches, excavations, or pits. If rain is occurring or forecasted, or if active seepage into the open trench is encountered, the trench shall be backfilled on the same day of the excavation. Dewatering pumps shall be available at the site as a contingency and recovery plan during rain or possible flooding.

The contractor shall inspect and restore any existing drains during backfilling to ensure proper water drainage. If the existing drains need rectification, the contractor shall rectify such drainage before backfilling.

Photographic evidence of compaction, including pre- and post-backfilling, should be recorded and submitted to ARTC.

5.7.3 Compaction

Refer to ARTC Earthworks Construction Specifications ETC-08-04.

5.8 New Drainage Pipes within an Existing Culvert

ARTC may approve the installation of a new drainage pipe within an existing culvert if the pipe is slightly smaller than the culvert itself, instead of approving an underground service installation using trenchless methods. In this case, the pipe should be positioned as close to the soffit as possible. The pipe should be laid over an approved cementitious grout with a minimum compressive strength of 1 MPa at 48 hours under and over the pipe to present a smooth surface with an appropriate gradient for the water passing through the pipe. The gaps between the new pipe and the internal diameter of the existing culvert at the inlet and outlet of the culvert in ARTC railway corridor shall be properly filled with approved cementitious grout. The design of the culvert flow may also be subject to review. The pipe shall be returned underground at each end of the culvert as quickly as practical.

No fire service, toxic, corrosive material, petroleum, or combustible or flammable liquid, oil, or gas services shall be permitted to be installed in an existing culvert. In addition, the contractor shall thoroughly consider the risk of failure or fire affecting these pipes in proximity to the existing assets, such as railway stations or bridges.

6 Marking of Services

Table 6 lists the colours for identifying the underground services within ARTC railway corridors following AS 5488.1 and considering other existing ARTC Standards. For any unspecified services in Table 6, the relevant Australian Standards or the asset owner’s requirements should be followed.

Table 6- Pipe Identification

Service Type	Colour
Signalling, Electricity, or Power (LV & HV)	Orange
Telecommunication or Communication	White
Intelligent Transport System	Black
Fire Service, Toxic, or Corrosive Material	Red
Petroleum, Combustible and Flammable Liquid, Oil, or Gas	Brown
Pressure Gas	Yellow
Compressed Air	Light Blue
Drainage, Stormwater, Raw Water, and Wastewater	Green
Recycled water	Purple
Water (Potable)	Blue
Sewer Rising Main or Vacuum Sewer	Cream

Marker tapes shall be laid at least 500 mm above the services and at least 800 mm out of the ground at minimum intervals of 100 m. They shall be a minimum of 75 mm wide, distinctly coloured, and carry a warning about the presence of the services below them.

7 Track Monitoring

7.1 Monitoring Locations

For underground constructions with a diameter greater than 150 mm, the contractor shall implement a track monitoring process to fully detect any potential track movements. Track monitoring locations should include the rail webs, embankments, and other fixed points adjacent to the top of the construction, as specified in Table 7.

All surveying activities shall be carried out in accordance with ARTC survey procedures and RISSB AS 7634. Survey control to monitor the displacements shall comply with ARTC procedure Control Surveys ETD-00-04. Track monitoring should not be conducted using the Global Navigation Satellite System (GNSS) or observed from temporary control marks. Monitoring locations should be marked with reflective or adhesive targets, or any other approved method, to ensure repeatability of monitoring observations. Observations shall achieve the maximum survey uncertainty of ±2 mm.

Table 7-Recommended Monitoring Locations

Target Location	Surveying Method
Rail webs	Fixed survey targets, for example, epoxied or glued using wet grab adhesive to the small plastic brackets or angles, or any other approved method
Embankments	Fixed survey targets, for example, nailed, epoxied, or glued to wooden survey pegs or similar, driven into embankments
Fixed point (if any) such as pavement, a slab, a footing, or a fence adjacent to the top of the construction	Fixed survey targets, for example, epoxied or glued to the concrete, fixed to the pavement, or attached to the fence

7.2 Monitoring Recommendations

Any horizontal (x and y) and vertical (z) displacements at the locations listed in Table 7 should be measured in each survey. Table 8 sets the track monitoring recommendations for different constructions. ARTC track monitoring recommendations are determined based on the construction diameter and soil type, rather than the construction method, to not only optimise the measurement points and monitoring time at any stage but also effectively address potential risks of track displacements or damaging ARTC railway infrastructure. Should the contractor have any other proposal for track monitoring, depending on the depth of construction or site conditions, ARTC should approve.

