technical report D

land stability and ground movement.

Environment Effects Statement | May 2021

western outer ring main

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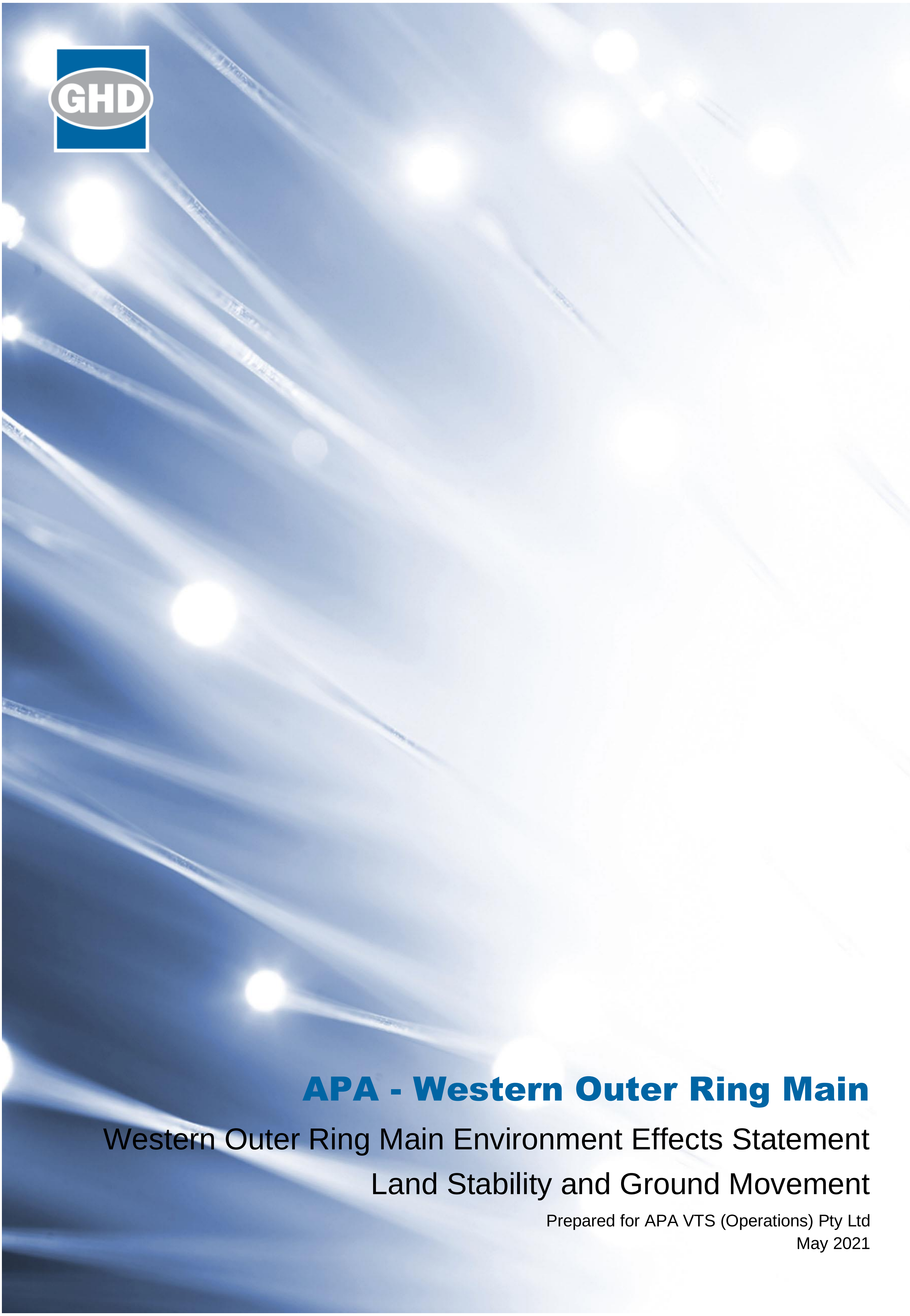

APA - Western Outer Ring Main

Western Outer Ring Main Environment Effects Statement

Land Stability and Ground Movement

Prepared for APA VTS (Operations) Pty Ltd

May 2021

This Land Stability and Ground Movement Impact Assessment Report (Report):

1. Has been prepared by GHD Pty Ltd (“GHD”) for APA VTS (Operations) Pty Ltd (APA);
2. May only be used for the purpose of informing the Environment Effects Statement and Pipeline Licence Application for the Western Outer Ring Main Project (and must not be used for any other purpose); and
3. May be provided to the Department of Environment, Land, Water and Planning for the purpose of public exhibition as part of the Environment Effects Statement and Pipeline Licence Application for the Western Outer Ring Main Project.

The services undertaken by GHD in connection with preparing this Report were limited to those specifically detailed in section 5 Methodology of this Report. The opinions, conclusions and any recommendations in this Report are based on assumptions made by GHD when undertaking services and preparing the Report (Assumptions), as specified in section 1.3, section 5.9 and throughout this Report. GHD excludes liability for errors in, or omissions from, this Report arising from or in connection with any of the assumptions being incorrect. Subject to the paragraphs in this section of the Report, the opinions, conclusions and any recommendations in this Report are based on conditions encountered and information reviewed at the time of preparation. GHD has not, and accepts no responsibility or obligation to update this Report to account for events or changes occurring subsequent to the date that the Report was signed.

Executive summary

This technical report is an attachment to the Western Outer Ring Main Project Environment Effects Statement (EES). It provides an assessment of the Land Stability and Ground Movement risks associated with the Project, and defines the environmental management measures necessary to meet the EES evaluation objectives.

Overview

The Western Outer Ring Main Project (the Project) is a buried 600 millimetre nominal diameter high pressure gas transmission pipeline between APA's existing Plumpton Regulating Station (approx. 38 kilometres north west of Melbourne's CBD) and Wollert Compressor Station (approx. 26 kilometres north of Melbourne's CBD), providing a high pressure connection between the eastern and western pipeline networks of the Victorian Transmission System (VTS).

The Project includes the new buried pipeline, three above ground mainline valves along the pipeline alignment, and an additional compressor unit and regulating station at the existing APA Wollert Compressor Station.

APA is the proponent for the Project.

On 22 December 2019, the Minister for Planning determined that the Project would require an Environment Effects Statement (EES) under the Environment Effects Act 1978 (EE Act).

GHD was commissioned to undertake a land stability and ground movement assessment for the purpose of the EES.

Land stability and ground movement context

The scoping requirements for the EES issued by the Minister for Planning set out the specific environmental matters to be investigated and documented in the Project's EES, which informs the scope of the EES technical studies. The scoping requirement relevant to the land stability and ground movement assessment is:

Effects on land stability and erosion related to the construction and operation of the project, including rehabilitation works.

For the purposes of this EES study, land stability and ground movement are considered to be the two areas for assessment required to address the scoping requirement. These are defined below, along with the key issues relevant to each area of assessment.

Ground Movement refers to smaller-scale soil or rock deformations induced by pipeline construction or operation activities. These deformations may subject nearby assets or features to unacceptable strains. The following sources of ground movement are considered to be the key issues for assessment:

- **Trenchless crossings:** Inward ground movements ("volume loss") due to ground relaxation as a result of boring
- **Open trench excavations:** Horizontal and vertical movements that occur adjacent to the open trench excavations
- **Construction drawdown:** Consolidation of compressible soil due to groundwater drawdown caused by construction dewatering required for excavation below the water table

Land stability refers to larger scale movements due to the formation of unstable soil or rock masses. Land stability effects may result in mass movement of soil bodies and disturbance to the natural landscape. The following key issues are identified under land stability:

- **Slope stability:** down slope soil mass movement caused by trench excavation. Can be immediate or long term
- **Trench stability:** short-term failure of an unstable soil mass into the trench excavation causing local disturbance
- **Erosion:** Longer term loss of soil structure and stability due to surface and/or subsurface erosion due to "dispersive" or "suffosive" failure mechanisms in susceptible soils. Erosion effects will be considered insofar as they have the potential to exacerbate the other key issues identified

Potential impacts resulting from the above key issues can include damage to built infrastructure, vegetation, natural landforms and farmland and loss of land function. In the extreme, complete failure of a slope can result in significant and permanent changes to the landscape. It is therefore important to mitigate ground movement and land stability risks to safety, amenity, land function, cultural or historical heritage, flora and fauna and hydrogeological processes.

Existing conditions

An existing conditions assessment was undertaken to establish a baseline for the ground and groundwater conditions for the project alignment and identify ground movement hazards inherent in the existing built environment and natural landscape.

Geological conditions along the alignment are expected to be dominated by the Newer Volcanics basaltic flows and stony rises. Alluvium is present in the Jacksons Creek and Deep Creek watercourses. Outcrops of the Silurian to Devonian Deep Creek Siltstone and the Neogene Brighton Group are also present within the vicinity of Deep Creek. The proposed alignment also transverses the Silurian Humevale Siltstone, Holocene colluvium and Quaternary alluvial terraces within the suburb of Mickleham.

The depth to water table varies considerably across the study area but is considered to be generally greater than 5 m below ground surface except in areas close to watercourses and the Kalkallo retarding basin. As a consequence of the presence of saline water in the soils, there is the potential for dispersive behaviour ("sodicity") in fine grained residual soils within the Project area, leading to erosion effects.

The pipeline alignment was divided into 46 land stability and ground movement 'Reaches' to delineate changes in geology and/or construction methodology. A high level description of the existing conditions for each of the Projects 46 Reaches was then documented to gain an appreciation of where land stability and ground movement risks may arise. This process ruled out a significant portion of the alignment from further specific assessment.

The existing conditions in conjunction with the Project description were used to prioritise the key issues, whereby slope stability, trench stability, dispersive soils and trenchless crossings were identified as requiring further assessment.

Impact assessment

The impact assessment considered the risks relevant to each land stability and ground movement key issue. As determined from the risk assessment, five land stability and ground movement hazards were assessed as part of the impact assessment to understand the potential effects and requirement for mitigation. These assessments included:

- Open trench excavations in unstable ground resulting in trench wall instability
- "Volume loss" arising from trenchless pipe installation in soil resulting in adverse ground movement effects
- Trenchless pipe installation encountering unexpected poor ground resulting in adverse effects
- Pipeline installation in proximity to existing slopes leading to slope instability resulting in slope failure
- Permanent ground surface and water flow changes exacerbating dispersive soil behaviour

The impact assessment identified additional management measures that would be required to reduce the residual impact of risks associated with the hazards listed above where practicable. In general, successful implementation of the recommended management measures is required to reduce residual risk ratings to 'low' or negligible' for all hazards identified.

A key outcome of the impact assessment is the requirement for further testing and analysis on the risks surrounding ongoing erosion and land degradation due to the presence of dispersive (sodic) soils.

Environmental management measures

Seven environmental management measures (EMMs) have been identified to avoid, minimise and manage the potential land stability and ground movement impacts. These EMMs are largely considered to be standard measures required for projects of this type and include adhering to asset clearance requirements; utilising available geotechnical and hydrogeological information to inform design and construction; trench erosion management; and the provision of temporary bore support during pipeline construction.

The provision of trench support for any trench deemed to be at risk of instability (as deemed by the contractor) (EMM GM3) is considered as an additional management measure, and aims to avoid the impact of trench or slope failure. The requirement for further confirmation of ground risk where there is currently a lack of geotechnical information (EMM GM6) aims to minimise the impact of ground movements damaging assets or blow-out of during trenchless activities. EMM GM7 is recommended to further identify and manage the impacts associated with dispersive soils during construction and operation, minimising the impact of long-term erosion.

Abbreviations

Abbreviation	Definition
BH	Borehole
CEMP	Construction Environment Management Plan
ε	Strain (defined as change in length / original length)
EES	Environment Effects Statement
EMM	Environmental Management Measure
DBYD	Dial Before You Dig
DN	Nominal Diameter
GPR	Ground Penetrating Radar
GRP	Glass reinforced pipe
HDD	Horizontal Directional Drilling
HDPE	High density polyethylene (pipe material)
HV	High voltage
KP	Refers to 'Kilometre Point', referencing chainage intervals along the alignment
MSA	Melbourne Strategic Assessment
OEMP	Operational Environmental Management Plan
OMR	Outer Metropolitan Ring Transport Corridor
PVC	Polyvinyl-Chloride (pipe material)
SPT	Standard Penetration Test
SW	Slightly weathered
UAV	Unmanned Aerial Vehicle
VTS	Victorian Transmission System
WORM	Western Outer Ring Main

Glossary

Term	Definition
APA	APA VTS (Operations) Pty Ltd, trading as APA Group, the proponent for the Project
Environmental management measure	Approaches, requirements or actions to avoid, mitigate or manage potential adverse impacts
Floaters	Pieces or fragments of rock that have been removed and transported from their original outcrop.
Foreign Crossings	Locations where the pipeline alignment traverses underneath a road, creek, utility or railway owned by a third party.
Project	The Western Outer Ring Main Project
Scoping requirements	The EES Scoping requirements for the Project issued by the Department of Environment Land, Water and Planning in August 2020.
Sensitive Receptors	Assets or features that may be subject to adverse effects due to the ground movement or land stability risks identified in this report.
Nominal diameter (DN)	Refers to the diameter by which a pipe is identified by, not necessarily reflecting the inside diameter, outside diameter, or wall thickness.
Zone of influence (ZOI)	The boundary around construction activities within which a damage risk to utilities or assets may exist.

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Appendices

1. Introduction

1.1 Purpose of this report

The Western Outer Ring Main (WORM) gas pipeline project (the Project) is a proposed buried 600 millimetre nominal diameter gas transmission pipeline that will provide a high pressure connection between the eastern and western pipeline networks of the Victorian Transmission System (VTS).

APA is the proponent for the Project. APA is Australia's largest natural gas infrastructure business. In Victoria, the VTS is owned and maintained by APA and consists of some 2,267 kilometres of gas pipelines. The VTS serves a total consumption base of approximately 2 million residential consumers and approximately 60,000 industrial and commercial users throughout Victoria.

The Project has been designed to provide critical infrastructure for Victoria's gas supply distribution, and consequent security, efficiency and affordability. The key objectives of the Project are to:

- Improve system resilience and security of gas supply
- Increase the amount of natural gas that can be stored for times of peak demand
- Improve network performance and reliability
- Address potential gas shortages as forecasted by AEMO in the March 2020 Victorian Gas Planning Report update

The Minister for Planning determined on 22 December 2019 that APA and the Western Outer Ring Main (WORM) gas pipeline project (the Project) would require an Environment Effects Statement (EES) under the *Environment Effects Act 1978* (EE Act). The EES will inform assessment of approvals required for the Project including under the *Pipelines Act 2005*, *Aboriginal Heritage Act 2006* and *Environment Protection and Biodiversity Conservation Act 1999*.

The purpose of this report is to assess the potential land stability and ground movement impacts associated with the Project and to define the environmental management measures necessary to meet the relevant EES evaluation objectives and scoping requirements. Note that the topics of land stability and ground movement are relevant to a number of different evaluation objectives and scoping requirements as outlined in Table 2-1.

1.2 Why understanding land stability and ground movement is important

In the context of this EES report, 'land stability and ground movement' refers to the potential for small or large scale movements that may arise during construction or operation of the Project. This may include localised movements around the pipeline itself, or larger scale and longer-term effects such as slope instability or ongoing erosion.

Local ground movement describes the horizontal or vertical displacements that are commonly associated with trenched or trenchless (i.e. bored) excavations for pipeline installation. The magnitude and extent of these movements and the potential for adverse effects largely depends on the ground conditions, the construction method and the quality of 'workmanship' employed in construction. For this assessment, 'good workmanship[1]' is assumed.

[1] 'Good workmanship' is defined as the standard of workmanship as reasonably expected of a competent contractor in performing the works.

Land stability refers to larger scale ground movements and the formation of unstable soil or rock masses through either human activity (e.g. by excavation) or natural processes (e.g. river erosion). For the Project, slope stability hazards exist where the excavations required for construction of the pipeline have the potential to undermine the natural stability of the adjacent ground, particularly where there are steep slopes or highly erosive soils present.

Potential impacts associated with land instability and ground movement can include damage to built infrastructure, vegetation, natural landforms and farmland and loss of land function. In the extreme, complete failure of a slope can result in significant and permanent changes to the landscape. It is therefore important to mitigate ground movement risks to safety, amenity, cultural or historical heritage, flora and fauna and hydrogeological processes.

It is important to undertake ground movement calculations at the early stages of a project. These calculations may also influence design decisions, such as the final trenchless bore depths or trench wall support requirements. Risks to infrastructure affected by ground movement are primarily assessed by determining the potential strains in the adjacent ground and in the structures themselves.

1.3 Limitations

GHD has prepared this report on the basis of information provided by APA and others who provided information to GHD (including Government authorities), which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

The opinions, conclusions and any recommendations in this report are based on information obtained from, and testing undertaken at or in connection with, specific sample points. Site conditions at other parts of the site may be different from the site conditions found at the specific sample points.

Investigations undertaken in respect of this report are constrained by the particular site conditions, such as the location of buildings, services and vegetation. As a result, not all relevant site features and conditions may have been identified in this report.

Site conditions (including the presence of hazardous substances and/or site contamination) may change after the date of this Report. GHD does not accept responsibility arising from, or in connection with, any change to the site conditions. GHD is also not responsible for updating this report if the site conditions change.

2. EES scoping requirements

2.1 EES evaluation objectives

The scoping requirements for the EES, released by the Minister for Planning, set out the specific environmental matters to be investigated and documented in the Project's EES, and informs the scope of the EES technical studies. The scoping requirements include a set of evaluation objectives. These objectives identify the desired outcomes to be achieved in managing the potential impacts of construction and operating the Project.

Whilst no specific "ground movement" evaluation objectives are referenced in the *Scoping Requirements for Western Outer Ring Main Gas Pipeline Environment Effects Statement - Environment Effects Act 1978* (June 2020), a key environmental risk identified under the Ministers Requirements for the EES is the "….*effects on land stability and erosion related to the construction and operation of the project, including rehabilitation works*".

The evaluation objectives considered broadly relevant to land stability and ground movement and their associated key issues are shown in Table 2-1, as well as the location where these items have been addressed in this report.

Table 2-1 Scoping requirements relevant to Land stability and ground movement

Evaluation objective	Key issue	Section addressed
Maintain the functions and values of groundwater, surface water and floodplain environments and minimise effects on water quality and beneficial uses.	Potential erosion sedimentation and landform stability effects during construction.	Section 7 Risk Assessment Section 8.1 Open trench excavations in unstable ground (Risk GM1) Section 8.4 Pipeline installation in proximity to existing slopes (Risk GM7)
Minimise potential adverse social, economic, amenity and land use effects at local and regional scales.	Potential for Project works and operations to affect business (including farming) operations or other existing or approved land uses through direct impacts of land loss or indirect impacts such as severance of land, erosion/sedimentation, reduced accessibility, or impacts on water supply and use. Relocation or other impacts to existing or proposed infrastructure, including road/rail networks and power infrastructure.	Section 7 Risk Assessment Section 8.2 "Volume loss" arising from trenchless crossings in soil (Risk GM5) Section 8.3 Trenchless pipe installation encountering unexpected poor ground (Risk GM6)

In addition to the key issues in Table 2-1, the following requirement for the Environmental Management Framework (Section 3.7 of the WORM Scoping Requirements Document) also applies to the topic of land stability and ground movement:

The proposed objective, indicators and monitoring requirements for managing landform and slope stability.

Routine inspection and monitoring of the construction easement is considered as part of Section 8.5 and EMM GM4 in Section 9.

2.2 Linkages to other reports

This report relies on or informs the technical assessments as indicated in Table 2-2.

Table 2-2 Linkages to other technical reports

Specialist report	Relevance to this technical study
EES Technical Report A: Biodiversity	The extent of vegetation removal has the potential to exacerbate land stability and erosion effects and is to be considered as part of the impact assessment.
EES Technical Report B: Surface water	The potential for the Project works to cause erosion effects within floodplain's or watercourses is covered in Technical report B: Surface Water. In addition, geomorphological analysis undertaken for this discipline provides key information, which has informed the existing conditions for this land stability and ground movement assessment.
EES Technical Report C: Groundwater	The groundwater report provides estimates of the groundwater table along the Project alignment, enabling an assessment of drawdown effects due to de-watering in construction. This information has been used to inform the assessment of potential consolidation settlement effects (in this report).
EES Technical Report I: Cultural heritage	Heritage listed structures and areas of cultural sensitivity within the proposed construction easement have been considered and assessed in this this technical report.

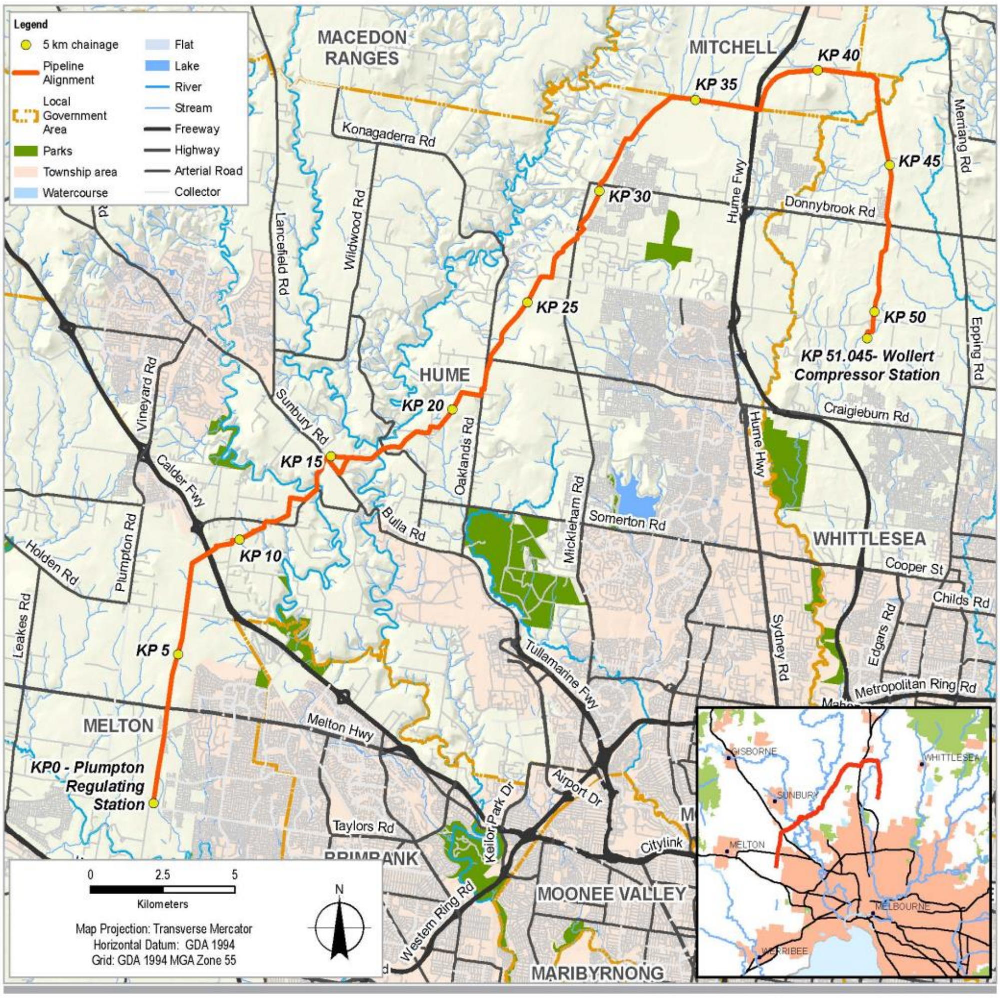
3. Project description

3.1 Project overview

The Project provides a new link between APA's existing Plumpton Regulating Station (approx. 38 kilometres north west of Melbourne's CBD) and Wollert Compressor Station (approx. 26 kilometres north of Melbourne's CBD). The Project includes the following key components:

- **A new pipeline**: The pipeline would be approximately 51 kilometres in length. The pipeline would be within a 15 metre wide permanent easement and be buried for its entire length to a minimum depth of cover of 750 millimetres.
- **Mainline valves**: Three mainline valves (MLV) would be located along the pipeline alignment. The area required for mainline valves would be subdivided and acquired by APA to provide ongoing access for any maintenance or inspection activities from the existing roads. The mainline valves would be spaced at intervals of approximately 15 kilometres, and located at approximately KP 6, KP 22 and KP 35.
- The **Wollert Compressor Station upgrade**: The installation of a new Solar Centaur 50 compressor, an end of line scraper station and a pressure regulating station within the existing APA facility at Wollert.

