REGIONAL ROADS VICTORIA

MAY 2021

BEAUFORT BYPASS ENVIRONMENT EFFECTS STATEMENT

SOILS AND GEOLOGY IMPACT ASSESSMENT

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Beaufort Bypass Environment Effects Statement
Soils and Geology Impact Assessment

Regional Roads Victoria

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ABBREVIATIONS

ASR	Acid sulfate rock
ASS	Acid sulfate soil
BTEX	Benzene, toluene, ethyl benzene, xylenes
CBR	California Bearing Ratio
CEMP	Construction environmental management plan
CHW	Central Highlands Water
DELWP	Department of Environment, Land, Water and Planning
DSE	Department of Sustainability and Environment
EE Act	*Environment Effects Act 1978*
EES	Environment Effects Statement
EMF	Environmental Management Framework
EMP	Environmental Management Plan
EP Act	*Environment Protection Act 1970*
EPA	Environment Protection Authority
ERA	Environmental risk assessment
HESP	Health and Environment Safety Plan
IWRG	Industrial Waste Resource Guidelines
Land SEPP	State Environment Protection Policy (Prevention and Management of Contamination of Land)
MTBE	Methyl ter-butyl ether
NEPC	National Environment Protection Council
NEPM 2013	National Environment Protection (Assessment of Site Contamination) Measure, 1999 Amendment 2013
OMC	Optimum Moisture Content
PAHs	Polycyclic aromatic hydrocarbons
PASS	Potential acid sulfate soil
PSD	Particle size distribution
RRV	Regional Roads Victoria (formerly VicRoads)
SCI	Site Conditions Information
SEPPs	State Environment Protection Policies
TD	Total depth

TDS	Total dissolved solids
TRHs	Total petroleum hydrocarbons
VOCs	Volatile organic compounds
WSP	WSP Australia Pty. Ltd.
WTP	Wastewater treatment plant

EXECUTIVE SUMMARY

GEOTECH AND SOILS CONTEXT

Regional Roads Victoria (RRV) proposes to construct a new duplication section of the Western Highway to bypass the town of Beaufort (the project), linking completed sections of the Western Highway duplication to the east and west of Beaufort. The project would include construction of a dual carriageway, interchanges to connect the township of Beaufort to the Western Highway, several waterway crossings, an overpass of the Melbourne-Ararat rail line and intersection treatments of local roads.

On 22 July 2015, the Victorian Minister for Planning determined that an Environment Effects Statement (EES) would be required for the project under the *Environment Effects Act 1978* (EE Act) to assess potential environmental and social impacts. WSP was engaged by RRV to undertake a project soils and geology impact assessment.

The evaluation objective, outlined in the Department of Environment, Land, Water and Planning (DELWP) 2016 *Scoping Requirements for Beaufort Bypass Project Environment Effects Statement*, relevant to the soils and geology impact assessment is:

- to protect catchment values, surface water and groundwater quality, stream flows and floodway capacity, and avoid impacts on protected beneficial uses.

METHOD

The soils and geology impact assessment is built upon previous preliminary, desktop and intrusive geological and soil investigations. The method utilised in this assessment included the following:

- desktop review
- site investigations that included:
  - geotechnical drilling program
  - laboratory testing
- risk identification and assessment
- impact assessment, resulting from the progressive refinement of the design and assessment of the potential impacts to beneficial users.

The impact assessment consisted of an initial assessment to screen the initial risks rating and where required, identify additional mitigation measures to avoid and minimise potential impacts resulting in a residual impact rating.

EXISTING CONDITIONS

The general topography of all four bypass corridor options is undulating, with gently sloping hills to the east and west of Beaufort, and steeper sections through the Camp Hill area.

The published 1:100,000 geology shown on the Department of Jobs, Precincts and Regions, Victoria, Australia GeoVic website, shows the study area is underlain by:

- Alluvium (Qa1): gravel, sand, silt; variably sorted and rounded; generally unconsolidated; includes deposits of low terraces; alluvial floodplain deposits.

- Incised Alluvium (Na): gravel, sand, silt; minor ferricrete; variably incised.