Table 8-Track Monitoring Recommendations

Construction Diameter (mm)	Monitoring Locations	Soil Type at Construction Level
≤ 150	No installation track monitoring (refer to Clause 7.3)	Any
> 150 but ≤ 300	1 × right at the top of the centreline of the installation for all the rail webs, embankments, and fixed points at a close distance (if any) 2 × 2 m intervals from 0 to 4 m on both sides of the installation on the rail webs only	Any
> 300 but ≤ 500	1 × right at the top of the centreline of the installation for all rail webs, embankments, and fixed points at a close distance (if any) 3 × 2 m intervals from 0 to 6 m on both sides of the installation on the rail webs only	* E ≥ 80 MPa *For example, rock, medium to dense gravel, or sand*
	1 × right at the top of the centreline of the installation for all rail webs, embankments, and fixed points at a close distance (if any) 4 × 2 m intervals from 0 to 8 m on both sides of the installation on the rail webs only	40 < E < 80 MPa *For example, loose gravel or sand, or medium to dense sand*
	1 × right at the top of the centreline of the installation for all rail webs, embankments, and fixed points at a close distance (if any) 5 × 2 m intervals from 0 to 10 m on both sides of the installation on the rail webs only	E ≤ 40 MPa *For example, silty gravel or sand, or any cohesive soft soil such as silt or clay*
> 500	1 × right at the top of the centreline of the installation for all rail webs, embankments, and fixed points at a close distance (if any) 6 × 2 m intervals from 0 to 12 m on both sides of the installation on the rail webs only	Any

** E= Young's modulus of soil material. The conclusion of the geotechnical investigation report or the technical note should explicitly include the confirmation of the associated track monitoring method. No track monitoring method should be left for interpretation by the contractor responsible for drilling works based on the soil data.*

Figure 1 shows a schematic of the track monitoring recommendations listed in Table 8.

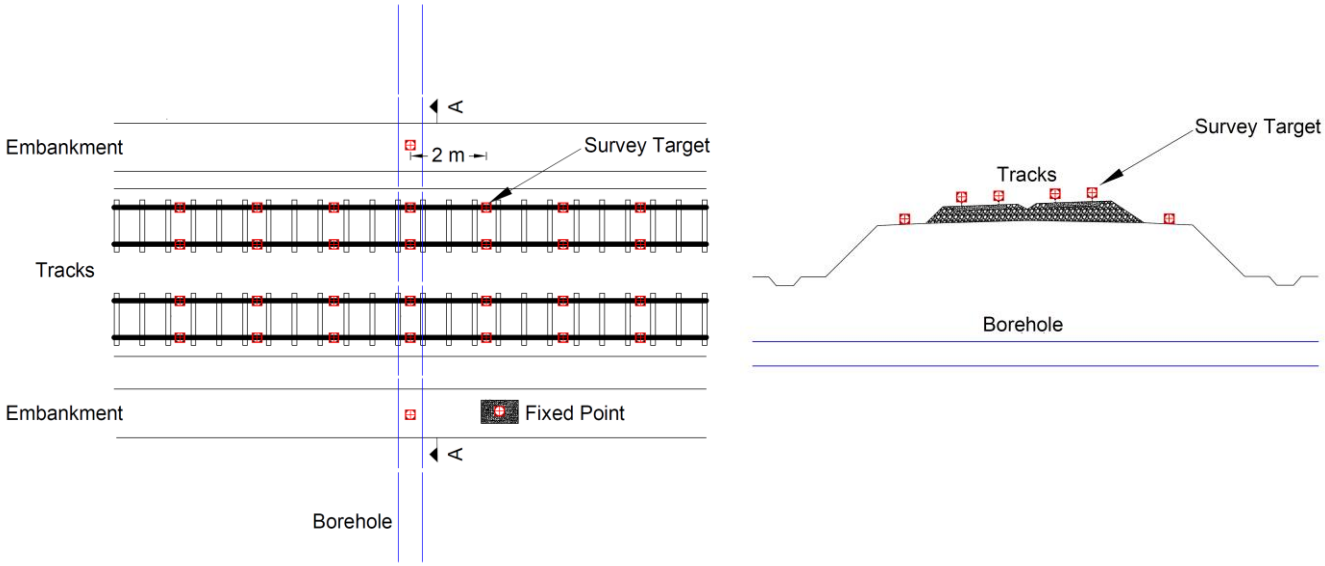

Figure 1-Schematic of Track Monitoring and Locations of Survey Targets (Plan and Section A-A)

In skewed alignments, if approved by ARTC, the monitoring locations should follow the alignment, i.e., right at the top of the alignment centreline and 2 m intervals on both sides following the skew angle.

7.3 Monitoring Reporting

At any monitoring stage, the information related to the track monitoring visit including but not limited to ARTC track kilometrage, the date of the survey, the time of the survey, the name of the surveyor(s), the temperature at the commencement of the survey, and the general weather conditions during the survey should be recorded on the contractor's track survey report/form within the Detailed Track Monitoring Report.