A schematic illustration of the Project context is shown in Figure 3-1.



Data source: APA, 2020; GHD, 2020'; DELWP, Vicmap, 2020 Created by:kgardner

Figure 3-1 Western Outer Ring Main (WORM) overview

3.2 Construction

Subject to the staging of the works, construction for the entire Project is expected to take approximately nine months. Key construction activities for the Project include:

- Establishing offsite construction sites and construction/laydown areas
- Constructing the pipeline
- Constructing three mainline valves
- Construction of upgrades associated with the Wollert compressor station
- Rehabilitation

3.2.1 Construction laydown and pipeline stockpiling areas

Two temporary construction sites would be established for construction.

One offsite compound for pipeline works nominally 200 metres x 200 metres, include laydown and storage areas. This would be located on a site where the activity is permitted under the relevant Planning Scheme, most likely within an existing industrial area.

The second temporary laydown area and construction offices would be established for the Wollert Compressor Station construction works. The construction offices and site laydown area for the compressor station equipment would be located within the existing compressor site area at Wollert.

3.2.2 Pipeline construction area

The Project would require a construction area for the pipeline, which would typically comprise a 30 metre wide corridor along the pipeline alignment. Most construction activity would be located within this construction area. The activities and facilities within the construction corridor would include access tracks and additional work areas such as vehicle turn around points and additional work spaces for crossings, stockpiling of materials and storage of pipe. Additional work areas up to 50 m x 50 m or 50 m x 100 m (such as for vehicle turn-around points, areas to accommodate HDD) would be required in some locations.

3.2.3 Pipeline construction methodology

The techniques used to construct the underground pipeline would comprise various methods including, open trench construction and trenchless techniques including horizontal directional drilling (HDD), pipe-jacking or horizontal boring. Trenchless construction techniques, such as HDD or shallow horizontal boring, are required where the pipeline is to cross watercourses, major roads or other constraints to avoid construction disturbance within the sensitive area.

For the trenching works, the pipeline construction sequence starts with survey works and continues with site establishment (including laydown area), clearing and grading, pipe stringing, pipe bending, welding and coating, open trench construction, lowering pipe into trench and backfilling, hydrostatic testing, commissioning, and ends with surface rehabilitation.

There would be dedicated access points into the construction corridor with vehicular movements along the Project alignment kept within the construction corridor. Blasting may also be used in various locations to increase efficiency of excavation through hard basalt rock.

3.2.4 Back fill requirements (OMR/ES PAO)

The back fill material(s), construction methodology and quality assurance adopted by APA shall comply with Department of Transport (DoT) minimum requirements.

APA will provide all the necessary documentation associated with its proposed work including, but not limited to, contract specifications and Issued for Construction drawings that would detail how the works will be carried out in accordance with DoT standards and requirements.

These requirements have been incorporated into a draft Coordination Deed to be executed by APA and DoT prior to the commencement of construction. Further, it is recognised there may be additional changes to the Project such as to the pipeline alignment and/or construction methodology that may alter DoT's position or require DoT's approval prior to construction. APA will construct the pipeline within the OMR/E6 PAO in accordance with the Coordination Deed agreed to with DoT. Relevant DoT requirements are also reflected in the Project's management measures (as outlined in the CEMP).

3.2.5 Construction of other facilities

The construction sequence for the Wollert Compressor Station works starts with survey works and continues with site establishment (including laydown area), bulk earthworks, civil works (concrete slab and footings), mechanical works, electrical and instrumentation works, hydrostatic testing, commissioning, and site completion.

Various components of the compressor are assembled offsite. When delivered to site the various components are assembled together in-situ. Cranes are used to lift the compressor into place with all connecting pipework fitted.

3.3 Operation

Following the reinstatement of land as part of the pipeline construction, the land would be generally returned to its previous use. When commissioned, the pipeline would be owned and maintained by APA. The pipeline would be contained within a 15 metre wide permanent easement corridor (within the area that formed the 30 metre construction corridor). Routine corridor inspections would be undertaken in accordance with APA procedures and AS 2885 to monitor the pipeline easement for any operational or maintenance issues.

Excavating or erecting permanent structures, buildings, large trees or shrubs over the underground pipeline would be prohibited in accordance with the *Pipelines Act 2005* and pursuant to easement agreements with landowners.

Maintenance and inspections of the MLVs and the Wollert Compressor Station would also be conducted periodically in accordance with APA procedures. The activities usually include vegetation management, valve and compressor operation and corrective maintenance.

The key operation and maintenance phase activities include:

- Easement maintenance (vegetation control, weed management, erosion and subsidence monitoring)
- Pipeline, MLVs and compressor station maintenance
- Specialist pigging operations
- Cathodic protection surveys for mechanical and electrical preventative and corrective maintenance
- Monitoring and routine inspections and surveillance

3.4 Activities and design considerations relevant to land stability

3.4.1 Trenchless excavations

There are 19 trenchless crossings required to install pipelines underneath roads, railways and creeks as part of the Project. Trenchless methods for the Project include Horizontal Directional Drilling (HDD), pipe-jacking and horizontal boring (thrust-boring). Depending on the trenchless method, the excavated bore diameter is expected to be slightly larger than the pipe diameter to allow for direction changes along the bore alignment and to facilitate the installation of grout after boring where required. Temporary bore support fluid, for example bentonite, is expected to be used during HDD boring.

The thrust bore and pipe-jacking trenchless excavation methods are expected to require launch and reception pits located at each end of the bore, which themselves may be a source of ground movement. This ground movement has been considered in addition to that associated with the bore itself arising from immediate "volume loss" ground movements (in soils), as well as any long term effects associated with seepage towards the tunnel bore.

HDD design details and construction method assumptions are based on preliminary APA design long sections for each HDD crossing. Horizontal boring and pipe-jack design details have been based on APA 'standard' profile drawings.

3.4.2 Trench excavations

Excluding the foreign crossings where trenchless techniques are required, the remainder of the pipeline would be installed via open trench methods. Over the 51 km pipeline, ground conditions encountered during trench excavations are expected to vary between fine and coarse grained soils to variably weathered rock.

Given that the proposed trench excavation depth is relatively shallow, the majority of trench excavations are expected to be within soil rather than rock. The potential to encounter shallow basalt bedrock or basalt 'floaters' should still be considered however. Some localised ground movement may occur due to lateral deflection of the trench sides when excavating through soils.

Construction dewatering would be required for those trench excavations that penetrate below the existing groundwater table. Drawdown of the water table has the potential to cause consolidation of nearby compressible soils and in many cases this can be the main source of ground movement associated with open trench construction.

Another potential source of movement associated with open trench construction is the potential for long term (operational) erosion of the disturbed soils/backfill by groundwater seepage and surface flows. This effect may be exacerbated by the presence of dispersive ("sodic") soils. However it is anticipated that trench barriers (sand bags or cement stabilised fill) would be installed at certain intervals along the pipeline to limit longitudinal groundwater flow.

4. Legislation, policy and guidelines

4.1 Legislation, policy and guidelines

The EES is prepared under the EE Act and will inform assessment of approvals required for the Project. The legislation relevant to the principal approvals required for the Project is:

- Commonwealth approval under the *Environment Protection Biodiversity Conservation Act 1999* (Cth) (EPBC Act). For the component of the Project that is located outside of the Melbourne Strategic Assessment, the Project requires assessment and approval under the EPBC Act, under the assessment bilateral agreement with Victoria made under section 45 of the EPBC Act.

  The MSA program is the Victorian Government's approach to managing the impact of urban development in Melbourne's growth areas on significant vegetation communities, plants and animals. Areas within the approved MSA area occur between approximately KP 0 to KP 3.2, KP 28.16 to KP 28.57, and KP 32 to KP 51. Areas outside of the MSA occur approximately between KP 3.2 to KP 28.1, and KP 28.57 to KP 32.

- Pipeline Licence approval is required under the *Pipelines Act 2005* (Vic) (Pipelines Act)for the Western Outer Ring Main Project. The Pipeline Licence application is exhibited with the EES.

  Section 49 of the Pipelines Act requires that the following matters be considered before granting a licence:

  a) *the potential environmental, social, economic and safety impacts of the proposed pipeline;*

  f) *the assessment of the Environment Effects Minister in relation to the proposed pipeline, if an assessment has been made;*

  g) *any written comments received from the Planning Minister or the relevant responsible authority on the effect of the proposed pipeline on the planning of the area through which it is to pass;*

  h) *any written comments received from the Water Minister and from the relevant Crown Land Minister on the impact of the proposed pipeline.*

  Section 3 of the Pipelines Act states the objectives of the Act including:

  a) *to facilitate the development of pipelines for the benefit of Victoria;*

  e) *to protect the public from environmental, health and safety risks resulting from the construction and operation of pipelines;*

  f) *to ensure that pipelines are constructed and operated in a way that minimises adverse environmental impacts and has regard for the need for sustainable development*

  Section 4 of the Pipelines Act sets out the principles of sustainable development to be given regard in implementing the Act including that *decision-making should be guided by a careful evaluation to avoid serious or irreversible damage to the environment wherever practicable and an assessment of the risk-weighted consequences of various options.*

  Section 54(c) of the Pipelines Act states that conditions on a licence may include conditions concerning the protection of the environment.

- Cultural Heritage Management Plan (CHMP) under the *Aboriginal Heritage Act 2006* (Vic) (AH Act). Two CHMPs are currently in progress for the Project (CHMP 16593 and CHMP 16594).

No specific legislation or policy guidelines apply to the detailed assessment of ground movement or land stability. Instead, specific assessments of structures and assets have been undertaken using established engineering principles and methods that consider the particular construction details and condition of the effected structures or utilities.

Relevant technical guidelines and standards include, but may not be limited to:

- International Erosion Control Association (2008), Best Practice Erosion and Sediment Control, Appendix P – Land-Based Pipeline Construction (IECA, 2008).
- EPA Guidelines 1834 – Civil construction, building and demolition guide (2020).
- AS/NZS 2885.1:2018 Pipelines – Gas and liquid petroleum Design and Construction.
- Burland JB, Standing J and Jardine R, eds. (2001), *Building Response to Tunnelling. Volume 1: Projects and Methods* and *Volume 2: Case studies*, Construction Industry Research and Information Association (CIRIA) – Special Publication 200, UK
- Attewell PB and Taylor RK, eds. (1984), *Ground Movements and their effects on structures*, Surrey University Press
- Preene M, Roberts TOL and Powrie W (2016), *Groundwater control design and practice* (2nd ed.), Construction Industry Research and Information Association UK (CIRIA) – report C750
- Gaba A, Hardy S, Doughty L, Powrie W and Selemetas D (2017), *Guidance on embedded retaining wall design,* Construction Industry Research and Information Association UK (CIRIA) – report C760
- Australian Geomechanics Society (2007), *the Australian Geoguides for Slope Management and Maintenance'*, Journal and News of the Australian Geomechanics Society, Vol. 42
- Code of Practice for the Risk Management of Tunnel Works (ITIG 2012)
- Australian Standard AS 2870 – 2011 Residential slabs and footings
- Australian Standard AS 1726 – Geotechnical Site Investigations
- Australian Standard AS 2566.2 – 2002 Buried Flexible Pipelines
- Department of Transport and Main Roads (2015) *Geotechnical Design Standard – Minimum Requirements*, Form No. F: GEOT 017/10, February 2015
- EPA (2020) Publication 1834 – Environmental Guidelines for Major Construction Sites

Design guidance relating to the risks and methods for microtunnelling is also found within the following publications:

- British Tunnelling Society (2011), Monitoring Underground Construction – a Best Practice Guide, ICE publishing
- Jacking Design Guidelines – Concrete Pipe Association of Australasia (2013)
- Guide to best practice for the installation of pipe jacks and microtunnels. Pipe jacking association (UK), 1995 – under revision
- Australasian Society for trenchless technology – guidelines for horizontal directional drilling, pipe bursting, microtunnelling and pipe jacking. ASTT, September 2009
- Australasian Society for trenchless technology – Specification for horizontal directional drilling. ASTT, September 2009
- Horizontal Directional Drilling (HDD) Good Practice Guidelines – 4th Edition, 2017. North American Society for Trenchless Technology (NASTT)

5. Method of assessment

5.1 Overview of approach

A risk based approach was applied to prioritise the key issues for assessment and inform measures to avoid, minimise and offset potential effects. Figure 5-1 shows an overview of the assessment method.

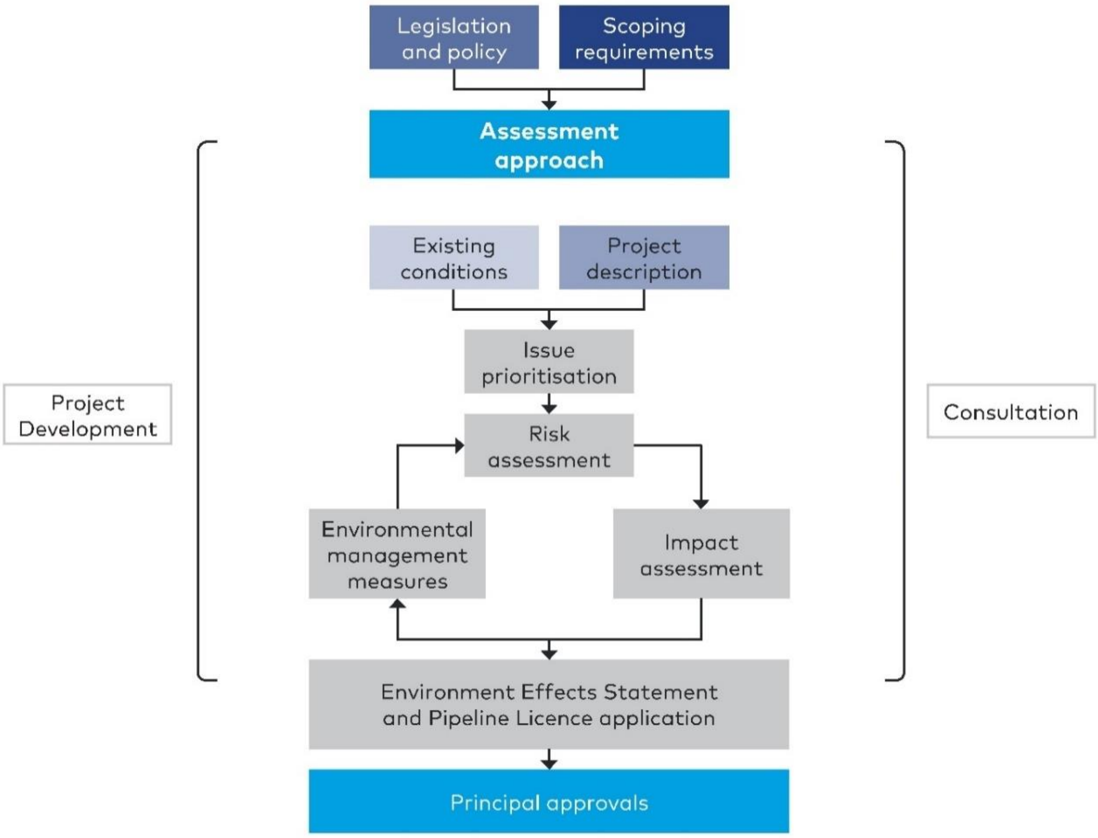


Figure 5-1 Overview of assessment method

Table 5-1 below includes the impact assessment methodology steps as outlined in Section 4 of the *Scoping Requirements for Western Outer Ring Main Gas Pipeline Environment Effects Statement - Environment Effects Act 1978* (June 2020) as well as where these steps are addressed in the report.

Table 5-1 Impact assessment structure (scoping requirements, 2020)

Step	Section addressed
Identify key issues or risks	Section 1.1 and Section 6
Characterise the existing environment	Section 6
Identify the potential effects (pre-mitigation)	Section 7 and Section 8
Present design and mitigation measures in accordance with the mitigation hierarchy	Section 8 and Section 9
Assess the likely residual effects (assuming implementation of design and mitigation measures)	Section 7 and Section 8
Propose performance criteria and management	Section 1

5.2 Study area

The construction method and regional geology have been used to divide the alignment into 45 “Reaches”, as shown in Figure 5-2. The Reaches were defined between chainage (KP) reference points to delineate changes in geology or construction methodology.

In regards to the lateral extent of the Project, the construction corridor has been used as the study area boundary. Given that land stability and ground movement effects are considered to be fairly localised to the immediate area surrounding the pipeline, this boundary is considered to capture any ground movement or land stability risks that may arise from pipeline construction or operation activities.

5.3 Overview of land stability and ground movement

Local ground movement induced by ground excavation is a common phenomenon seen in all construction projects. Ground movements arise from elastic and plastic deformations associated with stress relaxation caused by the removal of soil or rock. In general, the magnitude and extent of ground movement depends on the strength and stiffness of the ground, depth of excavation, construction methodology and degree of support.

These ground movements may result in adverse social, economic, amenity and land use effects. Significant land disturbance associated with ground movements or land instability may impact on native vegetation or other flora and fauna, or have adverse effects on waterways and floodplain environments.

For the assessment of local ground movement effects for the Project, three sources of movement have been considered to define the following key issues:

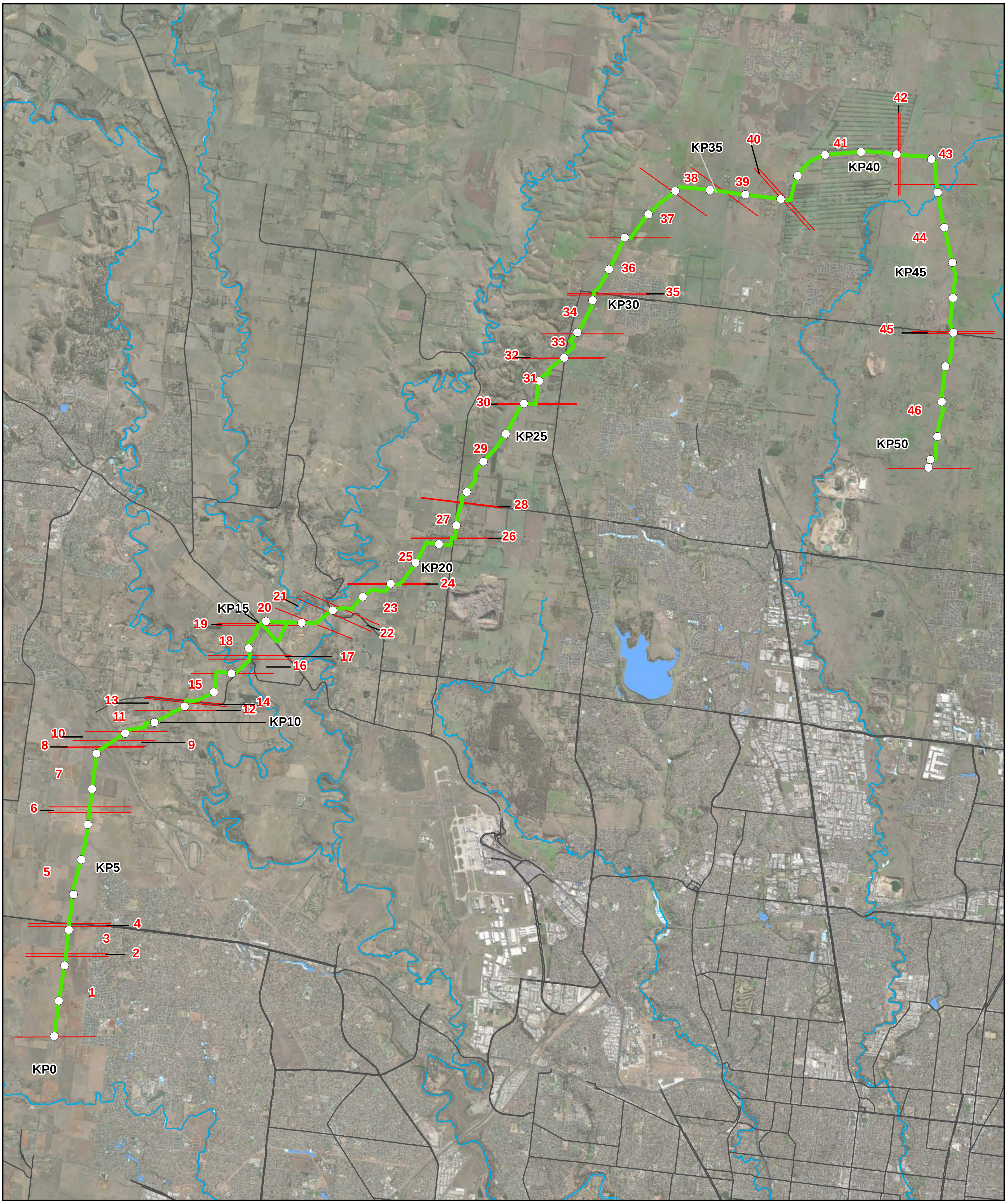
- **Trenchless crossings:** Inward ground movements (“volume loss”) due to ground relaxation as a result of boring.
- **Open trench excavations:** Horizontal and vertical movements that occur adjacent to the open trench excavations.
- **Construction drawdown:** Consolidation of compressible soil due to groundwater drawdown caused by construction dewatering required for excavation below the water table.

Other sources of movement such as liquefaction, vibration-induced compaction, thermal effects or ‘reactive/expansive’ soils that result in seasonal ground movement are considered to present low risk to the overall Project and therefore not considered as part of the assessment.

Land stability effects may arise as a result of the following key issues:

- **Slope stability:** down slope soil mass movement caused by trench excavation. Can be immediate or long term.
- **Trench stability:** short-term failure of an unstable soil mass into the trench excavation causing local disturbance.
- **Erosion:** Longer term loss of soil structure and stability due to surface and/or subsurface erosion due to “dispersive” or “suffosive” failure mechanisms in soil. For this report, erosion effects are considered insofar as they have the potential to exacerbate the other risks identified.

Land stability considerations due to temporary construction effects, such as from construction machinery, are not considered as part of this assessment.



Legend

○ WORM_Rev7_Pipeline_KPs

Reach Boundary

WORM_Rev7_Pipeline_Ln

Paper Size A3

0 1,500 3,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

APA
Western Outer Ring Main Gas Project

Study Area
Project Reaches

Job Number	12529997
Revision	7
Date	10 Dec 2020

Figure 5-2

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5.4 Existing conditions

An existing conditions assessment was undertaken to establish a baseline for the ground and groundwater conditions for the Project alignment and to identify any ground movement hazards inherent in the existing built environment and natural landscape.

Preliminary information on the existing conditions along the pipeline alignment is available in the form of a desktop study for APA by Alluvium: Assessment Report - Western Outer Ring Main – Surface Water and Groundwater desktop assessment, August 2019; and a Biosis (Golder Associates) – Report - Geological and Soils Desktop Study -Western Outer Ring Main Project, August 2019. These documents have been referred to for this assessment.

Supplementary information has been provided by APA comprising:

- Factual and interpretive geotechnical data included in Pipeline ROW, Water Crossing and HDD Crossing Geotechnical Report - 5044/P/37.4 (Construction Sciences, 2020)
- Historical geotechnical investigation report: Merrifield Central Channel Soil Stabilisation (Project N. 511.1, Van de Graaf & Associates, 2018)
- Preliminary Geotechnical, Environmental and Hydrogeological Site Investigation at 555 Donnybrook Road (Tonkin & Taylor, 2017)
- Merrifield Residential Development Preliminary Geotechnical Information (Golder Associates, 2016)
- Recent groundwater and geotechnical data obtained from hydrogeological investigations completed by GHD (2020)
- Draft long section drawings for trenchless crossings at Melton Highway, Bendigo Rail Line Reserve, Calder Freeway, Sunbury Road, Deep Creek, Hume Highway and North Eastern Rail Line Reserve (18035-DWG-L-0001.01 to 18035-DWG-L-0001.08.01) completed by Bamser and provided by APA. Note that the APA Deep Creek long section drawing (18035-DWG-L-0006.01 Rev.03) includes interpolations of ground conditions based on seismic survey data.
- ‘Standard’ general arrangement drawings provided by APA on 28/05/2020
- Utility survey data for the Revision 7 alignment provided by APA (including Dial-Before-You-Dig and Yarra Valley Water Asset database information), containing information on each utility crossing. Note that utility information at some crossings is inferred only, and actual utilities and details may vary
- Construction method information (APA PowerPoint file)

Other information referenced by GHD include:

- In-house and published geotechnical information including the results of the groundwater monitoring program undertaken for the EES groundwater assessment (Refer EES Technical Report B: Water)
- A report entitled “Fluvial geomorphology of the Jacksons Creek, Deep Creek and Merri Creek crossings” prepared by The University of Melbourne for GHD. The complete report can be found in EES Technical Report B - Surface Water specialists report.
- Regional geology maps published online by Geoscience Australia, GeoVic – Earth Resources (Victoria)
- Victorian Resources Online – Sites of Geological and Geomorphological Significance http://vro.agriculture.vic.gov.au/dpi/vro/portregn.nsf/pages/port_lf_sig_sites_melbourne
- Victorian Resources Online – The Victorian Map of Sodic Soils (VRO, 2014)

- The Victorian Heritage Database and Planning Schemes Online were consulted to identify relevant heritage places and their relevant listing under the Victorian Heritage Register (VHR), the Victorian Heritage Inventory (VHI) or a council Heritage Overlay (HO)
- Landfill data was obtained from National Waste Management Database, EPA Victoria Publication 1270 (EPA Victoria, 2009) and council reports
- Current land use data was obtained from Planning Maps online (Victorian Government, Department of Environment, Land, Water and Planning)

Based on the information gathered from the above sources, specific existing conditions were documented for each Project Reach defined for this assessment to gain an understanding of the risks that may be present at each location.