- White Hills Gravel (-Pxh): Vein quartz conglomerate, sand, silt, clay in fluvial braid plain, outwash fan and colluvial deposits; typically compositionally mature, with ubiquitous well-rounded pebbles and cobbles of reef quartz, lesser more angular vein quartz and bedrock clasts; moderately to well sorted, massive to crudely stratified, cross-bedded and channelled; richly auriferous in places; variably ferruginised, silicified or kaolinized.
- Pyrenees Formation (-Cap): Sandstone and mudstone; dominantly sand-rich turbidite facies; moderately to well-rounded quartz with minor feldspar and lithic grains in quartz silt or clay matrix; medium to thick bedded; unfossiliferous; weathered to partly kaolinised; deep marine deposits. Mostly nonmagnetic, but some parts are weakly to moderately magnetic.
- Beaufort Formation (-Cab): Sandstone, mudstone and black shale; sand-poor turbidite facies tectonically modified to phyllite, quartz-mica or graphitic schist; weathered to partly kaolinised; deep marine deposits.

The sandstones and mudstones of the Pyrenees and Beaufort Formations form the low-lying hills to the north, east and west of Beaufort, while the alluvial deposits and White Hills Gravel are contained within the valleys below the proposed embankments. The more recent Quaternary Alluvium lies above the older Incised Alluvium.

The *Beaufort Bypass Geotechnical Desktop Study* undertaken by Halcrow (2011) studied potential route alignments to the north and south of Beaufort. The report noted the following potential geotechnical constraints:

- potential for small scale slips on low lying hills formed within the Pyrenees Formation and the Beaufort Formation
- compressible soft soils within deposits of colluvium and alluvium and swamp deposits
- basaltic soils with a high shrink-swell potential and high plasticity index (it is noted that these soils lie to the east of the current alignments).

The report contained information from two Site Conditions Information reports relating to investigations for the Burrumbeet to Beaufort and Beaufort to Buangor Western Highway duplications. The ground investigations for these studies are located close to the ends of the proposed alignments and encountered alluvium (Na) and the Beaufort (-Cab) and the Pyrenees (-Cap) Formations. Locations of the historic investigations have been included on Figure 6.3.

A review of aerial photography supplied by VicRoads (2016) was conducted to identify any pre-existing landslides with respect to the proposed bypass corridor options.

A review of Australia's National Heritage List (https://www.environment.gov.au/heritage/places/national-heritage-list) was undertaken regarding the study area. No areas of geological significance were listed within the proposed study area.

Most of the materials encountered from the geotechnical site investigations were stiff to hard. Limited soft/weak materials were encountered as follows:

- BH06: 2.7–3.5 – possibly disturbed by drilling
- BH11: 0.0–0.9 – surface softening in Alluvium/Topsoil
- BH12: 0.0–0.2 – surface softening in Alluvium/Topsoil.

Aggressivity testing was undertaken to identify if there are any soils that would adversely affect the durability of concrete piles. The results were compared to Australian Standard AS 2159-2009 'Piling – Design and installation' for exposure classification applicable to concrete piles. The results of testing are consistent with an exposure classification for concrete piles of 'Non-aggressive' to 'Mild' and therefore indicative of a low potential to impact on design of concrete pile foundations.

A review of PASS database was conducted on the Australian Soil Resource Information System (ASRIS) website (ASRIS 2017). The database indicated low probability of ASS albeit with very low confidence. As the site is not within a coastal area, encountering coastal ASS during the construction works is unlikely.

Soil samples collected as part of the geotechnical assessment reported pH ranging between 4.8 (BH05) and 8.6 (BH01) within the study area, however no field indicators for the presence of ASS were identified.

Based on the study area, surroundings and available information, a Conceptual Site Model has been developed to consider potential impact pathways associated with land contamination. Table ES.1 outlines the key impact pathways considering the source-pathway-receptor scenarios for the study area.

Table ES.1 Conceptual Site Model

SOURCE	CONTAMINANTS OF INTEREST	EXPOSURE PATHWAY	RECEPTORS	
			Human health	**Environment**
Former mining activities, agriculture/ grazing land use, railway land use, unknown historical fill, service stations, former landfill, WTP, etc.	TRH, BTEX, PAHs, VOCs, MTBE, phenols, pesticides/herbicides, heavy metals, sulphides, organics acids, nitrates, ammonia, alkanes, and fluoride	Dermal contact and ingestion	Construction workers	Ecological receptors such as flora and fauna, groundwater, and buildings and structures
		Air inhalation of vapour and dust	Construction workers, commercial and residential users nearby	
		Volatilisation and enclosed space accumulation	Workers in excavations and trenches	Groundwater
		Leaching and groundwater transport	Groundwater users in and near the study area	Soil, groundwater and surface water

RISK AND IMPACT ASSESSMENT

A risk assessment was undertaken in accordance with AS/NZS ISO 31000:2009 Risk Management Process.