The contractor should tabulate monitoring locations (in track kilometrage), the x, y, and z directions of (+ or -) measurements, and their variations (in mm or m) in each stage in a preferred Table format or plot the longitudinal colour curves during each survey to represent changes in elevations or distances.

During any under-track construction with a diameter greater than 150 mm, a GSE should be present throughout the construction work to assist in interpreting the possible displacements.

For all under-track constructions regardless of diameter, the pressures shall be controlled by the contractor responsible for the drilling works to ensure frac-out, ground settlement, or heave does not occur.

For all under-track constructions regardless of diameter, a Track Certifier (TC) shall certify that the track geometry complies with ARTC Section 5: Track Geometry ETS-05-00 before the passage of trains.

7.4 Monitoring Stages and Frequencies

The track monitoring stages should be conducted as below:

1. Baseline (pre-installation) monitoring: Before any work begins, a complete survey of the monitoring locations similar to what is listed in Table 8 should be conducted and documented as a baseline. A minimum of two sets of baselines should be taken on different days to ensure greater confidence in surveying and account for any uncertainties in level changes

caused by, e.g., temperature fluctuations. If there are uncertainties and obvious variations in the baseline surveying sets, the surveying may be repeated to gain confidence in the data before moving forward. The baseline monitoring should be used by the TC to set levels to ensure the track remains compliant with ARTC Section 5: Track Geometry ETS-05-00 and safe for the passage of trains.

2. Installation (during) monitoring: Refer to Table 8. After the commencement of installation, a survey of the locations listed in Tables 7 and 8 should be taken and compared to previously defined surveyed levels (variations) in a preferred Table format. During the construction, monitoring should occur regularly during working hours while the installation is within 1.6 meters from the edge of the sleepers. Additional monitoring may be recommended outside of working hours if advised by the PGE or GSE and approved by ARTC. The track shall be certified by the TC before the passage of the first rail vehicle after completion.
3. Post-installation monitoring: Table 9 lists the recommended post-installation monitoring frequencies.

Table 9-Recommneded Post-Installation Monitoring Frequencies

Construction Diameter (mm)	Post-Installation Monitoring Frequencies
≤ 150	No post-installation track monitoring (refer to Clause 7.3)
* > 150 but ≤ 300	The first 3 days and weekly monitoring up to a minimum of 1 week
> 300 but ≤ 500	The first 3 days and weekly monitoring up to a minimum of 2 weeks
> 500	The first 3 days and weekly monitoring up to a minimum of 4 weeks

** Post-installation monitoring frequencies for the constructions within this range occurring deeper than 3 m from the ToR may be reduced to a minimum of the first 3 days only, provided that the construction proceeded smoothly with minimal recorded displacements (refer to Clause 7.5, within Level 1 limits). If the contractor intends to proceed, this should be documented and signed by the PGE in a technical note or memorandum and approved by ARTC.*

ARTC shall be notified immediately if any issues arise during any stage of the post-installation measurements mentioned above. In certain clay-rich soils, fluctuations in moisture may lead to volume changes in the soil due to shrinkage or swelling. Therefore, the geotechnical investigation report should include a section in advance regarding what is expected to occur during the post-installation survey.

If any visible displacements (refer to Table 10) are detected during any post-installation survey that can cause damage to the rails, surface drainages, buried services, access roads, and other assets, the contractor shall propose necessary remedial actions and submit them to ARTC. All costs associated with remedial work on the third-party underground installations shall be the contractor's responsibility, unless stated otherwise in the terms and conditions of the Property Agreement.

Track maintenance activities, such as tamping or rail grinding, can also affect rail levels. The contractor should request from ARTC the plan for any potential track maintenance at the installation location to ensure that post-installation monitoring plans are completed before such activities.

7.5 Monitoring Alarm Levels

The maximum relative displacement (+ or -) of any 4-meter length of rail in any direction (x, y, or z) shall be taken as 12 mm (given that the works do not occur under special trackwork such as turnouts or diamond crossings). Additionally, the maximum baseline displacement of the embankments and the fixed points (if any) at any time shall be taken and limited to 12 mm. Table 10 outlines recommended alarm levels to be set and the necessary immediate actions to be taken for each level during the installation.