5.5 Risk assessment method

A risk assessment for the Project was carried out using an approach that is consistent with Australian/New Zealand Standard AS/NZS ISO 31000:2018 Risk Management Process.

This risk assessment was used to identify the issues for assessment and apply a structured approach to the level of assessment and analysis undertaken of potential environmental effects within each technical study. Applying the risk framework facilitated an approach for the EES to identify and then investigate issues with a focus proportionate to the risk, and to consider management measures focused on reducing identified risks.

The risk assessment method included:

- Defining the context for the risk assessment based on the existing assets, values and uses relevant to each technical area, and the proposed Project activities which interact with those existing conditions
- Identifying the risk pathways for the Project based on a specific cause and effect
- Identifying standard management/mitigation measures (including those in guidelines and standards) and whether additional mitigation measures may be required
- Analysing the consequence and likelihood of the identified hazard (risk pathway) based on a consequence guide developed for each technical area and a likelihood guide
- Defining the risk level based on the risk matrix

The risk assessment provided a framework for the impact assessment, which included a stronger focus on risks with a medium or higher rating and/or where additional management/mitigation measures may be required. The identification, analysis and evaluation of risks was conducted within each technical area and across technical areas where there was input or connection across disciplines.

The consequences of a ground movement or land stability hazard occurring were assigned using consequence categories from insignificant to severe developed for land stability and ground movement based on the existing conditions and values in the study area. The consequence levels and descriptors are provided in Appendix A. A likelihood rating for each identified risk was assigned ranging from *‘almost certain’* where the event is expected to occ*ur to ‘rare’, where the* event may occur only in exceptional circumstances. The likelihood levels and descriptors are provided in Appendix A.

The risk matrix used to define each risk level is also provided in Appendix A.

The risk ratings were revisited during the impact assessment where additional environmental management measures were applied to identify the residual impacts and risks.

5.6 Impact assessment method

5.6.1 Ground movement risk assessment criteria

The following ground movement and damage thresholds are used to classify the consequence of damage on the affected assets based on the estimated ground movements. These are based on the standard thresholds used for Preliminary (Rankin, 1988) and Second Stage (Burland et al., 2001) assessments, modified slightly to find equivalence with the WORM EES qualitative descriptors. Note that methods for detailed evaluation are highly varied, and individual risk criteria would be developed in the scenario where a detailed evaluation is required.

Table 5-2 Preliminary ground movement assessment risk classification (after Rankin, 1988)

Preliminary consequence rating	Maximum slope (V:H)	Maximum settlement (mm)	Description of risk
Insignificant	<1/500	<10	Superficial damage unlikely
Minor to severe, as determined in second stage (below)	>1/500	>10	Determined in second stage (below)

Table 5-3 Second Stage ground movement assessment damage risk classifications applied to buildings and utilities (modified after Burland et al, 2001)

Second stage consequence rating	EES qualitative descriptor for damage consequence[1]	Limiting tensile strain, ε_{lim} (for structures / buildings)	% of allowable strain limit, ε / ε_{allow} (for utilities)[2]
Minor	Ground movements cause a *slight* to *very slight* risk of damage to asset. Strains felt by asset may result in some non-structural superficial or minor aesthetic damage to surface structures.	0.05 – 0.15	<50% of ε_{allow}
Moderate	Ground movements cause a *moderate* risk of damage to asset. Possible structural damage to surface structures (requiring local repairs), and possible rupture of rigid/inflexible buried utilities.	0.15 – 0.3	50 - 100% of ε_{allow}
Major	Ground movements cause a *high* risk of damage to asset. Expected structural damage to surface structures (requiring extensive repairs), possible damage to flexible utilities.	>0.3	>100% of ε_{allow}

Second stage consequence rating	EES qualitative descriptor for damage consequence[1]	Limiting tensile strain, ε_{lim} (for structures / buildings)	% of allowable strain limit, ε / ε_{allow} (for utilities)[2]
Severe	Ground movements cause a *high* risk of damage to a significant asset. Expected structural damage to surface structures (requiring partial rebuilding and shoring). Loss of serviceability of flexible utilities.	>0.3 for significant structure	>100% of ε_{allow} for significant utility

[1] Based on the damage classification descriptions as in Burland et al (2001) and Mair, Taylor & Burland (1996)

[2] Utility damage risk criteria has been interpreted by GHD for the purposes of the EES assessment and is not included in Burland et al. (2001).

5.6.2 Land stability risk assessment criteria

The approach to the risk evaluation for land stability will focus on the likelihood of failure. The factor of safety of the slope or trench can be translated to a probability of failure using the method prescribed by Silva et al (2008). Probabilities of failure are then assigned equivalent EES risk likelihood ratings, referring to the guidelines outlined in the Australian Geoguide for Slope Management and Maintenance (AGS, 2007). Table 5-4 below shows the defined criteria.

Table 5-4 Slope and trench stability risk assessment categories

Likelihood rating	EES qualitative descriptor for likelihood	Annual probability of failure, % (Silva et al. 2008)	Equivalent factor of safety (FoS)
Rare	The event is conceivable and may occur only in exceptional circumstances	0.001	>2
Remote	The event could occur but is not anticipated and may occur if certain abnormal circumstances prevail	0.01	1.75 < FoS ≤ 2
Unlikely	The event is unlikely but could occur if certain circumstances prevail	0.1	1.5 < FoS ≤ 1.75
Likely	The event will probably occur in most circumstances	1	1.2 < FoS ≤1.5
Almost certain	The event is expected to occur in most circumstances or is planned to occur	10	< 1.2

5.6.3 Ground movement impact assessment – operation

Operation of the pipeline will not result in more than negligible movements (over and above those experienced during construction). Possible ground movements may arise due to long term consolidation of compressible soils or from pore water pressure dissipation in cohesive materials. If this is considered as a medium or higher risk, the consequence of damage to any sensitive receptors would be assessed against the same criteria as in Table 5-2 and Table 5-3 above.

5.6.4 Land stability impact assessment – operation

Activities during pipeline operation are not expected to have a significant effect on slope stability. Disturbance at the toe of a slope could initiate movements even when the trench is backfilled. Pathways for disturbance include soil creep or ongoing dispersion in disturbed ground due to seepage. If this is considered as a medium or higher risk, the probability of slope failure can be assessed against the same criteria as in Table 5-4 above where sufficient information is available.

5.7 Cumulative impacts from other projects

The following proposed future projects have been considered for cumulative ground movement or land stability effects:

- Outer Metropolitan Ring Transport Corridor Project (E6)
- Sunbury Road Upgrade
- Bald-Hill, Yan Yean Pipeline
- AusNet / Mondo's Western Victoria Transmission (WVTN) project

5.8 Rationale

The staged assessment of settlement damage risk (after Burland et al., 1995, Mair et al., 1996 and Rankin, 1988) has been adopted as it is a well-established approach used on major infrastructure projects in Australia and the United Kingdom. The 'Burland method' is well suited to the 'risk-based' approach required for an EES and provides a rigorous and transparent means of assessment.

Limit equilibrium analysis to assess slope stability is the standard and industry accepted approach for ultimate limit state failure mechanisms.

5.9 Limitations, uncertainties and assumptions

The following limitations apply to the information in this report:

- The desktop study is based on a snapshot of conditions that existed at the time of the assessment. Any variations to existing conditions that have occurred after completion of this assessment have not been considered.
- The environmental effects of blasting are not considered for this assessment and are instead considered as part of EES Technical Report F – Noise and Vibration
- The pipeline has been designed by APA based on desk top studies and intrusive geotechnical investigations undertaken between August 2019 and June 2020 for the reference design. Further groundwater investigations were also undertaken by GHD between August and September 2020. GHD has largely based our ground movement and land stability work on these data sources, supplemented by additional desk top work undertaken to establish the existing conditions for our assessment.
- The pipeline alignment used for the assessment was the Revision 7 alignment
- Information obtained from EES Technical Report C - Groundwater is constrained by the limitations, uncertainties and assumptions contained within that report
- The ground movement assessment was completed based largely on information obtained from the geotechnical investigations completed to date (both historical, and more recently, by Construction Science). That information is therefore subject to the limitations, uncertainties and assumptions made for those investigations.

- The recent geotechnical investigations completed by Construction Sciences were not available at the time of writing this report and have therefore not been considered in the assessment. This includes investigations at the following locations: Mt. Ridley Road (BH50), Parkland Crescent (BH51 to BH 54), Calder Freeway (BH55), Hume Freeway (BH56), Sunbury Road (BH57 and BH58) and in the vicinity of Oaklands Road (BH59).
- Some of the trenchless crossings had insufficient geotechnical information available to complete the assessment at the time of writing this report meaning that an impact assessment could not be completed at these locations. These areas will therefore be subject to a generalised risk mitigation approach that requires further assessment of the risk when additional information is obtained.
- At the time of completing the EES assessment, a site walkover was not able to be completed due to access limitations surrounding COVID-19. The assessment instead relied on desktop information and digital data sources, including a drone survey completed by AUAV (2020). These sources are considered to provide sufficient information to assess the land stability and ground movement risks identified.
- Details on utilities that transect the Project alignment were obtained from available survey data, obtained by APA and provided to GHD on 8/12/2020. Where data gaps existed in the survey data, DBYD information as well as online asset database’s (such as the Yarra Valley Water Asset Map) were consulted. Note that some of the utility data is inferred only (ie. where GPR was used, or where surveys have not yet been completed at the time of writing this report), and actual details may vary.
- Identification of dispersive soils was done through Emerson and Double Hydrometer testing. Both of these tests have limitations regarding their accuracy, however, are considered to provide a preliminary indication of dispersive behaviour at a higher level. To further define dispersive risk, it is considered that further testing would be required.
- Interpolation of ground conditions at Deep Creek based on seismic survey data included in APA drawing 18035-DWG-L-0006.01 Rev.03 are relied on for this assessment and is assumed to be accurate

5.10 Stakeholder engagement

Whilst stakeholder and community engagement was undertaken during the preparation of the EES, no community engagement was specifically required to inform this assessment.

EES Attachment III *Community and Stakeholder Consultation Report* provides details of the consultation activities undertaken for the Project more broadly and outcomes from those activities.

6. Existing conditions

6.1 Geology and geomorphology

The Project area lies within the easternmost Western Plains geomorphic province of Victoria. The area is characterised by multiple Quaternary basalt volcanic eruption points that protrude above extensive lava plains produced by repeated volcanic episodes over long time periods. Within this predominantly volcanic setting, ranges of low hills protrude above the basalt plains, composed of pre-volcanic basement rocks and Neogene cover units.

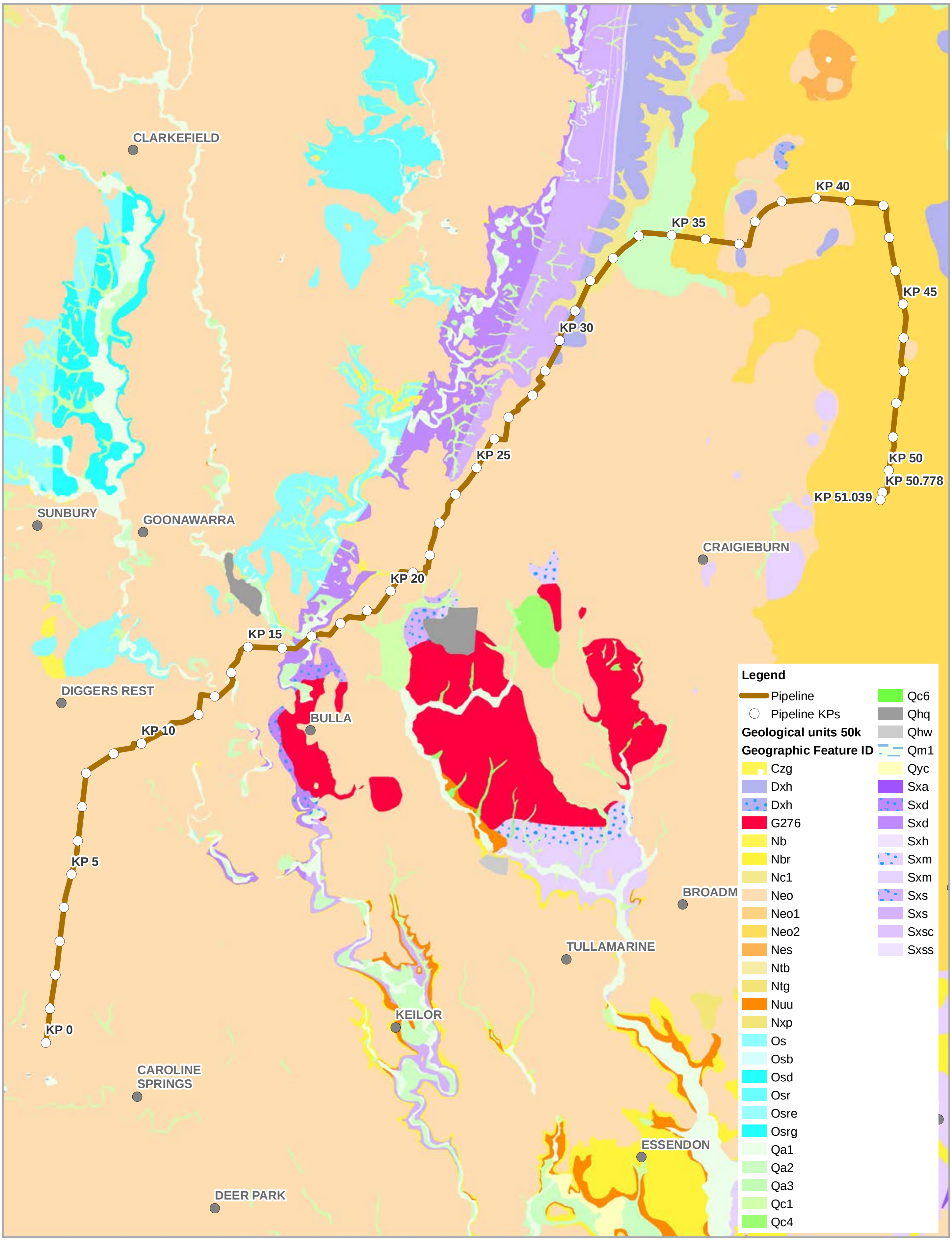
The topography of the study area is generally flat to gently undulating, with the exception of significant low elevations at Jacksons Creek and Deep Creek where the valley sides are steep compared to the surrounding plains.

Much of the western plains has poor drainage, however the Maribyrnong catchment, which includes the major tributaries of Deep Creek and Jacksons Creek, contains a deeply incised network of rivers and streams covering 1406 km^2 west of Melbourne. Within these incised channels, alluvial terraces (such as the Keilor terraces) have yielded indigenous cultural and extinct faunal remains that have been dated to the late Pleistocene.

The regional geology in the area is dominated by the Newer Volcanics basaltic flows and stony rises. Alluvium is present in the Jacksons Creek and Deep Creek watercourses. Outcrops of the Silurian Deep Creek Siltstone and the Neogene Brighton Group are also present within the vicinity of Deep Creek. The proposed alignment also transverses the Siluro-Devonian Humevale Siltstone, Holocene colluvium and Quaternary alluvial terraces within the suburb of Mickleham. A summary of the geological units is provided in Table 6-1. An extract from GeoVic Seamless Geology digital map data base is also shown in Figure 6-1 below.

The Newer Volcanics are characterised by multiple lava flows typically ranging in thickness from approximately 7 m to 10 m each, although significantly thinner and thicker flows are also found. The Newer Volcanics are often characterized by the following features, from youngest to oldest:

- Scoriaceous and fractured flows (Second Phase) – also known as ‘stony rise’ basalts. These are typically much younger than the First Phase basalts, and less weathered. They are also typically emplaced directly upon a former weathering horizon (palaeosol), which can be up to few metres thick. Below this weathered horizon, there is often a highly scoriaceous and permeable interval, formed by lava de-gassing.
- Low to moderate permeability sheet flows (Upper First Phase), which are typically massive and relatively unfractured. Depending on the number of flows, there may also be a number of former weathered interflow horizons present, also referred to as ‘palaeosols’. These often consist of plastic clays and represent the weathered tops of the underlying basalt flows but may also contain alluvial deposits.
- Highly fractured, high permeability basal flows (Lower First Phase), which typically do not outcrop but rather are emplaced in pre-existing topographic depressions (e.g. former rivers, creeks and lakes)



Paper Size ISO A4

0 1,800 3,600

Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA2020
Grid: GDA2020 MGA Zone 55

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Australian Pipeline Limited
Western Outer Ring Main Gas Project

Seamless Geological
Data Coverage 50K

Project No. 12529997
Revision No. A
Date 12/08/2020

FIGURE 6.1

Data source: DELWP, VicMap, 2020; Geoscience australia 2012, GHD, 2020; Biosis, 2020. . Created by: sacevedo

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Table 6-1 Summary of geological units across Project area

Geological Unit (Reference on Figure 6-1)	Description
Quaternary Alluvium (Qa1)	Gravel, sand, silt: variably sorted and rounded; generally unconsolidated; includes deposits of low terraces; alluvial floodplain deposits.
Quaternary Alluvial terrace (Qa2)	Gravel, sand, silt: variably sorted and rounded, generally unconsolidated; dissected to form terraces higher than Qa1, alluvial floodplain deposits.
Quaternary Incised colluvium (Nc1)	Silt, sand, gravel: generally poorly sorted and poorly rounded except within channels cut into colluvium material; dissected to variable degrees.
Neogene to Quaternary Newer Volcanic Group (Neo) – First Phase	Basaltic flows: minor scoria and ash, sheet lava flows and valley flows and intercalated gravel, sand, clay.
Neogene to Quaternary Newer Volcanic Group (Neo) – stony rises	Basalt: youngest flows with little weathering or soil development (stony rises and hummocky lava flows).
Neogene Brighton Group (Nb)	Gravel, sand, silt: variably calcareous to ferruginous sandstones and coquinas; marine to non-marine.
Devonian Humevale Siltstone (Dxh)	Siltstone: brown, laminated; minor very fine- to fine grained sandstone laminae and thin beds towards the top of the formation.
Silurian Deep Creek Siltstone (Sxd)	Siltstone and sandstone: siltstone: dark grey-green, thin to thick-bedded, mostly strongly bioturbated; sandstone: regularly interbedded with siltstone; thin to very thin, commonly with ripple marks; rare conglomerate.
Source: GeoVic Explore Victoria Online – Earth Resources , Department of Jobs, Precincts and Regions, Victoria, Australia	

6.2 Hydrogeology

The depth to water table varies considerably across the study area but is considered to be generally greater than 5 m below ground surface for much of the alignment. Recent hydrogeological investigations (GHD, 2020) indicate that the following locations may have water tables of less than 5 metres depth. Groundwater drawdown may therefore be required at these locations to enable trench excavations.

- Bendigo Railway and the Tame St Drain (Reach 8 and Reach 9)
- Jacksons Creek (Reach 17)
- Deep Creek (Reach 21)
- Donovans Lane and the North East Rail reserve (Reach 42)
- Merri Creek (Reach 44)
- Donnybrook Rd East (Reach 45)
- North of the Wollert Compressor Station (Reach 46)

The Alluvium report (2019) provides the following key observations regarding the hydrogeology of the Project area:

- The pipeline crosses three drainage basins that discharge to Port Phillip Bay: the Werribee Basin (tributaries of Kororoit Creek); the Maribyrnong Basin (Jacksons and Deep Creeks); and the Yarra Basin (Merri Creek)
- The permeability[2] of the underlying Newer Volcanics basalt is highly variable, ranging from 0.001 m/d to 10 m/d due to flow in the fracture network. Where present, the residual clay soils, have a permeability ranging from 10^{-6} m/d to 10^{-2} m/d
- In some areas the groundwater in the Newer Volcanic aquifers discharge to low elevation points in streams and gullies. Groundwater in the Silurian and Devonian basement rocks and the Quaternary alluvium is also likely be discharging to streams and other surface water expressions in some areas.
- While regional water table elevation mapping indicates that the water table depth is 5 m or greater in some areas, in other areas the water table is considered to be at least equal to the stream elevation and may be shallower than 2 m
- The pipeline traverses Merri Creek catchment in the north. The area was previously a swamp (Inverloch swamp), but this and similar areas were drained during agricultural development of the area after European settlement. In these areas, the water table may be at, or near ground surface.
- Groundwater in these aquifers is brackish, ranging from 2000 mg/L to 10,000 mg/L total dissolved solids. Groundwater extraction from these aquifers occurs mainly for stock and domestic use

As reported in the EES Technical Report C: Groundwater, a groundwater monitoring program has been undertaken by GHD to confirm the hydrogeology of the Project area. The data collected from these investigations has been considered in this report.

6.3 Dispersive (sodic) soils

As a consequence of the presence of saline water in the soils, there is the potential for dispersive behaviour ("sodicity") in fine grained residual soils. The more abundant cations dissolved in the pore water in these soils means that the exchangeable sodium amounts are higher, and thus the risk of dispersivity of the soil when exposed to fresh water may be greater. An example of eroded dispersive soils within the Project area is shown in Figure 6-2 below.

A physical test for dispersivity potential is the Australian Standard Emerson "crumb" test. (AS 1289.3.8.1-2006 - Methods of testing soils for engineering purposes Soil classification tests - Dispersion - Determination of Emerson class number of a soil).

Soils that are classified as class 1, 2 of 3 in this test have the potential for dispersive behaviour in the field (IECA, 2015). Emerson tests undertaken for the Construction Sciences Geotechnical Investigation (2020) yielded Emerson Class Numbers consistently around Class 2, with several instances of Class 1 for residual basaltic soils. A small number of tests were conducted on alluvial soils, such as those near Jacksons Creek and within Kalkallo Basin, also typically reporting Emerson Class values of 1 to 3.

[2] Units of m/day is approx. equivalent to 10^{-5} m/second.

Figure 6-2 Example of eroded dispersive soils near the town of Beveridge (GHD, 2020)

There were a few instances of higher (less dispersive) Emerson Class numbers reported for the sandy soils overlying sedimentary bedrock in West Mickleham (~KP29 to ~KP32) as well as the alluvium near Deep Creek (KP16.7). However, other nearby tests within these same areas indicated that dispersive potential still exits.

Double hydrometer tests were also undertaken for the Construction Sciences Geotechnical Investigation (2020) on the same soil samples that underwent Emerson tests, obtaining percent dispersion values for the soil. The results of the double hydrometer tests generally confirmed the results of the Emerson tests, the exception being in Kalkallo Basin where low percent dispersion values were obtained from the double hydrometers and low Emerson Class numbers (ie. high dispersion) were obtained from the Emerson testing. In these instances, the Emerson test results are considered to take precedent over the percent dispersion (hydrometer) results.

Given the available testing results, the presence of dispersive soils is known at the locations listed in Table 6-2. Note that the presence of dispersive soils is still considered possible for the remainder of the Project area where testing has not yet been undertaken, particularly for areas containing residual basaltic soils. By illustration, the Victorian Soils Map (Victorian Resources Online, 2014) indicates that the Project area lies within an area described as containing 'dense, dispersive subsoils' on a regional scale. It is considered that further sampling or testing along the alignment would be required to identify other areas containing dispersive soils.

Table 6-2 Reaches where dispersive soils have been identified based on available test data

Location	Reach and chainage (KP)
Jacksons Creek and surrounds	Reach 17 (KP 13.68 to KP 13.79)
Deep Creek and surrounds	Reach 21 and 22 (KP 16.32 to KP 17.23)
Donnybrook Road (West) and surrounds	Reach 34 to Reach 36 (KP 28.94 to KP 31.98)
Kalkallo Basin	Reach 38 (KP 33.94 to KP 35.42)
Merri Creek and surrounds	Reach 44 (KP 42.64 to KP 46.86)

It is advisable that the dispersion testing completed to date be supplemented by further testing and analysis as the design proceeds to identify additional areas where dispersive soils are present and develop appropriate mitigation measures.

6.4 Sites of geomorphological or geological significance (SGGS)

6.4.1 General

Sites of Geological or Geomorphological Significance (SGGS) are identified on the basis that they either represent a specific characteristic of the region, or that they include an outstanding, rare, or possibly unique geological or geomorphological feature (Agriculture Victoria, 2018). Sites are generally selected as commissioned by the Victorian Environmental Assessment Council in accordance with the Victorian Environmental Assessment Council Act 2001. A Project specific investigation on this matter has not been requested under the Victorian Environmental Assessment Council Act 2001, however existing SGGS of relevance to the Project can be identified from various publications (Rosengren, 1986).

The following sections provide a brief description of each site of “Regional Significance”.

6.4.2 Merri Creek Channel (VRO site 35)

An open trench is proposed for the crossing of Merri Creek near KP42.8. A SGGS is located on private land (“Merri Creek Park”) in the Shire of Whittlesea (Site 35, Victorian Resources Online - VRO, 2020). The Merri Creek channel is orientated northeast to southwest, and north to south, meandering across a relatively flat flood plain. The active river channel and flood plain is between 50 and 100 m wide.

The Merri Creek channel is incised between 5 m and 8 m below surface level, and includes a variety of geomorphological features including small rapids alternating with pools, large joint-bounded lava blocks, low rocky cliffs, rock terraces and alluvial terraces. This section of the Merri Creek is considered to be of regional significance because the landscape and vegetation is relatively ‘untouched’ since pre-European settlement.

This SGGS may be affected by erosion effects induced by the trench excavation as discussed in EES Technical Report B: Water though it not considered to be at risk of ground movement or land stability effects.

6.4.3 Hayes Hill Eruption Point (VRO site 38)

The Hayes Hill eruption point is situated just east of the proposed open trench north of Donnybrook Road near KP46. Hayes Hill is a small scoria dome located on private land in the Shire of Whittlesea, approximately 700 m north of 1140 Donnybrook Road, 3 km east of Donnybrook. The dome is relatively symmetrical in shape with the vent or crest reaching an elevation of 282 m Australian Height Datum (AHD) at its highest point. The immediate surrounding area is relatively flat, gently sloping down to the south (Donnybrook Rd 240 m AHD).

Hayes Hill comprises superficial Newer Volcanic (Neo) basalt deposited in successive flows between the Miocene and Holocene epochs. Near the dome vent, the original basalt flow structures are well preserved. Although not a major eruption centre Hayes Hill is a significant site as the likely source of lava that determined long-term landform development along the Merri and Darebin Creeks and the Yarra River. The site is considered to be of Regional significance (Site 38, VRO, 2020).

The pipeline is to be constructed through the base of the shallow slope associated with the hill, however the pipeline alignment is approximately 250 m west of the top of the hill. This SGGS is not considered to be at significant risk of ground movement or land stability effects.

6.4.4 Jacksons Creek High Level Cut-off (VRO site Ko6)

Approximately 1 km North-East of the Jacksons Creek crossing at KP13.7, is the Jacksons Creek high level cut-off SGGS. At the site, the meandering Jacksons Creek is orientated northwest to south east with topography varying from 130 m AHD along the creek edge to between 160 and 200 m AHD at the river bank crest.

This site of significance comprises a unique bowl shaped feature at approximately 160 m AHD elevation, 30 m above channel level and comprises a remnant channel of the Jacksons Creek. At some point the Jacksons Creek channel was blocked by flooding, build-up of sediment, or landslip, forcing the river in a new direction. This site is considered to be of regional importance as it presents the best example of a high level cut-off in the area. Given the distance from the creek crossing, this SGGS is not expected to be affected by the pipeline.

6.4.5 Deep Creek Outcrop (VRO Site Ko5)

Approximately 200 m north of the pipeline crossing, the confluence of Deep Creek and Emu Creek is considered to be a site of special geological and geomorphological significance (site Ko5, VRO, 2020). The incision of the creeks into the Newer Volcanic Basalt has exposed the underlying Bullengarook Gravel resting on the Silurian sedimentary bedrock. The SGGS itself is approximately 200 m north of the trenchless crossing, and therefore not expected to be affected by the pipeline construction or operation activities.

6.4.6 Bald Hill Eruption Cone (VRO site 36)

Bald Hill is a composite volcanic cone located on private land in the Shire of Whittlesea, approximately 1.8 km east of 140 Hume Freeway, 3 km northeast of Kalkallo township. The cone is relatively symmetrical in shape with a pronounced vent at 357 m AHD, some 100 m above the flood plain of Merri Creek. The cone was emplaced between the Miocene and Holocene epochs (Geological Survey of Victoria, 1982) with the gently sloping topography to the south and west indicating the direction of the most recent lava flow.

The pipeline alignment follows the toe of the Bald Hill cone between approximately chainage KP39 to KP41, and at its closest point is approximately 650 m from the eruption vent. Construction of the pipeline and associated ground movement is not expected to be detrimental to the site geology and geomorphology. The site is considered to be of regional significance (Bald Hill (Kalkallo), 2018).

6.5 Existing conditions reach summary

Descriptions of exiting conditions along with associated key issues are provided in Table 6-3 below as well as Figures 6-3 through to 6-5.

Table 6-3 Reach summary

Reach ID	KP	Reach description
1	0 to 2.25	**Construction method:** Trench within agricultural land. **Description:** Ground conditions expected to comprise residual Newer Volcanics Basalt soils. Possible encounter of shallow basalt bedrock. Within APA's existing Sunbury Pipeline easement. Some ongoing urban development and minor utilities present near to Beatty's Road. **Key issues:** Trench instability, trench ground movement.
2	2.25 to 2.33	**Construction method:** Horizontal boring underneath Beatty's Road. **Description:** Two-lane rural road undergoing development. No recent geotechnical information, though historical geotechnical investigations (Tonkin & Taylor, 2017) indicate potentially shallow Newer Volcanics bedrock at around 1.1 m below ground surface. However, lack of targeted information classifies this crossing as having effectively 'unknown' ground conditions. Some existing and planned minor utilities running along the road. **Key issues:** Ground movement from boring.
3	2.33 to 3.10	**Construction method:** Trench within agricultural land. **Description:** Ground conditions expected to comprise residual Newer Volcanics Basalt soils. Possible encounter of shallow basalt bedrock. Within APA's existing Sunbury Pipeline easement. Some ongoing urban development and planned minor utilities. **Key issues:** Trench instability, trench ground movement.
4	3.10 to 3.18	**Construction method:** Trenchless HDD underneath Melton Highway **Description:** Two-lane tarmac rural Highway. Clearance to top of proposed bore is approximately 6.4 m. Basalt bedrock encountered at around 3 m below ground surface. Ground conditions at bore depth are therefore expected to comprise basalt rock. Multiple minor utilities present along road. **Key issues:** Ground movement from boring.
5	3.18 to 6.34	**Construction method:** Trench within agricultural land. **Description:** Ground conditions expected to comprise residual Newer Volcanics Basalt soils. Possible encounter of shallow basalt bedrock. Within APA's existing Sunbury Pipeline easement. Gentle topographic decline trending south implying increased erosion risk. **Key issues:** Trench instability, trench ground movement.

Reach ID	KP	Reach description
6	6.34 to 6.50	**Construction method:** Horizontal boring underneath Holden Road **Description:** One-lane rural earth road of heritage inventory status (H7822-2283). Basalt bedrock was encountered between 1.4 m and 3 m below ground surface, overlain by residual basaltic soils. Critical ground conditions at the depth of the bore comprise dense clayey gravel (Extremely weathered basalt). One low voltage power line crossing at road. **Key issues:** Ground movement from boring.
7	6.50 to 8.25	**Construction method:** Trench within agricultural land. **Description:** Ground conditions expected to comprise residual Newer Volcanics Basalt soils. Possible encounter of shallow basalt bedrock. Within APA's existing Sunbury Pipeline easement. Minor water course intersecting with potential shallow groundwater table. Trench parallel to optical fibre cable. Gentle topographic decline trending east implying increased erosion risk. **Key issues:** Trench instability, trench ground movement.
8	8.25 to 8.30	**Construction method:** Pipe-jacking underneath Bendigo Rail Line Reserve **Description:** Clearance to top of proposed bore from railway is approximately 4.4 m. Basalt rock was encountered at 1.2 to 1.4 m below ground surface, implying that bore is expected to be within basalt. High plasticity clays overly the basalt, potentially sensitive to moisture content changes. Shallow ground water depth is inferred at approximately 2 m below ground surface. Construction drawdown is required with an estimated 25 m zone of influence. Two areas of potential indigenous artefact scatter are identified approximately 30 m south-west of the crossing, listed on the Victorian Aboriginal Heritage Register as VAHR 7822-2426 and VAHR 7822-4275. **Key issues:** Ground movement from boring, trenches and nearby construction dewatering
9	8.30 to 8.64	**Construction method:** Trench within agricultural land. **Description:** Ground conditions expected to comprise residual Newer Volcanics Basalt soils. Possible encounter of shallow basalt bedrock. Within existing APA easement over Newer Volcanics Basalt. Trench intersects Tame Street Dam, with inferred groundwater table depths of 2 m below ground surface in the vicinity of the crossing. Construction drawdown is required with an estimated 20 m zone of influence. Soils near topsoils are expected to be reactive. **Key issues:** Trench instability, trench ground movement and construction dewatering.
10	8.64 to 9.06	**Construction method:** Trenchless HDD underneath Calder Freeway and Dillon Court and trench through agricultural land. **Description:** Calder Freeway is a four-lane rural tarmac freeway. Minimum clearance to the freeway is approximately 8 m to top of the proposed bore. Dillon Court is a one-lane rural road. Ground conditions at the depth of the bore are expected to comprise basalt rock underneath the Freeway. Two minor telecom cables located either side of the road reserve. No geotechnical information exists east of the Freeway, meaning that there is unknown ground conditions as the bore progresses for ~80 m underneath the private property. Following boring, the trench would be excavated through the private property in proximity to a small shed. **Key issues:** Ground movement from boring and trench instability.

Reach ID	KP	Reach description
11	9.06 to 10.74	**Construction method:** Trench within agricultural greenfields. **Description:** Ground conditions expected to comprise residual Newer Volcanics Basalt soils. Possible encounter of shallow basalt bedrock. Includes trenched crossings at Dillon Court and Duncan's Lane, as well as through a rural property used to store car wreckages. Water body exists just north of pipeline, and minor water courses intersecting. Gentle topographic decline trending North-West, implying an increased erosion risk. **Key issues:** Trench instability and trench ground movement.
12	10.74 to 10.75	**Construction method:** Horizontal boring underneath Morefield Court **Description:** One-lane rural tarmac road. Morefield Court trenchless crossing using horizontal boring methods. No available geotechnical information at crossing. Minor utilities along road. Potential encounter of shallow basalt bedrock. **Key issues:** Ground movement from boring.
13	10.725 to 11.11	**Construction method:** Trench through agricultural greenfields. **Description:** Ground conditions expected to comprise residual Newer Volcanics Basalt soils. Possible encounter of shallow basalt bedrock. An EPA Priority Site comprising industrial dumping of illegal waste exists 30 m south of the construction corridor near KP11. Gentle topographic decline trending South-East, implying an increased risk of erosion. **Key issues:** Trench instability.
14	11.11 to 11.18	**Construction method:** Horizontal boring underneath Bulla-Diggers Rest Road. **Description:** Two-lane rural tarmac road. Basalt bedrock encountered around 2.5 m below ground surface, overlain by residual basalt soils. Ground conditions at bore depth inferred to be basaltic dense clayey sand. Multiple minor utilities present along road. Gentle topographic decline trending south. **Key issues:** Ground movement from boring.
15	11.18 to 12.53	**Construction method:** Trench through agricultural greenfields. **Description:** Ground conditions expected to comprise residual Newer Volcanics Basalt soils. Possible encounter of shallow basalt bedrock. Includes crossing through man-made water retention dam. Generally flat topography. **Key issues:** Trench instability.
16	12.53 to 13.68	**Construction method:** Trench through agricultural greenfields. **Description:** Ground conditions expected to comprise residual basaltic soils. Possible encounter of shallow basalt bedrock. Some minor utility crossings. Slope decline down to valley with an average slope angle of >10°. **Key issues:** Trench instability, trench ground movement, slope stability, erosion.

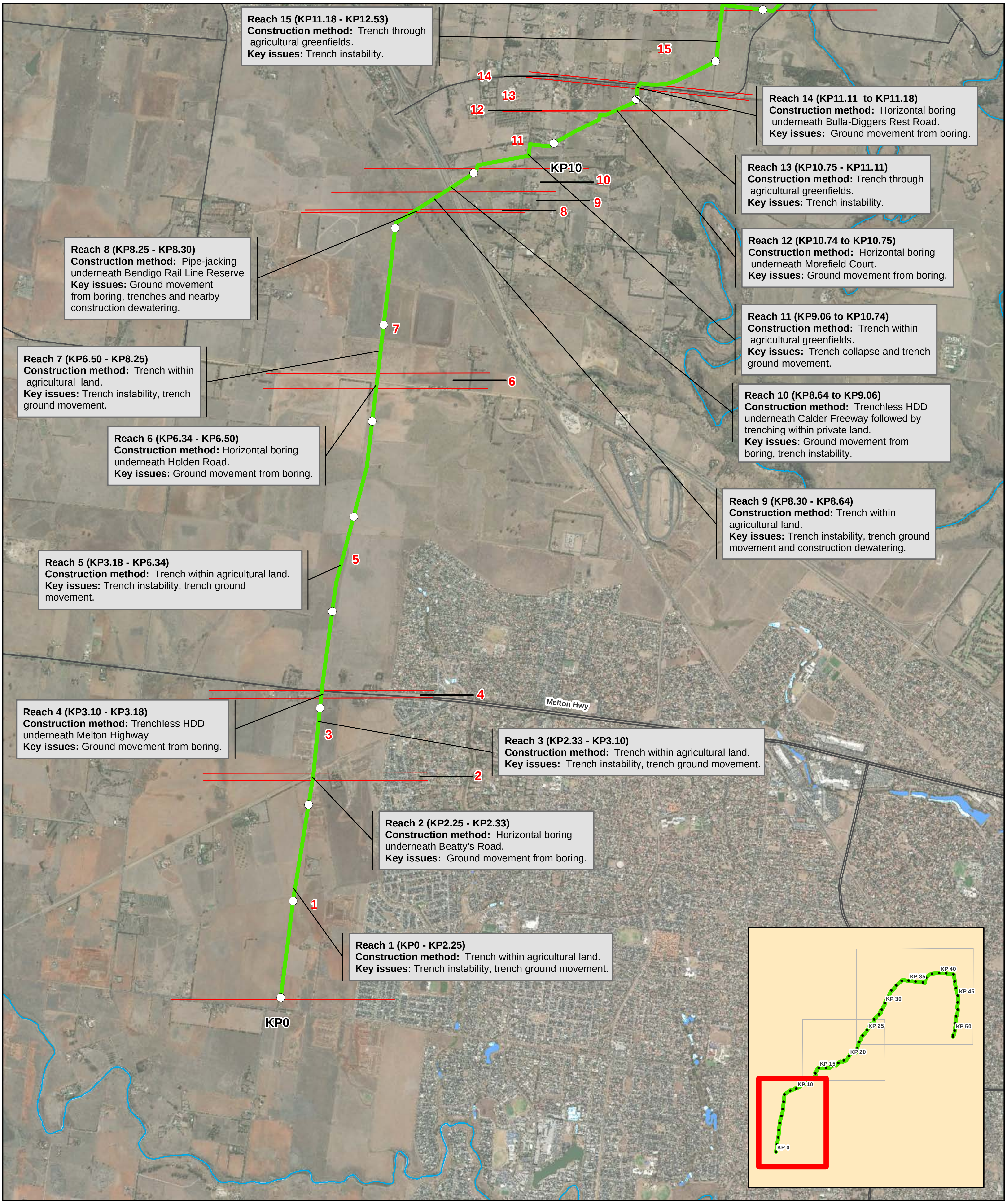
Reach ID	KP	Reach description
17	13.68 to 13.79	**Construction method:** Trench through Jacksons Creek crossing and surrounds. **Description:** Ground conditions during trench excavations are expected to largely comprise clay or gravel alluvium. Deeper open trench construction at Jacksons Creek may encounter residual siltstone. Extremely weathered Silurian siltstone or mudstone present >8 m below ground surface. Jacksons Creek High Level Cut-off SGGS present to north. Potentially shallow groundwater table at ~1.6m ground surface. 6 m of construction drawdown estimated. Dispersive soils have been identified within the area. Identified as an area of cultural sensitivity. **Key issues:** Trench instability, erosion, construction dewatering.
18	13.79 to 14.73	**Construction method:** Trench through valley north of Jacksons Creek crossing through inferred colluvial soil. **Description:** Ground conditions expected to comprise colluvial basaltic soils. Possible encounter of shallow basalt bedrock. Valley slopes dipping at steep angles of up to 27° into trench. Trench climbs up slopes to continue through agricultural greenfields over Newer Volcanics Basalt. Existing erosive behaviour evident at slope surfaces. Dispersive soils have been identified within the area. **Key issues:** Trench instability, slope stability, erosion.
19	14.73 to 14.80	**Construction method:** Trenchless HDD crossing underneath Sunbury Road. **Description:** Two lane rural tarmac road. Clearance to road of approximately 5.8 m to the road. No existing geotechnical information at depth of the bore, however basalt bedrock is inferred around 2.3 m below ground surface. Multiple utilities along road, including a DN450 DICL water main. **Key issues:** Ground movement from boring.
20	14.80 to 16.32	**Construction method:** Trench through agricultural greenfields. **Description:** Ground conditions expected to comprise residual Newer Volcanics Basalt soils. Possible encounter of shallow basalt bedrock. Includes Batey Court crossing, with some minor utilities present (telecom and power cables). Bulla Tip and Quarry exists approximately 20 m east of the Project construction corridor from KP15-KP16. Gradual topographic decline trending East towards Deep Creek, implying increased erosion hazard. **Key issues:** Trench instability, trench ground movement, erosion.
21	16.32 to 16.87	**Construction method:** Trench to Deep Creek, followed by trenchless HDD crossing underneath Deep Creek. **Description:** Identified as an area of cultural sensitivity. Clearance to the creek bed of approximately 16.1 m. Variable ground conditions are expected for the duration of the bore, comprising clay or sand alluvium closer to ground surface, transitioning residual siltstone at greater depths. Weathered sedimentary bedrock (siltstone and mudstone) was encountered at approximately 18 m below ground surface. Groundwater table estimated at >3 m below ground surface, meaning that construction drawdown is estimated for nearby trench excavations. Some sharp changes in elevation. Dispersive soils have been identified within the area. **Key issues:** Trench instability, slope stability, erosion, construction dewatering.

Reach ID	KP	Reach description
22	16.87 to 17.23	**Construction method:** Horizontal boring underneath Wildwood Road, followed by open trench construction up the slope to the East. **Description:** A one-lane rural tarmac road with existing cracking evident. Ground conditions at depth of bore expected to comprise stiff silty clays. No utilities exist along road. A steep slope exists East of Wildwood Road with slope angles of greater than 25° with some evidence of historical instability (Golder, 2019). Ground conditions along the slope are inferred to be colluvial soils. Dispersive soils have been identified within the area. **Key issues:** Trench instability, slope stability, erosion.
23	17.23 to 18.92	**Construction method:** Trench through agricultural greenfields. **Description:** Ground conditions expected to comprise residual Newer Volcanics Basalt soils. Possible encounter of shallow basalt bedrock. Utility crossings required, including a 200 mm PVC water pipeline. Gently undulating topography. **Key issues:** Trench instability, trench ground movement.
24	18.92 to 19.28	**Construction method:** Horizontal boring underneath St. Johns Road. **Description:** A one-lane rural tarmac road. Unknown geotechnical conditions at bore depth. Utilities present along road, including a 100 mm PVC water pipeline. **Key issues:** Ground movement from boring.
25	9.28 to 21.54	**Construction method:** Trench through agricultural greenfields. **Description:** Ground conditions expected to comprise residual Newer Volcanics Basalt soils. Possible encounter of shallow basalt bedrock. Some minor watercourses and water bodies intersecting. Gentle topographic decline trending South-West. **Key issues:** Trench instability.
26	21.54 to 21.65	**Construction method:** Horizontal boring underneath Oaklands Road **Description:** A two-lane rural tarmac road. Unknown ground conditions at bore depth. Minor utilities present along road. **Key issues:** Ground movement from boring.
27	21.65 to 22.65	**Construction method:** Trench through agricultural greenfields. **Description:** Ground conditions expected to comprise Newer Volcanics Basaltic soils. Possible encounter of shallow basalt bedrock. Gently undulating topography. **Key issues:** Trench instability.
28	22.65 to 22.67	**Construction method:** Horizontal boring underneath Craigieburn Road. **Description:** A two-lane rural tarmac road. Basalt bedrock encountered at 4.4 m and 5.1 m below ground surface, overlain by residual basaltic soils. Ground conditions at bore depth therefore expected to be within firm clay (residual basalt). **Key issues:** Ground movement from boring.
29	22.67 to 25.94	**Construction method:** Trench through agricultural greenfield. **Description:** Ground conditions expected to comprise Newer Volcanics Basaltic soils. Possible encounter of shallow basalt bedrock. Some minor watercourses intersecting. Undulating topography with slight incline trending North, implying increased erosion risk. **Key issues:** Trench instability.

Reach ID	KP	Reach description
30	25.94 to 26.36	**Construction method:** Horizontal boring underneath Mt. Ridley Road **Description:** Crossing near intersection of Mt. Ridley Road and Parkland Crescent. Both roads are one-lane tarmac rural roads, with existing cracking evident. Unknown ground conditions at bore depth. Minor utilities at crossing. **Key issues:** Ground movement from boring.
31	26.36 to 27.95	**Construction method:** Trench or horizontal boring through agricultural greenfields. **Description:** Trench proceeds parallel to Parkland Crescent. Includes crossing of Parkland Crescent near KP27. Ground conditions expected to comprise Newer Volcanics Basaltic soils. Possible encounter of shallow basalt bedrock. Some minor utilities exist near road. Undulating topography with minor topographic eruption point to North-East of intersection, implying increased erosion risk. **Key issues:** Trench instability, trench ground movement or ground movement from boring.
32	27.95 to 28.06	**Construction method:** Horizontal boring underneath Mickleham Road. **Description:** A two-lane rural tarmac road. Ground conditions comprise residual basaltic clays and gravels to around 2.5 m below ground surface, overlying basalt bedrock. Bore expected to be within medium dense gravel (Extremely weathered basalt). Minor utilities along road. **Key issues:** Ground movement from boring.
33	28.06 to 28.94	**Construction method:** Trench through agricultural greenfields. **Description:** Urban development ongoing East of proposed alignment. Ground conditions expected to comprise Newer Volcanics Basaltic soils. Possible encounter of shallow basalt bedrock. Trench through agricultural greenfield over Newer Volcanics Basalt. Minor utilities present. **Key issues:** Trench instability, trench ground movement.
34	28.94 to 30.16	**Construction method:** Trench near to agricultural greenfields to the West and residential developments to East. **Description:** Bedrock transitions to Humevale sedimentary bedrock, therefore ground conditions expected to comprise residual sedimentary soils. Gradual undulating slopes present, implying an increased erosion risk. Utilities present within development East of alignment. **Key issues:** Trench instability, trench ground movement, erosion.
35	30.16 to 31.21	**Construction method:** Horizontal boring underneath Donnybrook Road (West of Merrifield) **Description:** A two-lane rural tarmac road. No existing geotechnical information is available at the crossing location, therefore the bore is considered to be within unknown ground conditions. Based on nearby survey data, it is inferred that multiple utilities likely exist along the road, including a DN225 HDPE water pipeline. Details on utilities at the crossing location are not yet known. Dispersive soils have been identified within the area. **Key issues:** Ground movement from boring.