Table 10-Recommended Alarm Levels and Necessary Immediate Actions

* Alarm Levels	Description	Necessary Immediate Actions
Level 1	Any relative displacement in a 4-m long rail in any direction (x, y, or z) ≤ 3 mm	• Review the survey • Work should proceed as planned
Level 2	Any relative displacement in a 4-m long rail in any direction (x, y, or z) > 3 mm but ≤ 6 mm.	• Review the survey • The TC should examine the track geometry and validate inspection results following the detection of such displacements and immediately notify all the parties and the GSE • The GSE should inspect and reassess the condition and, if approved, work should proceed with caution in areas of detected displacements. The TC shall certify the track geometry before the passage of trains
Level 3	Any relative displacement in a 4-m long rail in any direction (x, y, or z) > 6 mm but ≤ 9 mm	• Review the survey • The TC should examine the track geometry and validate inspection results following the detection of such displacements and immediately notify all the parties and the GSE • The GSE should inspect and reassess the condition and, if approved, work should proceed with caution in areas of detected displacements. If not, remedial measures should be taken before work continues to prevent further displacements. The TC shall certify the track geometry before the passage of trains.
Level 4	Any relative displacement in a 4-m long rail in any direction (x, y, or z) > 9 mm but ≤ 12 mm *If the displacement leading up to this Level had occurred gradually, the previous alarm levels should have already been implemented to prevent reaching this stage of displacement. Therefore, the control measures specified for this*	• Review the survey • The TC should examine the track geometry and validate inspection results following the detection of such displacements and immediately notify all the parties and the GSE • Consider stopping. The installation methodology and monitoring procedure should be reviewed, and any necessary remedial measures should be taken to prevent further displacements. This may also include speed restrictions or further

* Alarm Levels	Description	Necessary Immediate Actions
	Level are based only on the occurrence of sudden displacement.	consultation with ARTC, GSE, or PGE. The TC shall certify the track geometry before the passage of trains.
Level 5	Any relative displacement in a 4-m long rail in any direction (x, y, or z) > 12 mm *If the displacement leading up to this Level had occurred gradually, the previous alarm levels should have already been implemented to prevent reaching this stage of displacement. Therefore, the control measures specified for this Level are based only on the occurrence of sudden displacement.*	• Review the survey • The TC should examine the track geometry and validate inspection results following the detection of such displacements and immediately notify all the parties and the GSE • Apply emergency response procedures, thresholds, and immediate actions as indicated in the contingency and recovery management plans. This may include stop trains, speed restrictions, necessary remedial measures, or further consultation with ARTC, GSE, or PGE. • Consider stopping. The installation methodology and monitoring procedure should be reviewed, and any necessary remedial measures should be taken. The TC shall certify the track geometry before the passage of trains.

** Additionally, the maximum baseline displacement of the embankments and the fixed points (if any) at any time shall be taken and limited to 12 mm following the above Alarm Levels.*

Before installation, the contractor should confirm with ARTC if the track has any existing geometry defects or if there are other considerations made by ARTC. This is to ensure that poor track geometry does not deteriorate to an unacceptable level, potentially leading to major issues during the construction or after the completion of works.

8 Documentation

All service crossing documents shall be covered by a Master Access Deed or Infrastructure License, and/or Agreement.

A copy of each Deed, License, or Agreement, including all relevant documentation stated in this Standard, shall be maintained by the Regional Property Manager covering their area of responsibility.

Appendix A-Task Management Checklist

Table A below lists a checklist for the main tasks assigned to the third-party or the contractor engaged by ARTC. For more information, refer to the relevant Section or Clause in this Standard, or contact ARTC.

Table A-Task Management Checklist

Task Number	Task	Section/ Clause	Page	Organiser	Remarks
1	Third-party works application	1	3	Third-party	≥ 90 days before the intended start date of the construction
2	Property Agreement or Infrastructure License	1	3	Third-party	to be signed between the third party and ARTC Property Division (No application will be processed if the Agreement is not signed)
3	Construction of toxic or corrosive underground services?	2	3	Third-party	Conduct a risk assessment workshop along with the presence of the relevant ARTC representatives
4	Route locating	3	6	Third-party	BYDA and contact ARTC
5	Construction of under-track services with a diameter of ≤ 150 mm?	4.5	7	Third-party or ARTC's engaged contractor	Submit documents below: • Detailed sketch • Pipe design capacity calculations, design information, or datasheet • Detailed Method Statement
	Construction of under-track services with a diameter of > 150 mm?				Appoint a GSE and/or a PGE Submit documents below: • Design Drawings • Comprehensive Design Report including geotechnical investigation • Detailed Method Statement • Detailed Track Monitoring Report
6	Compaction of temporary trenches or excavations	5.7.2	15	Third-party or ARTC's engaged contractor	Provide photographic evidence of compaction, including pre- and post-backfilling

Task Number	Task	Section/ Clause	Page	Organiser	Remarks
7	Planned track maintenance activities	7.4	19	Third-party or ARTC's engaged contractor	Request for the upcoming plan for track maintenance at the installation location
8	Update of Table 10?	7.5	21	Third-party or ARTC's engaged contractor	Request for review and potentially update Table 10, considering the existing condition of the track at the installation location