Reach ID	KP	Reach description
36	31.21 to 31.98	**Construction method:** Trench through agricultural greenfields with residential developments to the East. **Description:** Ground conditions expected to comprise residual sedimentary soils of Humevale Siltstone. Some minor watercourses intersecting, with a large waterbody present just East of the pipeline North-West of Merrifield. Generally flat topography along alignment, however just West of the alignment topographic elevation decreases trending North to North-West, potentially implicating hydraulic gradients. **Key issues:** Trench instability, trench ground movement, erosion.
37	31.98 to 33.94	**Construction method:** Trench through agricultural greenfields. **Description:** Ground conditions expected to comprise Newer Volcanics Basaltic soils. Possible encounter of shallow basalt bedrock. Some intersecting minor watercourses. Generally flat topography. **Key issues:** Trench instability.
38	33.94 to 35.42	**Construction method:** Trench through Kalkallo Basin **Description:** Includes open trench construction through Kalkallo Creek and Kalkallo Basin primarily within an alluvial terrace deposit. Sections of trench are required to be deeper (up to 5 m) to allow for construction of future drains within the basin. Alluvial soils were present up to 5 m to 10 m below ground surface. Sedimentary bedrock was generally encountered at depths of greater than 8 m. Bedrock geology transitions to Newer Volcanics Basalt at approximately KP35. Multiple water courses intersecting. Shallow groundwater tables possible. Flat topography. Groundwater level observed at around 4 m below ground surface. Construction dewatering is not estimated for this Reach. Dispersive soils have been identified within the area. **Key issues:** Trench instability, erosion.
39	25.42 to 37.03	**Construction method:** Trench through agricultural greenfield. **Description:** Ground conditions expected to comprise Newer Volcanics Basaltic soils (Stoney Rises). Possible encounter of shallow basalt bedrock. Some minor utilities present. **Key issues:** Trench instability, trench ground movement.
40	37.03 to 37.18	**Construction method:** Trenchless HDD crossing underneath Gunn's Gully Road and Hume Freeway **Description:** Entry pit located just West of Gunn's Gully Road, a one-lane rural gravel road, where HDD will commence and continue underneath Hume Freeway, a four-lane rural freeway with a median strip. Clearance to Hume Freeway is approximately 12 m below ground surface. Basalt bedrock encountered at <1m below ground surface, implying that ground conditions at bore depth expected to be basalt for both Gunn's Gully Road and Hume Freeway. Some utilities along road, including a DN100 PVC water pipeline. **Key issues:** Ground movement from boring.

Reach ID	KP	Reach description
41	37.18 to 41.05	**Construction method:** Trench through agricultural greenfields. **Description:** Ground conditions expected to comprise Newer Volcanics Basaltic soils. Possible encounter of shallow basalt bedrock. Some residential development. Bald Hill Eruption Cone SGGS present to the south. Undulating topography in the vicinity of Bald Hill. Some minor watercourses intersecting. Includes Donovans Lane crossing, where 1.5 m of construction drawdown is estimated. Some minor utilities nearby. A small former quarry exists approximately 30 m west of the construction corridor near KP37.3. **Key issues:** Trench instability, construction drawdown, trench ground movement.
42	41.05 to 41.10	**Construction method:** Pipe-jack underneath North Eastern Rail Line reserve. **Description:** Clearance from railway line approximately 4 m. Shallow basalt bedrock encountered at 0.8m and 2m below ground surface, implying that ground conditions at bore depth are expected to comprise basalt. Potentially shallow groundwater table estimated at around 4 m depth. 1 m of construction drawdown is estimated within the basalt. **Key issues:** Ground movement from boring, construction drawdown
43	41.10 to 42.77	**Construction method:** Trench through agricultural land. **Description:** Ground conditions expected to comprise Newer Volcanics Basaltic soils (Stoney Rises). Possible encounter of shallow basalt bedrock. Flat topography. **Key issues:** Trench instability.
44	42.77 to 46.97	**Construction method:** Trench through Merri Creek wetlands **Description:** Trench through Merri Creek crossing and wetland area over Newer Volcanics Basalt (Stoney rises). Shallow groundwater table expected at >2m below ground surface. Construction drawdown would be required in the vicinity of the creek. Includes. APA gas pipeline crossing. Hayes Hill Eruption Point (SGGS) to the East. Dispersive soils have been identified within the area. **Key issues:** Trench instability, trench ground movement, construction dewatering, erosion.
45	46.97 to 47.03	**Construction method:** Horizontal boring underneath Donnybrook Road (East of Merrifield). **Description:** A two lane rural tarmac road. Shallow basalt bedrock encountered between 0.5m and 1.05m below ground surface. Ground conditions are bore depth therefore expected to be within basalt. Potentially shallow groundwater table, with 1 m of construction drawdown estimated within the basalt. **Key issues:** Ground movement from boring, construction drawdown.
46	47.03 to end	**Construction method:** Trench through agricultural land **Description:** Ground conditions expected to comprise Newer Volcanics Basaltic soils (Stoney Rises). Possible encounter of shallow basalt bedrock. Within existing APA easement. Potentially shallow groundwater table where 1 m of groundwater drawdown is estimated during excavation of the trench. Includes the construction of the Wollert Compression Station where some bulk earthworks are required. **Key issues:** Trench instability, trench ground movement, construction drawdown.



Legend

- ○ WORM_Rev7_Pipeline_KPs
- Reach Boundary
- WORM_Rev7_Pipeline_Ln

Paper Size A3

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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Job Number	12529997
Revision	7B
Date	08 Dec 2020

Existing Conditions
Reach 1 to 15

Figure 6-3

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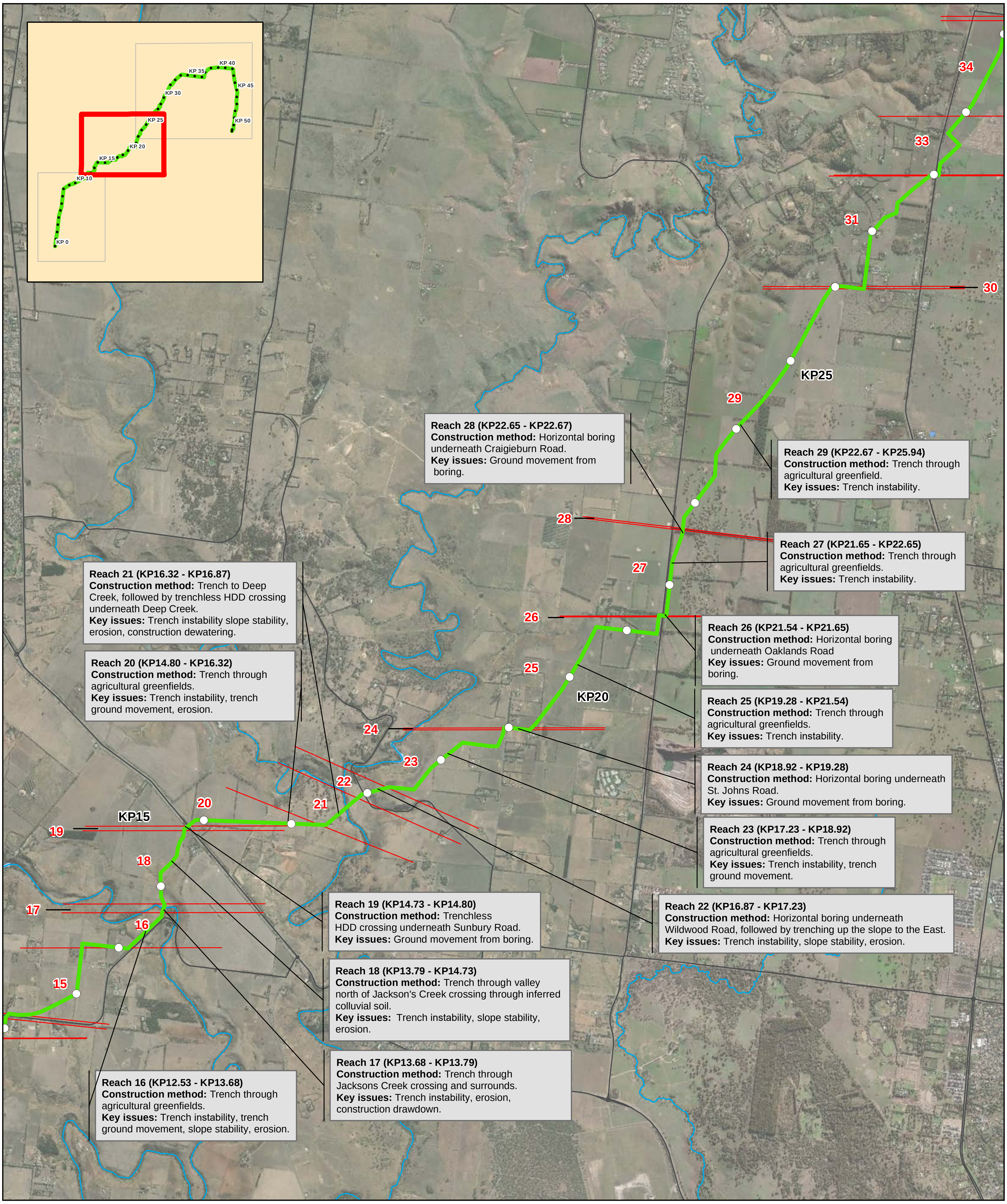

Legend

WORM_Rev7_Pipeline_KPs — Reach Boundary

WORM_Rev7_Pipeline_Ln

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Metres
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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Existing Conditions
Reach 16 to 29

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Figure 6-4

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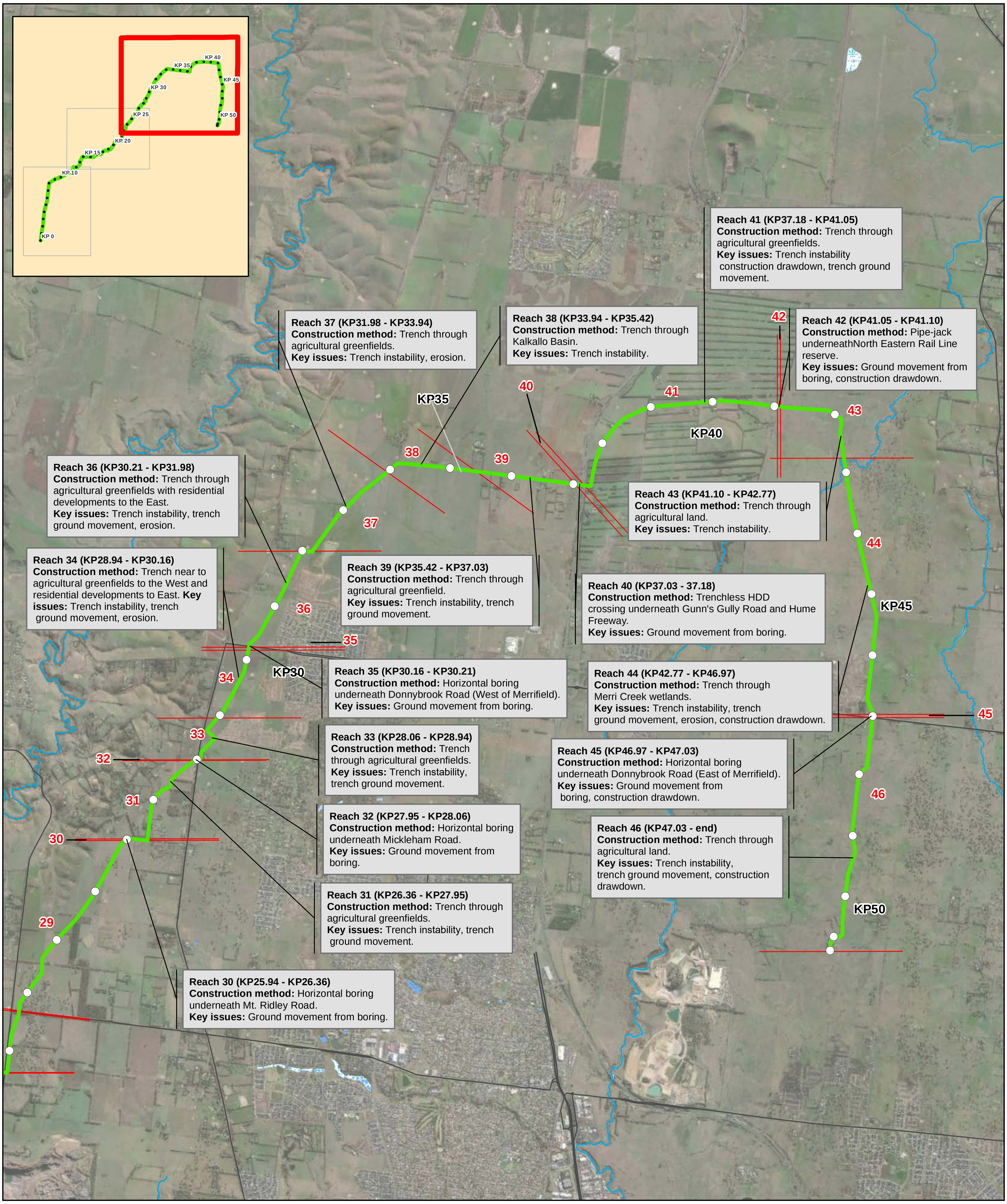

Legend

○ WORM_Rev7_Pipeline_KPs

Reach Boundary

WORM_Rev7_Pipeline_Ln

Paper Size A3

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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Existing Conditions
Reach 30 to 46

Job Number	12529997
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Figure 6-5

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6.6 Key issue prioritisation

Table 6-4 below reconciles the land stability and ground movement key issues for assessment (See Section 1.1) against the existing conditions and Project description to identify the areas where further assessment may be necessary and to inform the risk assessment.

Table 6-4 Key issue overview

Key issue		Overview
Ground movement	Trenchless crossing	Ground movement may occur at the trenchless crossings due to radial convergence of the soil surrounding the bore. Ground movement may subject nearby assets and features to unacceptable strains. Therefore, there is potential impact for this key issue at crossings where sensitive receptors are present. Further assessment is considered necessary (see impact assessment Section 8.2).
	Trench excavations	Identified sensitive receptors near to trench excavations are considered to be at a distance where trench excavation induced ground movements would be negligible. A simple model in Rocscience's *Plaxis 2D* was run to simulate the vertical and horizontal movements induced by a three metre (assumed as worse case) trench excavation. Model results indicate that maximum vertical movements would be within the negligible or 'insignificant' (Refer Section 5.6.1) damage risk category after Rankin (1988) and would reduce to zero at a distance of 1.5 times the trench depth away from the trench wall. No further assessment is considered necessary, however these movements will be superimposed on the trenchless excavation induced movements at the crossings where necessary.

Key issue		Overview
	Construction drawdown	The groundwater table is expected to be beneath the construction activities for the majority of the alignment and therefore minimal construction dewatering is expected overall. This also implies that potential for long term drawdown effects causing ongoing consolidation settlement due to the pipeline and / or trench acting as a permanent drain would be minimal. Construction drawdown may be required during open trench construction due to shallow groundwater tables at the following locations (see EES Technical Report C – Groundwater): Bendigo Railway and the Tame St Drain (Reach 8 and Reach 9) Jacksons Creek (Reach 17) Deep Creek (Reach 21) Donovans Lane and the North East Rail reserve (Reach 42) Merri Creek (Reach 44) Donnybrook Rd East (Reach 45) North of the Wollert Compressor Station (Reach 46) The two railway reserves as well as Donnybrook road (West) contain existing assets that may be sensitive to ground movements. However, the potential groundwater drawdown is estimated to generally occur at greater depths to where compressible soils were encountered during the geotechnical investigations (Construction Sciences, 2020). For example, the groundwater table near both railway reserves was observed to be within the basalt bedrock. Any construction drawdown would therefore only result in pore pressure changes within the basalt, which is not susceptible to consolidation settlement. This suggests that only negligible to minor consolidation may take place and there is therefore a low risk of damage to existing assets at these locations. See EES Technical Report C: Groundwater for estimated drawdown magnitudes and extents.
Land stability	Slope stability	The slopes north of the Jacksons Creek crossing where trench excavations are proposed near to the slope toe may be at risk of instability and will be assessed further. Other slopes present near to the proposed alignment are not anticipated to be at significant risk of instability. The steep slope East of Wildwood Road may experience some instability due to erosion effects induced by the trench excavations up the slope. Stability at the Jacksons Creek slopes will be considered further (see impact assessment Section 8.4).

Key issue		Overview
	Trench stability	Trench instability is considered as applicable to a varying degree to all the trench excavations required for the Project depending on the ground conditions. This will therefore be assessed as conditional, whereby ground condition 'scenarios' will be considered as informed by the geotechnical investigation (see impact assessment Section 8.1).
	Erosion	The potential for erosion effects to compromise land stability is considered as applicable to the entire alignment to a varying degree, particularly due to the presence of dispersive soils throughout the Project Area (See Section 6.3). Erosion effects may be more prevalent in the vicinity of watercourses, such as within Merri Creek Wetlands and Kalkallo basin, or in areas with variable topography, such as near Deep Creek and Jacksons Creek. Erosion of creek banks at the waterway crossings affecting creek health is not considered a land stability and ground movement topic. This is assessed apart of Technical Report C – Surface Water. Erosion effects alone are not expected to result in significant ground movement or land stability effects during construction, rather it may exacerbate the other risks identified. Erosion will therefore not be considered as an isolated risk, rather it will be considered insofar as it has the capacity to worsen the other risks identified for pipeline construction. During operation, there is potential for ongoing erosion to occur within the construction easement resulting in adverse land stability effects, particularly if dispersive soils are present. Further consideration to this issue is given in the risk and impact assessments.

7. Risk Assessment

A risk assessment of Project activities was performed in accordance with the methodology described in Section 5.5. Consequence risk descriptors are described in Table A-2 and likelihood risk descriptors are described in Table A-3 in Appendix A.

The initial risk ratings considered a set of mitigation measures (where relevant), which are based on compliance with legislation and standard requirements that are typically incorporated into the delivery of infrastructure projects of similar type, scale and complexity. Risk ratings were applied to each of the identified risk pathways assuming that these mitigation measures were in place.

Where the initial risk ratings were categorised as medium or higher, these risks were a focus of the impact assessment and additional management measures were considered (where possible) as part of the impact assessment. Appropriate implementation of any recommended additional EMMs is considered to reduce the initial risk ratings to the final risk ratings included in Table 7-1 below. Additional management measures aimed to achieve 'avoidance' of the impact. Justification is provided if avoidance could not be achieved, as per Section 3.7 of the Scoping Requirements for WORM document (2020).

The recommended EMMs are outlined in more detail in Section 9 of this report.

The risk register showing the risk pathways and findings of the risk assessment for land stability and ground movement is attached in Appendix A. Section 8.1 through to Section 8.4 provide more detail for the risks identified.

Nine land stability and ground movement construction risks were identified and assessed and two operational risks.

A summary of the risk assessment results is presented in Table 7-1.

Table 7-1 Risk results

Risk ID	Risk description	Construction/ operation	Pipeline/ MLV/ compressor	Initial risk rating	Final risk rating
GM1	**Open trench excavations in unstable ground (granular material)** Potential instability and collapse of granular material resulting in disturbance to nearby land and native vegetation.	Construction	Pipeline	Medium	Negligible
GM2	**Open trench excavations in stable ground (cohesive material)** Potential elastic movements within the soil as a result of the trench excavations subjecting nearby sensitive receptors to unacceptable strains.	Construction	Pipeline	Negligible	Negligible

Risk ID	Risk description	Construction/ operation	Pipeline/ MLV/ compressor	Initial risk rating	Final risk rating
GM3	**Construction dewatering in compressible soils** Causing consolidation settlement of compressible soils subjecting nearby assets and features to unacceptable strains.	Construction	Pipeline	Negligible	Negligible
GM4	**Construction dewatering in dispersive soils** Movement of the groundwater table through dispersive soils causing erosion and land disturbance.	Construction	Pipeline	Negligible	Negligible
GM5	**"Volume loss" associated with trenchless pipe installation in soil** Ground deformations resulting from horizontal boring or HDD in unstable soils subjecting nearby assets and features to unacceptable strains.	Construction	Pipeline	Low	Low
GM6	**Trenchless pipe installation encountering unexpected poor ground conditions at crossings with insufficient geotechnical data** Insufficient information leading to unanticipated asset damage or HDD "blow-out" during construction.	Construction	Pipeline	Medium	Low
GM7	**Pipeline construction in proximity to existing slopes** Open trench construction causing ground movements, erosion and potential slope instability.	Construction	Pipeline	Medium	Low
GM8	**Trench excavations through waterways and wetland areas**	Construction	Pipeline	Low	Low

Risk ID	Risk description	Construction/ operation	Pipeline/ MLV/ compressor	Initial risk rating	Final risk rating
	Open trench waterway crossings resulting in land disturbance as a result of increased erosion effects.				
GM9	**Pipeline construction near sites of Special Geological or Geomorphological Significance including the following:** -Deep Creek Wildwood Outcrops -Jacksons Creek high level cut off -Hayes Hill Eruption Point -Bald Hill eruption cone -Merri Creek Incised Channel. Ground movement / land instability associated with the construction works causing land disturbance at significant sites.	Construction	Pipeline	Negligible	Negligible
GM10	**Pipeline acts as a long term drain in compressible soils** Causes consolidation and / or swelling of reactive soils subjecting proximal assets and features to unacceptable ground strains.	Operation	Pipeline	Negligible	Negligible
GM11	**Permanent ground surface and water flow changes as a result of excavations** Alteration to water flow regimes, especially near watercourses or natural drainage paths, causing ongoing erosion of nearby dispersive soils, land disturbance (gully erosion) or slope creep.	Operation	Pipeline	Medium	Low

8. Impact Assessment

8.1 Open trench excavations in unstable ground (Risk GM1)

8.1.1 General

Wall instability and collapse could result in a large amount of land disturbance to a localised area near the trench. The degree of disturbance could have considerable effects on nearby sensitive receptors including natural landforms and native flora and fauna as well as compromising agricultural functionality. In addition, trenches are proposed through several areas identified as having cultural sensitivity (such as the areas surrounding Jacksons Creek, Deep Creek and Kalkallo Creek), meaning that land disturbance should be minimised in these areas (See EES Technical Report H Cultural heritage for full assessment).

Excavations of deep trenches are often associated with wall stability risks, typically mitigated by the provision of wall support in the form of trench shields, struts or anchors. The trench excavations required for the Project are slightly deeper than what would traditionally be classified as a ‘shallow trench’, with assumed typical excavation depths around 2 m deep. Deeper open trench construction required for the excavation of entry and exit pits for trenchless boring, open trench construction for crossing of watercourses such as Jacksons Creek, Merri Creek and Tame Street Drain or within the Kalkallo basin would be subject to greater risk of instability. If unsupported, trench stability will therefore depend on the strength of the material through which the trench is excavated.

As a general indication of the proportion of fine grained and granular soils, particle size distribution testing (Construction Sciences, 2020) on the soil samples retrieved along the alignment (residual basalt and alluvial) indicate that approximately 90% of the soil samples tested comprise fine grained, cohesive materials as the primary component. The remaining 10% comprise granular material as the primary component. There is insufficient data over the course of the alignment to identify specific locations where the expected soil can be accurately identified, therefore the occurrence of either soil type should be expected for all trench excavations. Both scenarios are considered for trench stability in the following sections.

8.1.2 Trench through fine grained soil (clays or silts)

The majority of the open trench construction is expected to be excavated through clays or silts of residual basalt, which may remain temporarily stable up to a limiting height depending on the undrained shear strength of the soil (excluding minor ravelling of clay blocks due to desiccation effects in summer conditions and/or the presence of relict features in the clay such as joint planes). The failure mechanism in this case would comprise formation of a sliding block that fails into the excavated area. Limit analyses is therefore considered appropriate and the following equation may be used to determine the limiting height (where factor of safety equals one) for an unsupported trench (Taylor, 1948):

$$h \leq \frac{4 * c_u}{\gamma}$$

Where h is the limiting excavation height for wall instability, c_u is the undrained shear strength of the material and γ is the unit weight of the excavated material. Assuming a c_u of 25 kPa and a unit weight of 20 kN/m^3 (for a firm (worst-case), residual basaltic clay soil, Construction Sciences, 2020) as a lower bound estimate for the fully softened residual basalt clay properties, an unsupported trench depth of 5 metres is achievable. Based on this, the majority of the trench excavations through the Newer Volcanics cohesive soil would not be subject to stability risk (providing local unfavourable oriented “relict” features are not present).

It is also noted that where trench excavations are in proximity to existing APA easements (such as from KP0 to KP9 and KP42 to KP51), pre-existing ground disturbance may be present as a result of the historical excavations required to install those pipelines, potentially increasing the risk of ground instability. The deeper open trench construction within Kalkallo Basin may be at greater instability risk depending on final design depths.

8.1.3 Trench through granular material (sands or gravels)

Vertical cuts cannot be sustained in granular soils (ie. sand or gravel) under drained conditions, as a drained-cohesionless soil will always fail when the slope angle is greater than the angle of friction of the soil. Failure could occur even if only a portion of the trench depth is excavated through these unfavourable conditions. Encountering these conditions would therefore be considered to be associated with a 'almost certain' likelihood rating for wall instability (See table in Section 5.6.2).

Some cohesion may exist in these soils due to the presence of significant fines content (or variable secondary iron oxides), however it is considered that predominantly drained-cohesionless conditions will govern the soil strength and instability could arise if the trench remains unsupported.

8.1.4 Erosion and long term stability during construction

Internal erosion effects (suffosion) for granular soils or adverse reactions associated with dispersive behaviour in fine grained (cohesive) soils may reduce stability of the trench wall. Management of erosion and/or dispersive soils during construction is therefore recommended. The rate at which this instability may occur may be increased during periods of elevated antecedent rainfall in fine grained soils. Given the low permeability expected for the cohesive materials and the time taken to reach drained conditions, it is considered that keeping open trench durations to less than three months is desirable.

8.1.5 Recommended environmental management measures

Although the majority of trench excavation through fine grained clays or silts is expected to be stable, the potential for unfavourable conditions, such as encountering granular soils, require management to reduce potential impacts to nearby land. There is insufficient geotechnical information to determine specific locations where granular soils may be encountered along the alignment, therefore the mitigation measures listed below are considered for all trench excavations.

Additionally, erosion and reduction in trench wall stability over time may lead to wall instability if the trench is left open for significant periods. The following Environmental Management Measures (EMMs) are therefore required for all trench excavations.

- EMM GM3 – Management of trench stability: support and duration (additional), which broadly includes requirements for trench excavation works to be conducted in accordance with the requirements of the Safe Work Australia Code of Practice: Excavation Work (2018) and WorkSafe Victoria Compliance Code: Excavation (2019) to minimise the risk of trench wall collapse. Furthermore, the time that trenches and bell holes remain open would be minimised as far as reasonably practicable.
- EMM GM4 – Management of trench erosion, consolidation and swelling (initial), through erosion and sediment control measures including the use of trench breakers installed at regular intervals along the trench excavation. Furthermore, compaction of the trench backfill will be required as per APA's performance requirement and/or contractor's construction requirements. Routine inspection and monitoring of the construction area must be undertaken throughout operation as per the VTS OEMP.

- EMM GM7 – Preparation and implementation of sodic soil management measures as a part of the final CEMP (additional).

Successful application of the above EMMs is considered to reduce the likelihood of wall instability to ‘rare’ along the alignment, seeking to achieve ‘avoidance’ of the impact according to the mitigation hierarchy. See Section 9 for more detail on the above EMMs.

If avoidance is achieved, the residual impact is not anticipated to occur. In a worst-case scenario, if wall instability occurs, contingency response measures will be required to minimise the duration and intensity of the impacts. These are to be detailed in the final Construction Environment Management Plan (CEMP) and may include for example, specifications for temporary shoring and the removal, replacement, and rehabilitation of the disturbed soil.

8.2 “Volume loss” arising from trenchless crossings in soil (Risk GM5)

8.2.1 General

The process of boring causes ground movements ahead of the bore face and an inevitable ‘convergence of the ground’, meaning that a volume of ground slightly greater than the theoretical volume of the tunnel will be excavated (i.e. “volume loss”). Volume loss movement is traditionally associated with the “face take” and radial convergence around bores excavated in soft ground such as firm to stiff cohesive soils or granular soils. Volume loss is often expressed as a percentage of the theoretical excavated face area of the bore. The use of drilling support fluid (for example bentonite) as a form of temporary bore support during HDD and pipe-jacking can significantly reduce the potential for high volume losses, however movements are still possible. For horizontal (‘thrust’) boring methods, the pipe casing is pushed in directly behind the cutting head meaning that no temporary bore support is required, however ground movements may still occur upon encountering unfavourable ground conditions.

For stronger or stiffer ground such as rock, movements at typical civil engineering depths can often be characterised by small ‘elastic’ movements or movements associated with the displacement of discrete fracture bounded blocks of rock, though unlikely to be of high magnitude.

The volume loss experienced at bore depth translates into surface settlement, typically assumed to take on the shape of an inverted bell curve orientated transverse to the bore alignment, with the maximum settlement occurring directly above the bore centreline (Peck, 1969). The maximum settlement, ground slope and strains felt by affected receptors will inform the damage risk.

For the Project, ground conditions are expected to vary at the depth of the bore between three ground condition types, each with varying degrees of potential impact. These are discussed in Table 8-1 below. These ground conditions have been informed by the Construction Sciences Geotechnical Report (2020). If the actual ground conditions differ to those assumed here, the results and conclusions drawn from the following assessment are no longer applicable.

Table 8-1 Trenchless crossing ground conditions

Ground conditions at bore depth	Discussion	Reaches
Rock	Some minor ground movement may occur if weathered seams are encountered, but overall expected to be negligible. It is noted that the two railway lines may be highly sensitive to ground movements. Though only minor movements are expected in the pipe-jack through basalt at these crossings, liaison with asset owners may require the implementation of settlement monitoring and contingency plans. No further assessment is deemed necessary.	Reach 4: Melton Highway Reach 8: Bendigo Rail Line Reach 10: Calder Freeway Reach 40: Gunns Gully Road / Hume Freeway Reach 42: North Eastern Rail Line Reach 45: Donnybrook Road (East)
Cohesive soil (clay or silt)	Some convergence of soil may occur, however the stiff soils expected would "arch", minimising movements. A volume loss of around 3% could arise (using the 'load factor' method (Dimmock & Mair, 2007) with zero internal support pressure). Associated maximum settlements and trough gradients would be within the minor or 'insignificant' damage risk category after Rankin (1988) (See Section 5.6.1). No further assessment is considered necessary.	Reach 21 and 22: Deep Creek and Wildwood Road Reach 28: Craigieburn Road
Granular soil (sand or gravel)	Dense granular soils would be expected to "dilate" upon excavation, resulting in low to negligible movements. Boring through loose soils may lead to partial bore collapse if the ground is temporarily unsupported. The granular soils are generally expected to be of sufficient density to exhibit some dilation, meaning that only minor convergence and 'face-take' is expected. However, there is the possibility of localised brittle failure of the soil resulting in greater movements, particularly where no bore support fluid is used such as in the case of horizontal boring. A volume loss of 5% is considered suitable for these ground conditions. Further impact assessment has therefore been completed at each of these crossings as included below.	Reach 6: Holden Road Reach 14: Bulla-Diggers Rest Road Reach 32: Mickleham Road

Each of the trenchless crossings within granular soil will therefore undergo a specific assessment as below.

8.2.2 Description of crossings assessed

Reach 6 – Holden Road trenchless crossing

Horizontal boring (thrust boring) is proposed beneath Holden Road, a one lane rural tarmac road owned by Melton City Council. The road is listed on the Victorian Heritage Inventory under number H7822-2283. The site is of local historical significance as an early roadway built by local farmers. Remnant stone road foundation materials consisting of larger bluestone cobbles and smaller gauge aggregate are present on the ground surface (Heritage Council Victoria, 2020). Entry and exit pits for boring would be excavated in greenfield land in private property north and south of the road reserve. The site layout is included in Figure 8-1 below.

A geotechnical borehole drilled north of the road indicates that very dense clayey gravel (Extremely weathered basalt) may be present at the depth of the bore. The gravel layer is overlain by high plasticity stiff silty clay (residual soil). The borehole was terminated after auger refusal on inferred basalt. No laboratory testing was undertaken on the gravel, however an in-situ SPT test conducted at the depth of the gravel was refused, possibly due encountering a large gravel particle size.

Given that there is only one borehole available at this crossing, there is a high degree of uncertainty in the ground model. However, assuming the gravel conditions described above for the length of the bore would account for worst case conditions.

The identified sensitive receptors at this crossing comprise the following:

- Deer Park to Sunbury APA gas transmission pipeline parallel to WORM, a steel pipe of 0.15 m diameter. Lateral offset between the two pipelines is approximately 7.5 m at the crossing
- VHI listed 'cobbled stone' road (VHI number H7822-2283)
- Optical fibre cable owned by NextGen runs parallel to WORM with a lateral offset of 6 m

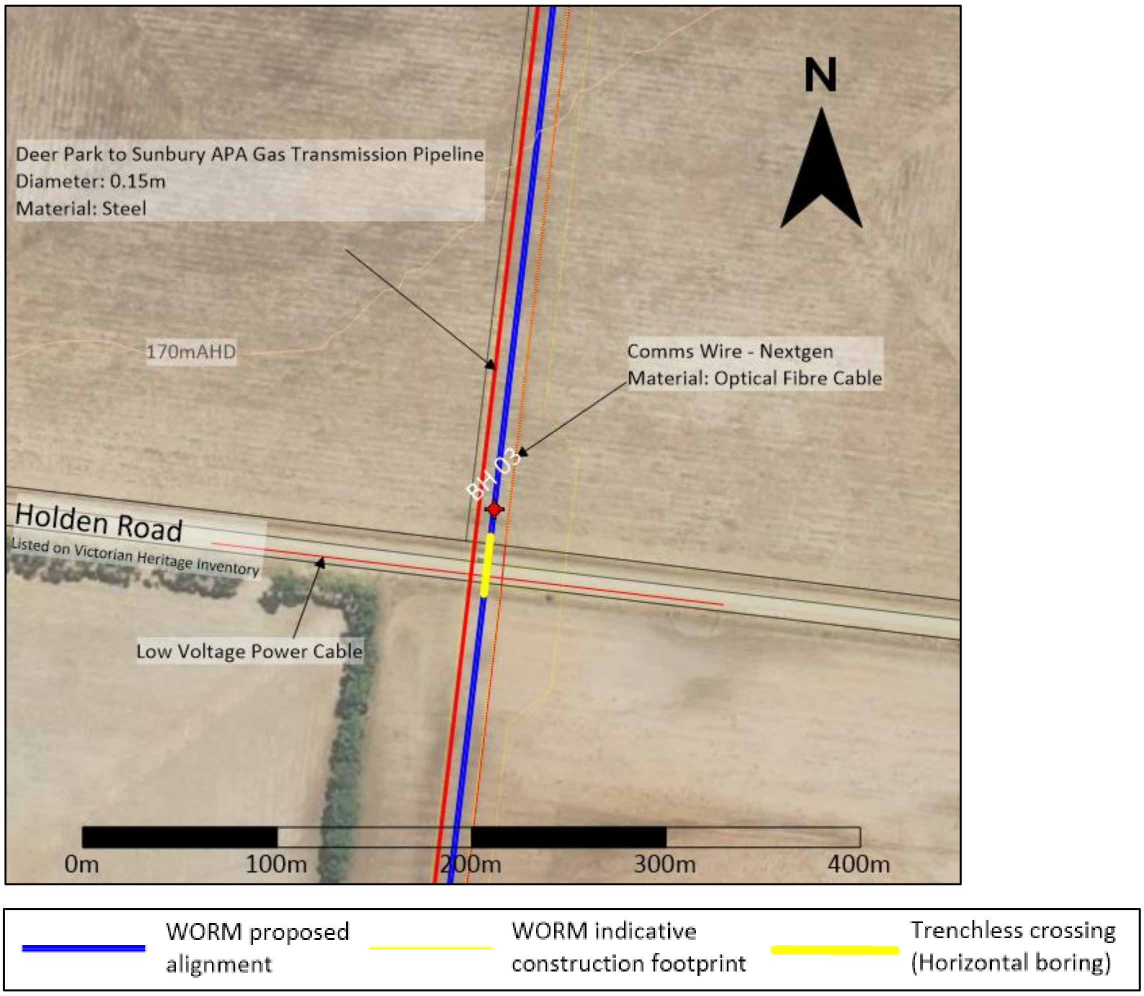

Figure 8-1 Site layout and sensitive receptors at Holden Road Trenchless Crossing

Reach 14 - Bulla-Diggers Rest Road trenchless crossing

Horizontal boring (thrust boring) is proposed underneath Bulla-Diggers Rest Road, a one lane rural tarmac road owned by Hume city council. The proposed bore alignment is at an acute angle to the orientation of the road to avoid impacts to a private driveway just north of the site. A shallow concrete drain culvert under the driveway lies parallel to Bulla-Diggers Rest road. A traffic safety barrier is present on the south side of the road, opposite the private driveway. A small man-made retention dam exists just north-east of the crossing. Entry and exit pits for boring would be required within the greenfield land in private property north and south of the road reserve, where some vegetation and trees exist. Site layout is shown in Figure 8-2 below.

A borehole drilled just north of the road indicates that dense clayey sand (SC) (Residual basalt) may be present at the depth of the bore. The sand is overlain by high plasticity clay. Basalt bedrock is inferred to be between 2.3 m and 3 m below ground surface. The sand moisture condition was logged as moist, meaning that perched water could be present within the sand material.

The identified sensitive receptors at this crossing comprise the following:

- Direct buried copper communication wire owned by Telstra at a depth of 1.2 m below ground level
- DN100 PVC water pipeline owned by Western Water at a depth of 1.2 m below ground surface in good condition

- Direct buried copper communication wire owned by Telstra at a depth of 0.2 m below ground level
- Concrete drainage culvert underneath the private driveway on the north side of the road

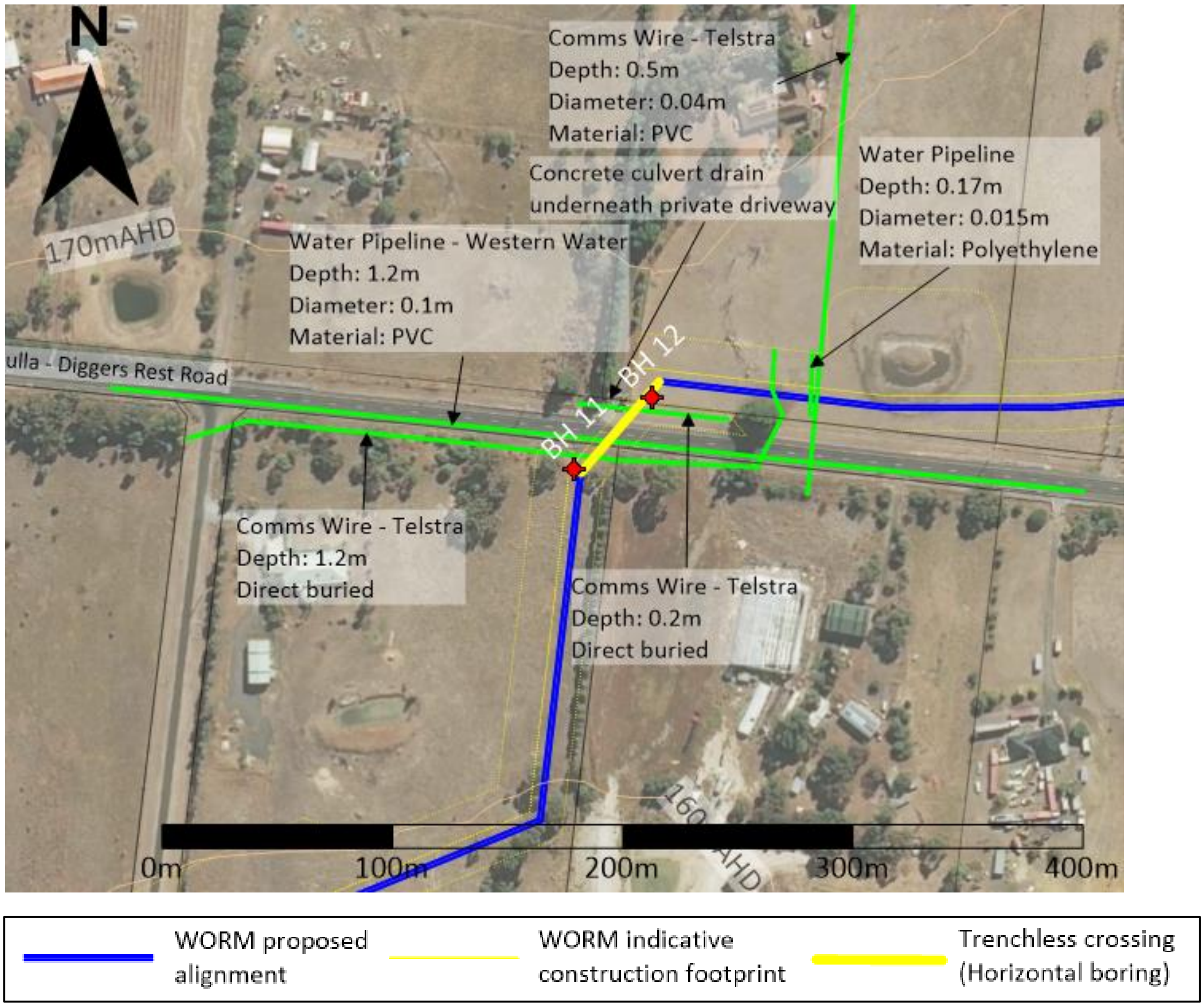

Figure 8-2 Site layout and sensitive receptors at Bulla-Diggers Rest Road Trenchless Crossing

Reach 32 - Mickleham Road trenchless crossing

Horizontal boring (thrust boring) is proposed underneath Mickleham Road, a one to two lane rural tarmac road owned by Hume City Council with wide road reserves. The entry and exit pits are proposed to be within private property east and west of the crossing. A concrete drainage culvert exists underneath a private driveway just north of the crossing. Some small bodies of water exist in the local area, associated with man-made water retention dams. The site layout is shown in Figure 8-3 below.

The ground model inferred from nearby boreholes comprises stiff clay near the ground surface overlying medium dense gravel (extremely weathered material) at around 1.9 m below ground level. Basalt bedrock is inferred at 2.55 m. The moisture condition in the gravel was recorded as moist, indicating that perched water could be present within the gravel material.

The sensitive receptors identified at this crossing include:

- Concrete drainage culvert approximately 12 m north of the crossing
- Communication wire owned by Telstra within a DN50 PVC casing at a depth of 0.55 m below ground surface in poor condition

- Direct buried communication wire owned by Telstra at a depth of 1.2 m below ground surface in good condition
- Direct buried optical fibre cable owned by Optus in good condition at a depth of 1.2 m below ground surface
- High voltage overhead power line with nearest power pole approximately 12 m north of the crossing. Owned by Jemena

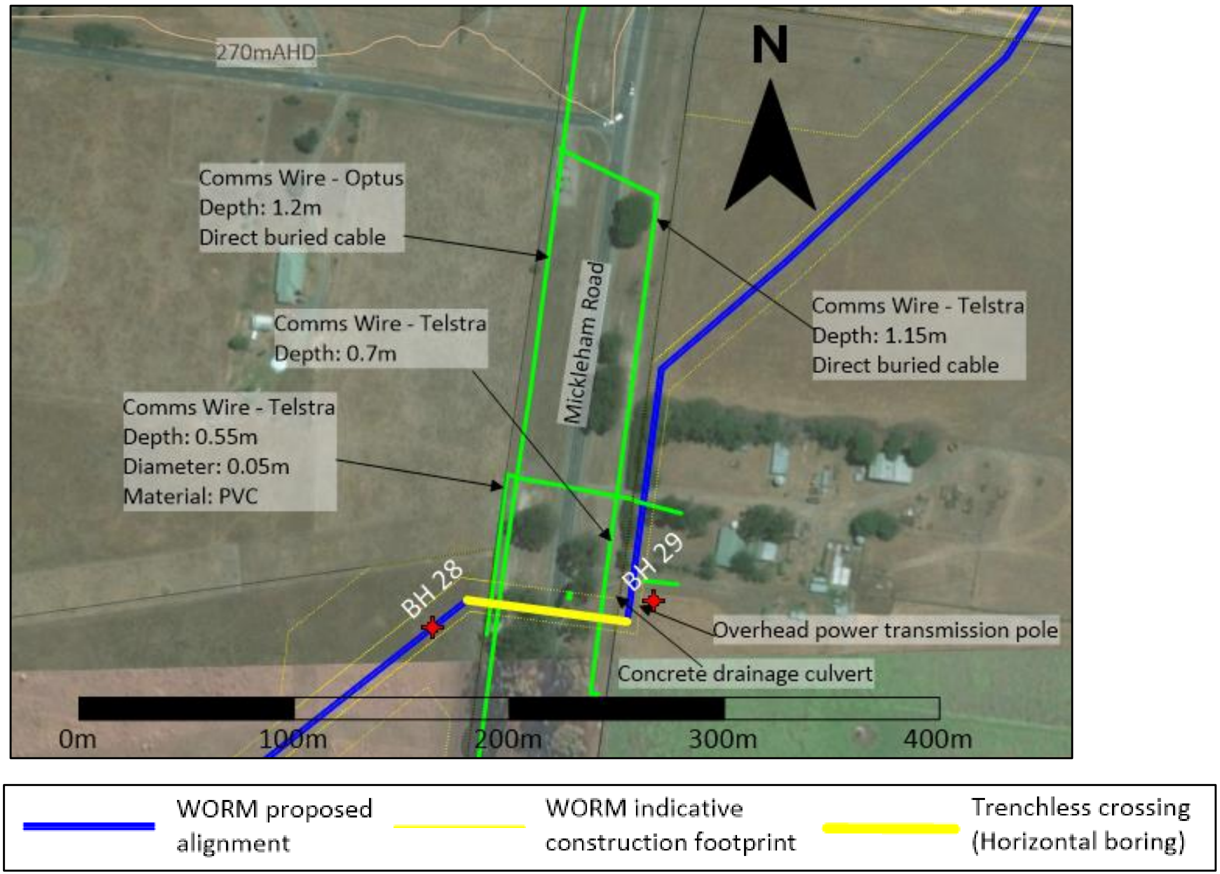

Figure 8-3 Site layout and sensitive receptors at Mickleham Road Trenchless Crossing

8.2.3 Ground movement assessment

The following ground movement assessments consider the immediate vertical and horizontal ground movements due to trench and trenchless excavations required for the road crossings and the effect these movements may have on existing assets or features. The assessment has been conducted on those crossings deemed to be at higher risk of ground movement, due to the presence of potentially unstable granular material at the depth of the bore.

Each crossing has been assessed whereby ground surface settlements are compared against simple damage risk criteria after Rankin (1988). Based on the results of this 'preliminary assessment', a second stage assessment has been undertaken where required, which accounts for pipe material properties, depths and relative stiffness effects.

Preliminary ground movement assessment (after Rankin, 1988)

For the horizontal boring in potentially unstable granular materials, a volume loss of 5% and a trough width parameter *K* of 0.3 is considered appropriate. An excavated bore diameter of 700 mm is assumed for installation of the DN600 mm pipe using horizontal boring methods as provided by APA. The additional diameter accounts for a pipe wall thickness of 13.4 mm and annular overcut of the bore a. These values have been used for each of the crossings considered for impact assessment. Ground movement as a result of the trench excavations was estimated using empirical relationships derived for excavations in stiff clay (Clough & O'Rourke, 1990) and validated by simulating the excavation using Rocscience's *Plaxis 2D*. Figure 8-4 below provides an example of the settlement contours expected at Bulla-Diggers Rest road, along with the potentially affected utilities. Table 8-2 below summarises the preliminary assessment for each crossing.

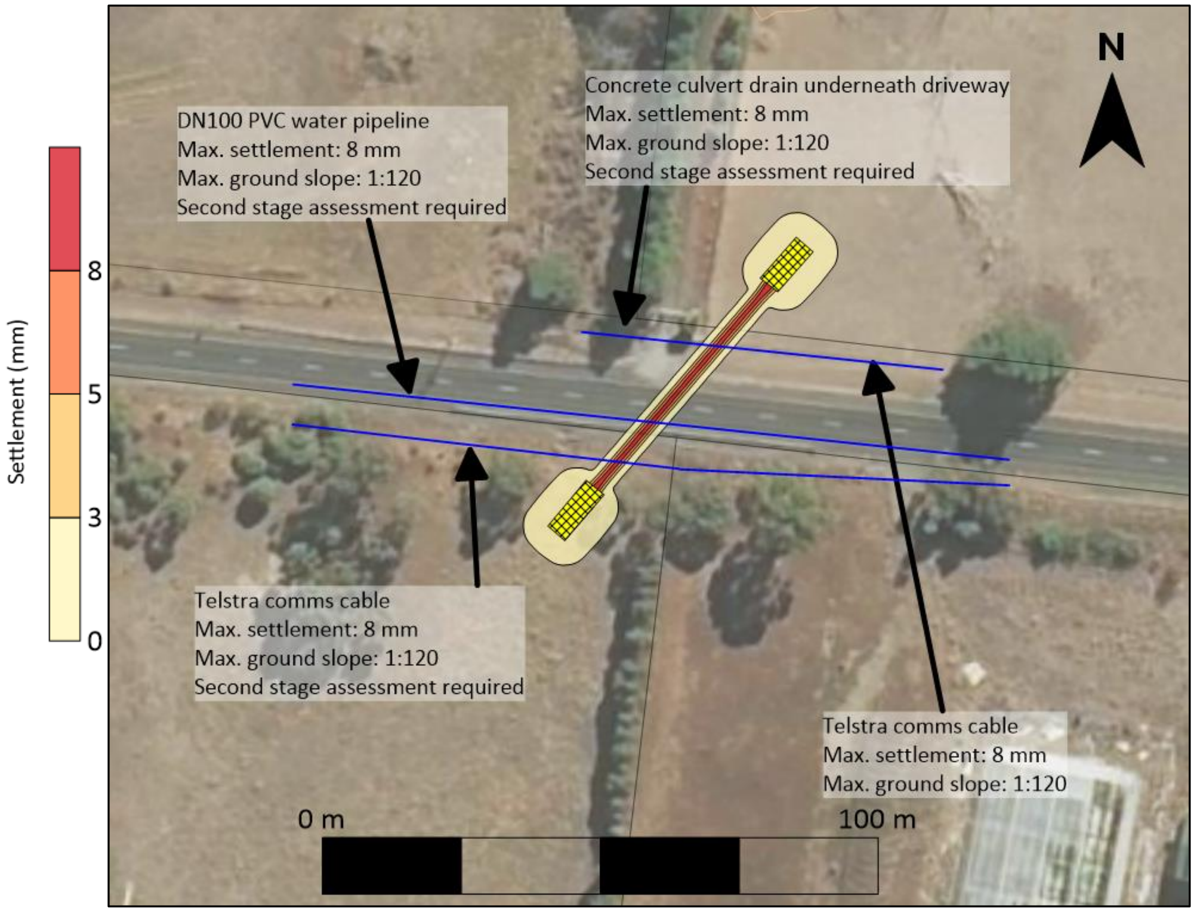

Figure 8-4 Settlement contour map at Bulla-Diggers Rest Road

Table 8-2 Preliminary Assessment Summary

Crossing	Preliminary assessment (refer Table 5-2)		Outcome
	S_{max} (mm)	θ_{max} (V:H)	
Holden Road	13	1:75	Only road is subject to movements, where damage would be negligible for the estimated movements. No second stage assessment is necessary.
Bulla-Diggers Rest Road	10	1:150	Second stage assessment necessary due to ground slope.

Crossing	Preliminary assessment (refer Table 5-2)		Outcome
	S_{max} (mm)	θ_{max} (V:H)	
Mickleham Road	10	1:150	Second stage assessment necessary due to ground slope.

Second stage ground movement assessment

A second stage assessment was conducted on each of the three crossings identified in Table 8-2. The second stage assessment considered the horizontal and vertical ground strains at the affected utility depth, utility materials and pipe-soil relative stiffness effects. An example of the results of the second stage assessment completed for Bulla-Diggers Rest Road on the DN100 pipeline is shown in Figure 8-5 below. This assessment considered ground strains felt by the water pipeline at a depth of 1.2 m from ground surface. The pipeline would be expected to behave as a 'flexible' pipeline, in that strains will be felt by the pipe material itself rather than being transferred to the joints. The same can be assumed for HDPE pipes. Axial strain reduction factors were considered to account for some of the pipe-soil relative stiffness effect (Attewell, Yeates, & Selby, 1986). No bending strain reduction was considered for this stage of assessment. Table 8-3 below presents the summarised results for the Second Stage assessments.

Tensile and compressive strains are estimated along the length of the pipeline, and are compared to the assumed acceptable strain limits at each point. In lieu of acceptable strain limits provided by the asset owners, the tensile and compressive strain limits assumed for the utility damage risk assessments have been based on lower bound thresholds within the expected range of values (AS2566.1: 1998 Buried Flexible Pipelines, Attewell & Woodman, 1982, Polymer Properties Database, 2019). The strain threshold values are related to the material yield strength, rather than the ultimate strength. This approach is considered appropriately conservative, given that material yield will still result in possible structural damage and loss of serviceability.

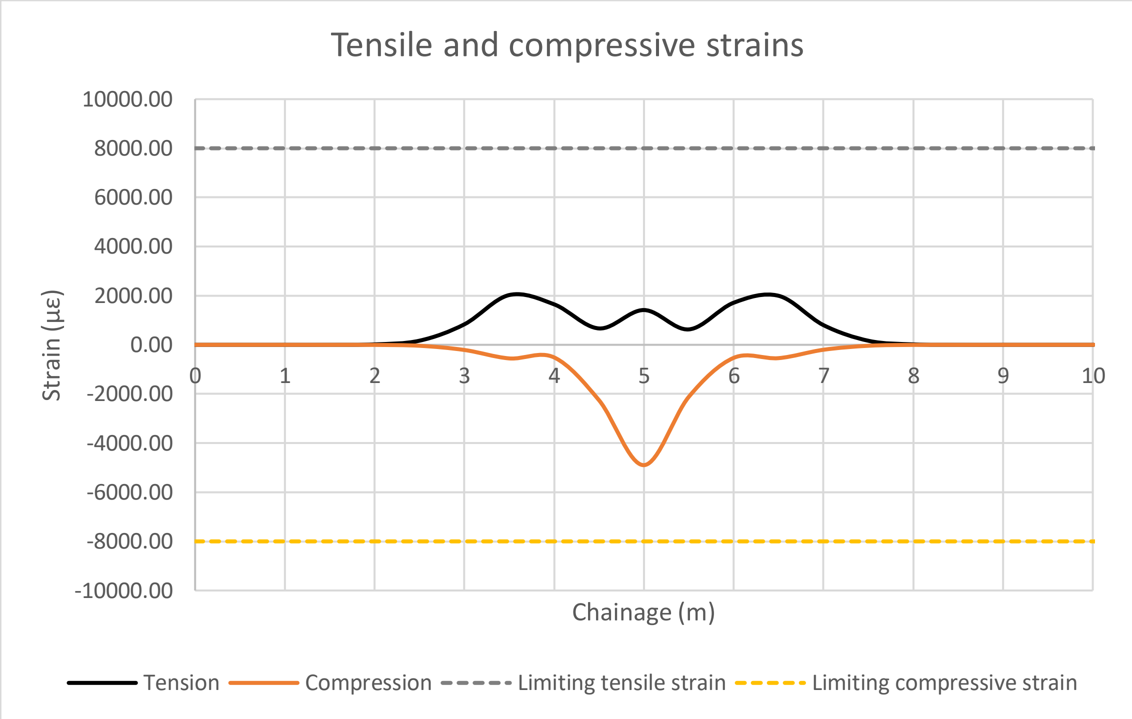

Figure 8-5 Estimated tensile and compressive strains on the DN100 water pipeline at Bulla-Diggers Rest Road

Table 8-3 Second Stage assessment results summary

Crossing	Critical utility	Strain limits (με)		Estiamted max. strain (με)		Impact (see Table 5-3)
		Tension	Comp.	Tension	Comp.	
Bulla-Diggers Rest Road	DN100 PVC water pipeline	8000	8000	2000	4700	Minor
Mickleham Road	DN50 PVC casing	8000	8000	2000	4400	Minor

8.2.4 Recommended environmental management measures

This assessment relies on information obtained from the Construction Science geotechnical investigation (2020) and assumes that the inferred ground conditions would be the same, or similar to, the actual ground conditions encountered along the length of the bore.

Given that the above assessment considered critical conditions and utilities[3], results are considered to reflect the worst-case impact on utilities for the trenchless construction works.

Based on the risk ratings apparent after the preliminary and second stage assessments, the worst-case residual impact is considered to be 'minor' (see Table 5-3 for description of consequence criteria) for all the trenchless crossings where information is available.

At this level of impact, the serviceability of the utilities assessed is unlikely to be affected, implying that no additional EMMs are considered necessary, however the following initial EMMs are considered appropriate:

- EMM GM1 – Third party asset management (initial)

[3] Based on the available geotechnical and asset information (see Section 5.9)

- EMM GM2 – Design and construction to be informed by geotechnical and hydrogeological conditions (initial)
- EMM GM5 – HDD trenchless bore management (initial) to temporarily support the bore during trenchless activities. To manage support fluid pressures, a volumetric drilling fluid tracking program is to be implemented with defined threshold levels for fluid loss, stop works and further investigation.

The application of the above management measures is considered to achieve ‘minimisation’ of the impact. ‘Avoidance’ of impact is not considered to be practicably achievable for the trenchless activities and ground conditions assumed.

Note that liaison with asset owners as EMM GM1 may result in the requirement for additional management measures as requested by that specific asset owner. For example this may include implementation of a settlement monitoring and contingency plan at the railway crossings.

See Section 9 for further detail on the above management measures.

8.3 Trenchless pipe installation encountering unexpected poor ground (Risk GM6)

8.3.1 Crossings with insufficient geotechnical information

This section considers the ground risk involved in conducting horizontal boring or HDD trenchless methods at locations where insufficient geotechnical information is currently available at the anticipated depth of the bore. No further specific assessment has been undertaken at these locations.

The level of risk at each site will also depend on the sensitivity of the existing assets at each crossing. It is therefore considered that where sensitive utilities may exist, the ground risk and damage risk to utilities should be confirmed prior to construction when ground information is made available.

Ground information may be obtained by geotechnical investigations prior to construction or by the contractor’s standard procedures (for example, logging of materials during entry and exit pit excavations, hand augers). Note that APA has planned additional geotechnical investigations at the following locations: Mt. Ridley Road, Parkland Crescent, Sunbury Road, in the vicinity of Oaklands Road, Calder Freeway and Hume Freeway. Table 8-4 below indicates the crossings where the contractor is to determine the risk based on the sensitivity existing utilities.

Table 8-4 Sensitive receptors at ‘unknown’ crossings

Crossing with ‘unknown’ ground	Sensitive receptors	Further confirmation of ground risk
Beatty’s Road	DN100 GRP drainage pipe, DN100 PVC casing pipe, DN400 water pipeline (identified through surface features only) and other minor utilities	Yes
Morefield court	DN100 PVC water pipeline and other minor utilities	Yes
Sunbury Road	DN150, DN375 and DN450 water main, DN100 casing and other minor utilities	Yes

Crossing with 'unknown' ground	Sensitive receptors	Further confirmation of ground risk
St. Johns Road	DN100 water main and other minor utilities	Yes
Oaklands Road	Minor utilities only	No
Mt. Ridley Road / Parkland Crescent	Minor utilities only	No
Donnybrook Road (West)	Communication wire conduit with DN100 PVC casing with two Optus cables and one Telstra cable, DN225 HDPE water pipeline owned by Yarra Valley Water, DN225 PVC drainage pipeline, two electricity cable's owned by Jemena within a DN150 PVC casing and other minor utilities. Note the above utilities are inferred from previously surveyed locations ~400m east of crossing location and actual utilities may vary.	Yes

8.3.2 Crossings subject to blow-out ("fracking") risk

The use of temporary drilling support fluid (such as bentonite) during trenchless HDD operations can result in blow-out (or "fracking"), whereby the drilling fluid leaks through the bore into the surrounding soil, potentially at high-pressures, resulting in escape of the drilling fluid. Other risk pathways associated with escape of bore fluid such as groundwater contamination have not been considered as part of this EES report, and is considered in EES Technical Report D – Contamination.

Blow-out is typically associated with loose, cohesionless granular soils. Based on the available geotechnical information, this is considered to be a rare circumstance for the trenchless crossings. If unexpected conditions arise, initial management measure EMM GM5 – Trenchless bore management is recommended, whereby the contractor is to conduct a detailed hydrofracture analysis to assess the requirements for the implementation of a volumetric fluid tracking program as well as the need for temporary bore stabilisation measures. Successful implementation of this EMM is considered to reduce the risk of blow-out to low, therefore no further impact assessment is deemed necessary.

Some gravel alluvial soil was identified in a borehole in the vicinity of Deep Creek, however APA interpretation of geophysical surveys completed by Black Geotechnical (APA drawing 18035-DWG-L-0006.01 Rev. 03) indicates that the gravel alluvium is not expected to extend to the depth of the proposed HDD. Based on this interpretation, "fracking" would not be anticipated in the weathered rock and cohesive soils and is considered a low risk.

8.3.3 Recommended environmental management measures

The following EMMs are applicable to each of the crossings where there are currently 'unknown' ground conditions:

- EMM GM1 – Third party asset management (initial)
- EMM GM5 – HDD trenchless bore management (initial) to temporarily support the bore during trenchless activities. To manage support fluid pressures, a volumetric drilling fluid

tracking program is to be implemented with defined threshold levels for fluid loss, stop works and further investigation.

The following additional EMM is considered for the 'unknown' sites that also have sensitive receptors, namely, Beatty's Road, Morefield Court, Sunbury Road, St. Johns Road and Donnybrook Road (West):

- EMM GM6 – Confirmation of ground risk (additional) for sites where there is insufficient or no geotechnical information, confirm the viability of proposed temporary works (i.e. choice of trenchless method) by completing additional geotechnical investigations.

Successful application of the above EMMs is considered to result in only negligible to minor impacts to existing utilities or creeks. This is considered to achieve 'minimisation' of the impact. 'Avoidance' of impact is not considered to be practicably achievable given uncertainties surrounding geotechnical risk for any form of trenchless activity. See Section 9 for more detail on the above EMMs.

8.4 Pipeline installation in proximity to existing slopes (Risk GM7)

8.4.1 General

This impact assessment considers the potential for trench excavations to reduce existing slope stability, potentially leading to slope failure. Slope failure would result in significant and potentially widespread impact to sensitive receptors such as natural landforms, farmland and flora and fauna. Excavation of a trench near a slope may act as a destabilising notch near the base of a slope, reducing the natural resistance of the slope to sliding failures. Further minor destabilizing effects induced by the construction works may also contribute to the overall stability of the slope, including surface erosion. This risk is expected to be most prevalent during open trench construction through the valley north of the Jacksons Creek crossing.

The steep slope East of Wildwood Road may also be subject to some slope instability risk, however given that the trench would be excavated up the slope gradient rather than perpendicular to it, different and less critical failure mechanisms would apply.

8.4.2 Description of Jacksons Creek slope

The pipeline is proposed to be installed using open trench methods for the Jacksons Creek crossing. Available geological maps (Heath et al.(2020), Geological Survey of Victoria (1970) suggest that Jacksons Creek is likely incised into basalts of the Springs Hill / Redstone Hill Flow.

Geotechnical boreholes were drilled in the vicinity of the creek, indicating a relatively consistent ground profile comprising clay or gravel alluvium overlying extremely weathered Silurian siltstone. This disagrees with the basalt bedrock inferred from regional geology. It is possible the alluvium at depth may represent a palaeochannel of the modern Jacksons Creek, from which it has been deflected by the gulley fan (Qat2 from Figure 8-6).

Emerson class testing completed on samples retrieved from geotechnical boreholes within the Qat0 and Qat2 areas indicated that high dispersivity of the alluvial soils is to be expected, with Emerson class values of one and two. No geotechnical investigations were completed on the slopes, therefore high dispersivity is inferred for the colluvial soils along the slopes.

A geomorphological assessment was completed by GHD (2020) for the Creek Crossing and surrounds, as summarised in Figure 8-6 below, showing the distribution of geological formations and geomorphological processes. The area shaded in red north of the crossing indicates deep scour and gullying within the valley incised by a tributary to Jacksons Creek at the north of the Crossing. Open trench excavations are proposed through this area, potentially exacerbating erosion effects and therefore compromising stability of the slopes to the east and west of the trench excavations. Figure 8-7 shows evidence of a historical land slip, likely induced by erosion, as photographed during a GHD site walkover undertaken in January 2020.

The maximum slope angle within the area is approximately 28°. Geomorphological evidence of natural slope instability across the site has been observed (Golder, 2019). It is considered that the surficial slope soil comprises a shallow colluvial "mantle" of Newer Volcanic Basaltic soils, as inferred from the geomorphological assessment (GHD, 2020).

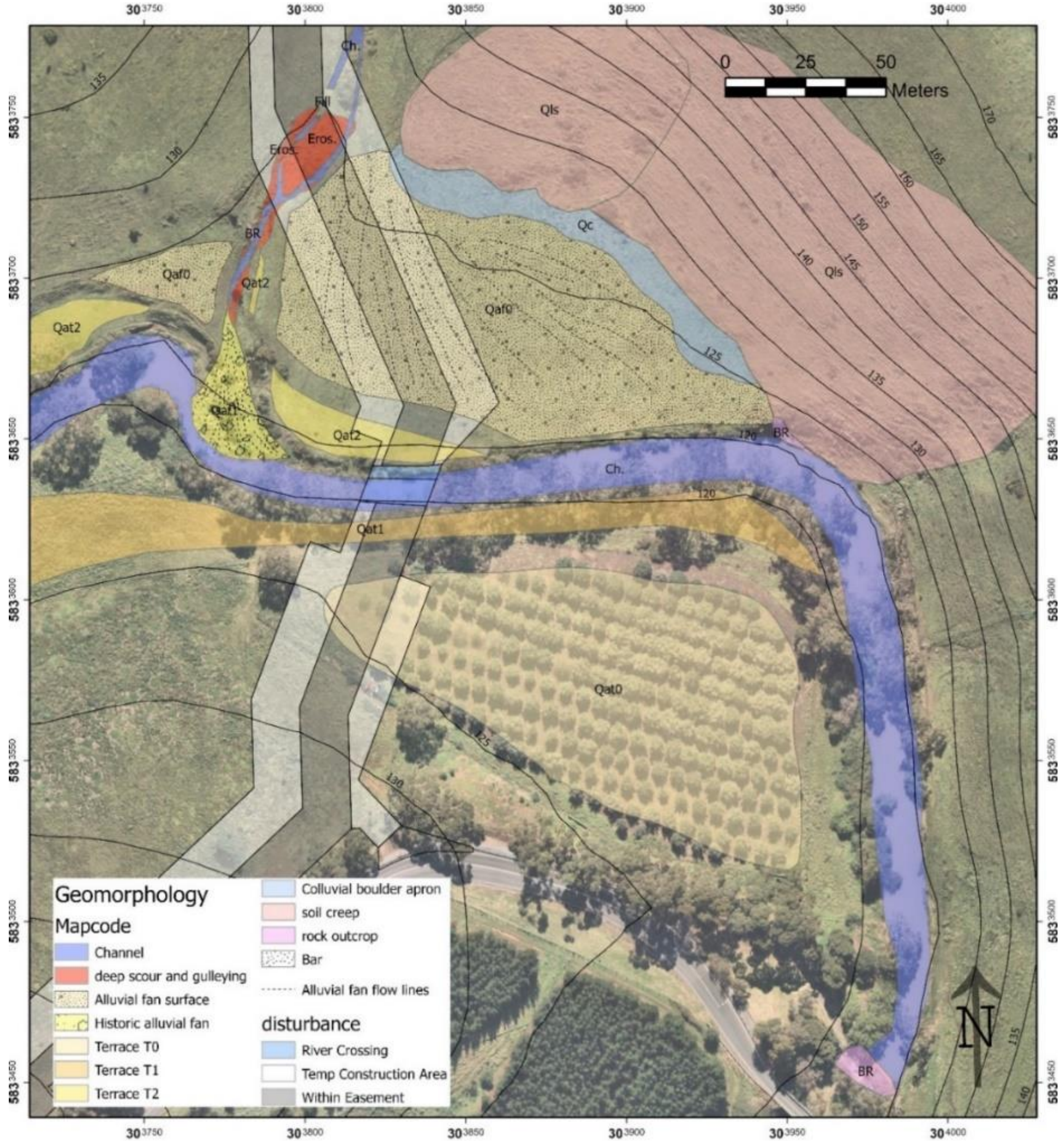

Figure 8-6 Geomorphological map of Jacksons Creek Crossing (GHD, 2020)

Figure 8-7 Evidence of gully erosion north of Jacksons Creek (GHD, 2020)

8.4.3 Slope stability assessment

For slope stability risk, the assessment will assume a slope failure surface parallel to the surface of the slope at a depth that is small compared with the length of the slope. The slope can then be considered as being of infinite length, with end effects being ignored (Knappett, 2012), effectively representing a 'translation slip' slope failure mechanism. The depth of failure surface is taken as the depth of the trench of two metres. Limit analysis methods were used to assess the slope, where a factor of safety is obtained and compared against the likelihood ratings set out in Table 5-4 after Silva et al. (2008). This failure mechanism is considered for the Jacksons Creek Slope, deemed to be the critical slope encountered during pipeline construction. The assessment assumes no trench support.

The assessment has considered the variable ground conditions that may exist during open trench construction near the slopes for three scenarios: an undrained scenario in cohesive soil for temporary stability (scenario 1); a drained scenario in cohesive soil to account for trench being open for long periods by including destabilising effects induced by rainfall events and erosion (scenario 2); and a drained scenario in granular soil to account for the potential of encountering unstable material (scenario 3).

Residual friction angles were derived using the method prescribed in Stark et al. (2005) where applicable to account for possible historical movements of the soil. The trench depth was assumed at 2 m for this assessment. Undrained shear strength for the colluvial cohesive material was assumed to be at 50 kPa (assuming similar properties residual basaltic soil, Construction Sciences, 2020). Factors of safety obtained from the analysis were compared against the likelihood criteria set out in Table 5-4 to determine the likelihood ratings. Table 8-5 below summarises the results.

Table 8-5 Limit analysis results summary (for an unsupported trench)

Scenario		Factor of safety (FoS)	Likelihood of failure
1.	Trench through cohesive material	4.3	Rare
2.	Trench through cohesive material, trench is left open for extended periods. Rainfall events considered.	<1	Almost certain
3.	Trench through granular material	<1	Almost certain

8.4.4 Recommended environmental management measures

Based on the above results, the most likely scenario for a two-metre trench through colluvial cohesive soils (Scenario 1) is not anticipated to be at significant likelihood of immediate failure.

However, if the trench is left open for extended periods of time so that erosion and rainfall events may reduce stability of the trench wall, the factor of safety of the Jacksons Creek slope could be decreased to below one (Scenario 2). This implies that it is important that unsupported trenches in proximity to slopes are not left open for extended periods of time.

Given the low permeability expected for the cohesive soils and the time taken to reach drained conditions, keeping open trench durations to less than three months would be considered desirable.

The last scenario (Scenario 3) assessed the translational slip failure along a cohesionless granular layer into an unsupported trench, returning low factors of safety below one. It is therefore considered necessary that cohesionless granular materials are identified during the trench excavations and managed where appropriate.

The following EMMs are therefore required for the trench excavations to reduce the likelihood of slope failure near Jacksons Creek. Note that these are the same EMMs that have been recommended for all trench excavations (See Section 8.1).

- EMM GM3 – Management of trench stability: support and duration (additional), which broadly includes requirements for trench excavation works to be conducted in accordance with the requirements of the Safe Work Australia Code of Practice: Excavation Work (2018) and WorkSafe Victoria Compliance Code: Excavation (2019) to minimise the risk of trench wall collapse. Furthermore, the time that trenches and bell holes remain open would be minimised as far as reasonably practicable.
- EMM GM4 – Management of trench erosion, consolidation and swelling (initial), through erosion and sediment control measures including the use of trench breakers installed at regular intervals along the trench excavation. Furthermore, compaction of the trench backfill will be required as per APA's performance requirement and/or contractor's construction requirements. Routine inspection and monitoring of the construction area must be undertaken throughout operation as per the VTS OEMP.
- EMM GM7 – Preparation and implementation of sodic soil management measures within the final CEMP (additional)

These EMMs seek to avoid the potential for trench excavations to reduce existing slope stability, potentially leading to slope failure. Application of these EMMs will effectively reduce the likelihoods of Scenario 2 and Scenario 3 to 'rare', indicating negligible residual impacts.

See Section 9 for more detail on the above EMMs.

If wall instability and slope failure is to occur, contingency response measures are to be detailed in the final CEMP and may include, for example, requirements for temporary shoring and the removal, replacement, and rehabilitation of the disturbed soil.

8.5 Permanent groundwater and surface water flow changes as a result of excavations (Risk GM11)

There is potential for permanent alterations to groundwater and surface water flows as a result of the pipeline construction. Unfavourable water flow conditions may cause ongoing erosion effects, reducing long-term slope stability and resulting in land degradation and slope creep throughout operation[4]. If dispersive ("sodic") soils (see Section 6.5) are present, the likelihood of this risk is increased. Application of initial management measure EMM GM4, which includes the usage of trench breakers, adequate compaction of trench backfill and routine monitoring and inspection, is considered to effectively manage the impact under most circumstances, however, may not effectively account for the presence of highly dispersive soils.

Existing geotechnical information has identified dispersive soil behaviour in the 7 locations identified in Table 6-2, however it is considered likely that dispersive soils are present for the majority of the Project area, particularly within areas overlying the Newer Volcanics Basalt.

Without any mitigation, the impact of this may include ongoing degradation of natural landforms and local flora and fauna, slope creep, as well as compromising functionality of nearby farmland at multiple locations along the alignment.

APA are currently considering an appropriate scope of site investigations prior to construction to further identify locations where dispersive soils are present and to classify their severity. The results of these investigations would inform the development sodic soil management measures which may specify management measures appropriate for the level of risk identified for each section of the alignment. Resulting management measures will be captured in the contractors final CEMP.

The following EMMs are therefore recommended to control this risk:

- EMM GM4: Management of trench erosion, consolidation and swelling (initial)
- EMM GM7: Preparation and development of sodic soil management measures (additional)

Application of these EMMs is considered to achieve 'minimisation' of the impact after the mitigation hierarchy. 'Avoidance' is not considered practically achievable given the anticipated extent of dispersive soils throughout the Project area and the variability inherent in geotechnical conditions.

8.6 Cumulative impacts

The following planned projects may induce land stability and ground movement effects cumulatively with the Project:

Table 8-6 Cumulative impact assessment summary

Project	Cumulative risk potential	Cumulative impact
Outer Metropolitan Ring (OMR) Transport Corridor Project (E6).	Cumulative ground movement and land stability risks may arise as a result of the excavation activities required for the construction of the OMR road embankments or from excess ground settlement due to increased surface loading. Generally, these effects are unlikely to overlap with the WORM Project, unless there is significant intersection of the two projects. In these instances, the design of the OMR project may need to consider the existing WORM pipeline as well	Minor, under the application of EMM GM4 and EMM GM7

[4] Note, wider erosion effects such as those associated with streamflow conditions is assessed as part of EES Technical Report B – Surface Water. This assessment considered erosion effects insofar as they may compromise the other land stability risks identified. The effect of dispersive soils on trench and slope stability during construction has been considered in Section 8.1 and 8.4).

Project	Cumulative risk potential	Cumulative impact
	as any existing or ongoing effects caused by the WORM Project. The key cumulative effects between the WORM pipeline and future OMR will be minimised through ongoing coordination between APA and the Department of Transport (DoT), in relation to the WORM pipeline design (depth, location, etc), construction methodology (backfill, compaction, etc) and future accessibility requirements. The WORM will need to be designed and constructed in a way that will minimise any impact to the OMR. APA will enter into a Coordination Deed with DoT to ensure its requirements are met.	
Sunbury Road Upgrade	Cumulative ground movement and land stability risks may arise as a result of the excavation activities required for the construction of the road embankments or from settlement of the ground due to increased surface loading. At the location where the Sunbury Road Upgrade would intersect with the WORM pipeline, the WORM pipeline is installed using trenchless HDD techniques. The ground conditions at the depth of the bore are inferred to be basalt bedrock. This implies that there would be minor to negligible changes to the ground surface or subsurface and that cumulative risks are minimal.	Minor to negligible
Bald Hill to Yan-Yean Pipeline	The proposed Bald-Hill to Yan-Yean Pipeline alignment may cross underneath the North Eastern Railway in the vicinity of the WORM Project crossing of the same railway. At this location, the WORM pipeline is to be installed using trenchless pipe-jack methods with a clearance of approximately 4 m to the railway line. The ground conditions at the depth of the pipe-jack bore are expected to comprise basalt bedrock, implying that minimal adverse effects on the railway line would be expected. Any ground movement assessment completed for the Bald Hill to Yan-Yean pipeline would need to consider the cumulative ground	Minor to negligible

Project	Cumulative risk potential	Cumulative impact
	movements (if any) with the WORM pipeline installation. If the Bald-Hill to Yan-Yean pipeline is to be installed using similar methods and in similar ground to that of the WORM Project, cumulative effects would be minor to unchanged. Liaison with the relevant railway authority would be recommended to confirm any mitigation or contingency requirements, such as the implementation of a settlement monitoring and contingency plan.	
AusNet / Mondo’s Western Victoria Transmission (WVTN) project.	No significant cumulative land stability or ground movement effects are considered to arise as a result of the construction or operation of overhead power lines.	None

9. Environmental management measures

9.1 Recommended environmental management measures

Table 9-1 lists the recommended environmental management measures relevant to land stability and ground movement. In general, these EMMs have been developed in reference to the guidelines outlined in Section 4.1, including the International Erosion Control Association Best Practice Erosion and Sediment Control, Appendix P – Land Based Pipeline Construction (IECA, 2008) and the EPA guidelines 1834 - Civil Construction, building and demolition guide (2020). Application of the mitigation hierarchy is discussed in Section 8 as relevant to each impact assessment.

Table 9-1 Environmental management measures

EMM #	Environmental Management Measure	Stage
GM1	**Third party asset management** Identify and prove all third party services prior to construction and agree vertical and horizontal clearance requirements with asset owners. Liaise with asset owners for any asset within the construction easement to confirm asset clearance and other mitigation, protection or contingency requirements, including possible settlement monitoring at the railway crossings. Where utility crossings occur during open trench construction, the asset protection must be agreed with the provider and adhered to.	Design
GM2	**Design and construction to be informed by geotechnical and hydrogeological conditions** Existing and planned geotechnical and hydrogeological investigations must form the basis of design and inform expected ground and water conditions during construction so that due consideration is given toward the existing ground key issues (such as those identified in Technical report D *Land stability and ground movement*). This information is to: • Provide information on the soil and rock expected to be encountered during all excavations • Provide information on the presence of reactive soils • Provide information on the presence of dispersive (“sodic”) soils Provide information on the locations and extent of groundwater drawdown requirements.	Design

EMM #	Environmental Management Measure	Stage
GM3	**Management of trench stability: support and duration** Carry out trench excavation works in accordance with the requirements of the Safe Work Australia Code of Practice: Excavation Work (2018) and WorkSafe Victoria Compliance Code: Excavation (2019). Measures are also to be considered where potentially unstable ground may compromise the stability of the trench as assessed by a suitably qualified geotechnical engineer. In addition, the time that trenches and bell holes remain open will be minimised as far as reasonably practicable. As a general rule, trenches should not remain open for longer than 3 months and should comply with SafeWork Australia (2018). For some excavations (for example for main line valves, hydrostatic test sections and tie-in locations) this time period may be exceeded and trench wall support is to be provided in accordance with SafeWork Australia (2018). Should failure occur, contingency response actions may include, for example, methods for temporary shoring and the removal, replacement, and rehabilitation of the disturbed soil.	Construction
GM4	**Management of trench erosion, consolidation and swelling** Implement measures to manage soil dispersion, erosion, consolidation and swelling risks including: • Implementation of erosion and sediment control measures in accordance with EPA 1834 guidelines (2020) and is to be informed by the International Erosion Control Association (IECA) Best Practice Erosion and Sediment Control, Appendix P – Land Based Pipeline Construction (2008). This includes the use of trench breakers installed at regular intervals along the trench excavation where necessary (for example, near to existing slopes and where shallow groundwater tables exist) to minimise ongoing erosion caused by altered water flow regimes as a result of trench construction. • Compaction of the trench backfill as per APA's performance requirement and/or contractor's construction requirements. Degree of compaction and design of backfill to take into account design load limits on the pipe and density and permeability of surrounding soil. • Routine inspection and monitoring of the construction area (easement patrols) must be undertaken throughout operation as per the VTS OEMP to identify any issues such as ongoing erosion, ground movement, slope creep or other adverse effects on land use. Management, monitoring and identification of issues may be in accordance with IECA Best Practice Erosion and Sediment Control (2008). Additional erosion control measures in proximity to waterways are contained in EMM SW4. Additional measures for rehabilitation and monitoring of trenched waterways are contained in EMM SW3.	Construction / operation

EMM #	Environmental Management Measure	Stage
GM5	**HDD trenchless bore management** Use trenchless bore support (such as a suitable drilling mud or bentonite) to temporarily support the bore during the trenchless activities in accordance with the guidelines for horizontal directional drilling, microtunnelling and pipe jacking (ASTT, 2009). Prior to construction, undertake a detailed hydrofracture risk assessment where appropriate to confirm that the risk of blow-out is low. Prepare and implement a volumetric drilling fluid tracking program with defined threshold levels for fluid loss, stop works and further investigation. Monitor and manage support fluid to effectively minimise ground deformations and risk of bore collapse in unstable ground to reduce the risk of damage to nearby sensitive receptors as well as the potential for frac-out.	Construction
GM6	**Confirmation of ground risk** For sites where there is insufficient or no geotechnical information, confirm the viability of proposed temporary works (i.e. choice of trenchless method) by completing additional geotechnical investigations. Additional investigations may include shallow surface geophysical methods, trial pitting or drilling as appropriate (subject to environmental or access constraints). Take into account any new geotechnical information at all relevant sites and develop and implement measures for trenchless construction to mitigate the risk of adverse environmental impacts (for example excessive settlement, damage to assets). Relevant sites include Beatty's Road, Morefield Court, Sunbury Road, Oaklands Road, Donnybrook Road (West). Carry out further utility proving works where information is not currently available at the crossing location (including at the Donnybrook Road (West) crossing).	Design / Construction
GM7	**Preparation and implementation of sodic soil management measures** Complete additional site investigations to further identify areas of higher dispersion risk along the alignment (in addition to those listed in Technical report D *Land stability and ground movement* Section 6.3). Develop, document within the CEMP and implement minimum requirements to be put in place to manage dispersive/sodic soils during construction and operation. Management measures may be proportional to the level of risk identified by the additional site investigations and in general accordance with the guidelines contained within Best Practice Erosion and Sediment Control, Appendix P (IECA, 2008) where applicable. A management plan must be developed prior to construction and implemented detailing how sodic soil hazards will be managed during construction. Application of EMM GM4 is also considered to assist in the management of dispersive soils.	Design / construction / operation

9.1 Recommended performance criteria and management

It is noted that no specific scoping requirement exists for the inclusion of performance criteria for the topic of ground movement and land stability. However, recommendations are included below that are considered broadly relevant to the evaluation objectives listed in Table 2-1.

The objective of the monitoring requirements proposed in is to minimise the risk of trench collapse or slope failure, using the indicators of ground movement, settlement and sensitivity of adjacent assets.

Table 9-2 Performance criteria and management

Key issue	Performance criteria
Ground movement	**Construction and operation:** Application of EMM GM1 requires the construction contractor to identify and prove all third party services potentially impacted, prior to construction and liaise with asset owners to confirm asset clearance and other mitigation, protection or contingency requirements, including possible settlement monitoring at the railway crossings.
Land stability	**Construction:** During construction, the contractor would be required to meet the performance criteria in the CEMP for the installation of trench support based on the prevailing conditions during construction (EMM GM3) as well as meeting the Safe Work Australia (2018) requirements for trench excavation. Performance criteria would require the contractor to successfully install support where necessary so that the impact associated with trench instability or slope failure is avoided. The contractors CEMP is also to include methods for contingency response in the case of trench or slope failure that may include, for example, requirements for temporary shoring and rehabilitation of the disturbed soil (EMM GM3). For land stability impacts surrounding sodic soils, performance criteria would require the contractor to implement sodic soil management measures during construction that meet the requirements outlined in APA's CEMP at a minimum. **Operation:** The VTS OEMP is to include requirements for routine inspections and maintenance of the construction area (easement patrols) during operation (EMM GM4). Performance criteria for inspections and monitoring would require APA operational personnel to inspect the construction easement so that any ongoing or immediate issues are identified accurately and timely and associated impacts are minimised. Relevant impacts may be associated with ongoing erosion, ground movement, slope creep or adverse effects on local land use. Management, monitoring and identification of issues (such as those surrounding dispersive soils) may be in accordance with IECA Best Practice Erosion and Sediment Control (2008) where applicable.

10. Conclusion

Purpose

The purpose of this report is to provide a land stability and ground movement impact assessment to inform the preparation of the EES required for the Project. The key issues identified belonging to both land stability and ground movement are summarised below:

Ground movement arising from:

- Trenchless boring
- Trench excavations
- Construction drawdown of groundwater

Land instability arising from:

- Slope instability
- Trench instability
- Erosion

Existing conditions

The existing conditions assessment established a baseline for the ground and groundwater conditions expected along the alignment. Existing conditions were established at a higher level for each of the 45 Project reaches defined as part of this assessment. Based on the existing conditions and in conjunction with the Project description, the land stability and ground movement 'key issues' were prioritised for assessment, indicating that trenchless crossing ground movement, slope stability, trench stability and long-term erosion of dispersive soils were the primary areas to consider for impact assessment.

Impact assessment

The impact assessment considered the following key issues:

- "Volume loss" arising from trenchless crossings in soil resulting in adverse ground movements
- Trenchless pipe installation encountering unexpected poor ground resulting in adverse effects
- Open trench excavations in unstable ground leading to trench wall instability
- Pipeline installation in proximity to existing slopes leading to slope failure
- Permanent ground surface and water flow changes as a result of excavations leading to long-term erosion of dispersive soils

The assessment of ground movement due to trenchless crossings in soil determined the potential degree of asset damage as a result of ground strains. The results indicated that the residual impact may comprise a 'minor' level of damage, however this level of damage is not anticipated to amount to any significant effect on the serviceability of the assessed utilities. Third party asset management (EMM GM1), utilising existing geotechnical and hydrogeological information (EMM GM2) and trenchless bore management (EMM GM5) is considered appropriate to achieve minimisation of the impact.

The assessment of trench and slope stability both indicated that encountering cohesionless granular material could result in trench wall instability and result in localised impact on nearby land, thereby requiring management measures such as the use of wall support to avoid the potential for impact (EMM GM03).

In addition, the presence of dispersive soils throughout the Project area may increase the potential for ongoing erosion during operation of the Project. It is considered that additional testing and analysis is required to effectively identify and assess the risk throughout the Project area. To minimise the impact, the contractor is to implement sodic soil management measures appropriate for the levels of dispersion risk identified for each section of the alignment.

Cumulative impact was considered for four future planned unfractured projects that are likely to intersect with the pipeline, such as the Outer Metropolitan Ring Transport Corridor project. For locations where the two projects are proposed to intersect, trench backfill must be specifically designed.

Environmental management measures

The impact assessment informed the Environmental Management Measures (EMMs) recommended to reduce the potential impact from each of the land stability and ground movement key issues identified. Of the seven proposed EMMs, some are generally considered to be part of the likely standard approaches for this type of project, such as the use of bore support fluid during HDD trenchless crossings or the requirement to meet third party asset clearances. Additional mitigation measures, such as the provision of trench support, or the preparation and implementation of sodic soil management measures during construction and operation, are considered necessary to avoid or otherwise minimise the impact.

Overall, land stability and ground movement impacts are not considered to result in any significant adverse environmental effects under the successful application of the proposed Environmental Management Measures.

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Appendices

Appendix A – Risk assessment

The scoping requirements require a risk-based approach to be adopted during the design of EES studies, so that a greater level of effort is directed at investigating and managing those

The risk assessment as part of the assessment framework for the EES, is described in Chapter 5 Evaluation and assessment framework.

The risk pathways define the cause and effect topics relevant to [technical area] based on an understanding of the existing conditions and the Project activities. The risk pathways are provided in Table A1. Each pathway shows the initial risk rating based on standard management measures, and a residual risk rating based on additional management measures (if required) recommended through the impact assessment process.

The consequence of the risk occurring were assigned using a consequence guide specific for each technical discipline. The consequence guide is provided in Table A2.

The likelihood was assigned using a likelihood guide applied to all technical disciplines. The likelihood guide is provided in Table A3.

The risk rating was determined using the risk matrix developed for this EES. The risk matrix is shown in Table A4.

Table A2 Consequence approach (land stability)

Level	Qualitative and/or quantitative description
Land stability	
Insignificant	Negligible soil disturbance and low erosion potential.
Minor	Some soil disturbance with minor implications for soil erosion or stability.
Moderate	Disturbance or changes to surface soil with moderate implications for soil erosion or stability.
Major	Surface soil, covering vegetation, land function significantly compromised.
Severe	Extensive impact to surface soil, covering vegetation or land function with irreversible soil erosion.
Asset damage	
Insignificant	Ground movements cause a negligible risk of damage to asset. Some strains may be felt by surface structures however no loss to serviceability or aesthetic damage is expected.
Minor	Ground movements cause a slight risk of damage to asset. Strains felt by asset may result in some non-structural superficial or minor aesthetic damage to surface structures,
Moderate	Ground movements cause a moderate risk of damage to asset. Possible structural damage to surface structures (requiring local repairs), and rupture of rigid/inflexible buried utilities.
Major	Ground movements cause a high risk of damage to asset. Expected structural damage to surface structures (requiring extensive repairs), possible damage to flexible utilities.

Level	Qualitative and/or quantitative description
Severe	Ground movements cause a high risk of damage to a significant asset. Expected structural damage to surface structures (requiring partial rebuilding and shoring). Loss of serviceability of flexible utilities.

Table A3 Likelihood approach

Level		Description
1	Rare	The event is conceivable and may occur only in exceptional circumstances
2	Remote	The event could occur but is not anticipated and may occur if certain abnormal circumstances prevail
3	Unlikely	The event is unlikely but could occur if certain circumstances prevail
4	Likely	The event will probably occur in most circumstances
5	Almost certain	The event is expected to occur in most circumstances or is planned to occur

Table A4 Risk rating approach

		Consequence rating				
		Insignificant	Minor	Moderate	Major	Severe
Likelihood rating	Almost certain	Low	Medium	High	Very high	Very high
	Likely	Low	Low	Medium	High	Very high
	Unlikely	Negligible	Low	Medium	High	High
	Remote	Negligible	Negligible	Low	Medium	High
	Rare	Negligible	Negligible	Negligible	Low	Medium

Table A1 Risk pathways

Risk No.	Works Area	Staging		Risk Pathway	Initial Environment Management Measures	Initial Risk			Additional Environmental Management Measures	Residual Risk		
	Pipeline or Compress or or MLV	Construction	Operation	Cause / effect		Consequence	Likelihood	Risk Level		Consequence	Likelihood	Risk Level
GM1	Pipeline	C		Open trench excavations in unstable ground (granular material) Potential instability and collapse of granular material resulting in disturbance to nearby land and native vegetation.	EMM GM4 – Trench; erosion, consolidation and swelling	Moderate	Unlikely	Medium	EMM GM3 – Trench excavation support and duration EMM GM7 – Preparation and implementation of sodic soil management measures	Moderate	Rare	Negligible
GM2	Pipeline	C		Open trench excavations in stable ground (cohesive material) Potential elastic movements within the soil as a result of the trench excavations subjecting nearby sensitive receptors to unacceptable strains.	EMM GM1 – Third party asset management EMM GM2 – Design and construction to be informed by geotechnical and Hydrogeological conditions	Moderate	Rare	Negligible	No additional mitigation measures identified.	Moderate	Rare	Negligible
GM3	Pipeline	C		Construction dewatering in compressible soils Causing consolidation settlement of compressible soils subjecting nearby assets and features to unacceptable strains.	EMM GM1 – Third party asset management EMM GM2 – Design and construction to be informed by geotechnical and Hydrogeological conditions	Moderate	Rare	Negligible	No additional mitigation measures identified.	Moderate	Rare	Negligible
GM4	Pipeline	C		Construction dewatering in dispersive soils Movement of the groundwater table through dispersive soils causing erosion and land disturbance.	EMM GM2 – Design and construction to be informed by geotechnical and Hydrogeological conditions EMM GM4 – Trench; erosion, consolidation and swelling	Minor	Rare	Negligible	No additional mitigation measures identified.	Moderate	Rare	Negligible
GM5	Pipeline	C		"Volume loss" associated with trenchless pipe installation in soil Ground deformations resulting from horizontal boring or HDD in unstable soils subjecting nearby assets and features to unacceptable strains.	EMM GM1 – Third party asset management EMM GM2 – Design and construction to be informed by geotechnical and Hydrogeological conditions EMM-GM5 – Trenchless bore management	Minor	Unlikely	Low	No additional mitigation measures identified. Impact assessment undertaken indicates a lower consequence of damage compared to the initial risk.	Minor	Unlikely	Low
GM6	Pipeline	C		Trenchless pipe installation encountering unexpected poor ground conditions at crossings with insufficient geotechnical data Insufficient information leading to unanticipated asset damage or HDD 'blow-out' during construction.	EMM GM1 – Third party asset management EMM-GM5 – Trenchless bore management	Moderate	Unlikely	Medium	EMM GM6 – Confirmation of ground risk	Moderate	Remote	Low

Risk No.	Works Area	Staging		Risk Pathway	Initial Environment Management Measures	Initial Risk			Additional Environmental Management Measures	Residual Risk		
	Pipeline or Compress or or MLV	Construction	Operation	Cause / effect		Consequence	Likelihood	Risk Level		Consequence	Likelihood	Risk Level
GM7	Pipeline	C		Pipeline construction in proximity to existing slopes Open trench construction causing ground movements, erosion and potential slope instability.	EMM GM4 – Trench; erosion, consolidation and swelling	Major	Remote	Medium	EMM GM3 – Trench excavation support and duration EMM GM7 – Preparation and implementation of sodic soil management measures	Major	Rare	Low
GM8	Pipeline	C		Trench excavations through waterways and wetland areas Open trench waterway crossings resulting in land disturbance as a result of increased erosion effects.	EMM GM3 – Trench excavation support and duration EMM GM2 – Design and construction to be informed by geotechnical and Hydrogeological conditions EMM GM4 – Trench; erosion, consolidation and swelling As well as the following EMMs contained within EEs Technical Report B – Surface Water. EMM SW3 – Develop appropriate Site Rehabilitation measures as part of the Construction Environment Management Plan (CEMP) for disturbance caused by open trench construction EMM SW4 – Develop appropriate control measures as part of the Construction Environment Management and Site Rehabilitation (CEMP)	Moderate	Remote	Low	No additional mitigation measures identified.	Moderate	Remote	Low
GM9	Pipeline	C		Pipeline construction near sites of Special Geological or Geomorphological Significance including the following: -Deep Creek Wildwood Outcrops -Jacksons Creek high level cut off -Hayes Hill Eruption Point -Bald Hill eruption cone -Merri Creek Incised Channel. Ground movement / land instability associated with the construction works causing land disturbance at significant sites.	EMM GM2 – Design and construction to be informed by geotechnical and Hydrogeological conditions EMM GM4 – Trench; erosion, consolidation and swelling	Moderate	Rare	Negligible	No additional mitigation measures identified.	Moderate	Rare	Negligible

Risk No.	Works Area	Staging		Risk Pathway	Initial Environment Management Measures	Initial Risk			Additional Environmental Management Measures	Residual Risk		
	Pipeline or Compress or or MLV	Construction	Operation	Cause / effect		Consequence	Likelihood	Risk Level		Consequence	Likelihood	Risk Level
GM10	Pipeline		O	Pipeline acts as a long term drain in compressible soils Causes consolidation and / or swelling of reactive soils subjecting proximal assets and features to unacceptable ground strains.	EMM GM4 – Trench; erosion, consolidation and swelling	Moderate	Rare	Negligible	No additional mitigation measures identified.	Moderate	Rare	Negligible
GM11	Pipeline		O	Permanent ground surface and water flow changes as a result of excavations Alteration to water flow regimes, especially near watercourses or natural drainage paths, causing ongoing erosion of nearby dispersive soils, land disturbance (gully erosion) or slope creep.	EMM GM4 – Trench; Erosion, consolidation and swelling	Moderate	Likely	Moderate	EMM GM7 – Preparation and implementation of sodic soil management measures	Moderate	Remote	Low

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