For all the main project activity categories (e.g. design, clearing, earthworks, operation, maintenance) impact pathways were created by identifying the project activity/aspect and the primary environmental impact in the risk register. The identification of impact pathways relies on an understanding of the existing environment as defined by the specialist studies, and an understanding of the project activities as dictated by the engineering design. The following risks were assessed for the construction and operation phases of the project:

- excavation exposes acid sulfate soils
- excavation exposes contaminated soil
- excavation causes erosions and sedimentation
- filling causes ground settlement
- construction causes ground instability
- excavation encounters unsuitable soils.

The impact assessment has assessed potential impacts to soils and geology within the study area and identified several mitigations to ensure residual impacts to soils and geology remain low.

Mitigations will include:

- construction environmental management plan (CEMP)
- spoil management strategy
- ASS management plan
- occupational health and environment safety plan (HESP)
- detailed intrusive soil assessment.

KEY FINDINGS

The evaluation objective was assessed by reviewing the existing conditions and undertaking an risk and impact assessment based on environmental management performance required for the project. The assessment concluded that:

- there are no significant differences between the assessed impacts of each of the proposed alignment options
- based on the existing conditions, the potential for contamination to impact the construction and operation of the project is medium. Any potential impacts can be further understood through a soil contamination investigation and laboratory testing for the preferred alignment during detailed design, with appropriate mitigation and/or management measures adopted as part of the Construction Environmental Management Plan (CEMP), resulting in a residual low risk to the project
- based on the existing conditions, the potential for acid sulfate soil (ASS) to impact the construction and operation of the project is considered low. Any potential impacts can be further understood through an ASS investigation and laboratory testing for the preferred alignment during detailed design, with appropriate mitigation and/or management measures adopted as part of the CEMP
- construction impacts on the soil and geology within the study area are likely to have only low potential impacts on the protected beneficial uses of the surrounding land. These minor potential impacts could be mitigated for the preferred alignment by minimising the extent of earthworks
- for all alignment options, there is a high risk associated with encountering unsuitable soils and there is a greater volume of fill material required for embankments than available from excavation of the proposed cuttings. Preliminary geotechnical investigations found that excavated soils are generally of low strength, comprising a high silt content, and dispersive. Earthworks design will need to consider opportunities to treat unsuitable soils for reuse as embankment fill or contain them within zoned embankments to minimise the volume of imported fill. Current findings show that it is likely that significant amounts of fill will need to be imported
- for all alignment options, there is a medium risk for excavation works causing sediments to enter watercourses. These risks can be mitigated through design and the Environmental Management Plan (EMP), which will require the CEMP to include erosion and sedimentation controls, including limiting exposed surfaces during construction, employing sedimentation basins, ensuring works near waterways will be controlled by VicRoads Section 177 EMP and the State Environment Protection Policy (Waters) (SEPP (Waters)) and best practice guidelines. Control measures will be monitored, cleaned and repaired as works progress
- low risks were identified around ground instability and settlement; however, these risks can further be reduced and mitigated during detailed design and through the implementation of standard industry practices.

The risks that have been identified are largely consistent across the alignment options and of a nature that would normally be managed and mitigated through geotechnical and soil contamination investigations, testing as part of design development, along with construction within the framework of an Environmental Management Plan.

1 INTRODUCTION

Regional Roads Victoria (RRV), formerly VicRoads, proposes to construct a new freeway section of the Western Highway to bypass the town of Beaufort (the project), linking completed sections of the Western Highway duplication to the east and west of Beaufort.

On 22 July 2015, the Minister for Planning determined an Environment Effects Statement (EES) would be required under the *Environment Effects Act 1978* (EE Act) to assess the potential environmental effects of the project. The EES includes consideration of four alternative alignments and selection of a preferred bypass alignment which identifies the land to be reserved for the future construction. The EES process provides for identification and analysis of the potential environment effects of the project and the means of avoiding, minimising and managing adverse effects. It includes public involvement and allows stakeholders to understand the likely environmental effects of the project and how they will be managed.

1.1 PROJECT BACKGROUND

The Western Highway is the primary road link between Melbourne and Adelaide. It serves interstate trade between Victoria and South Australia and is a key transport corridor through Victoria's west. Over 6,500 vehicles utilise the Western Highway, west of Ballarat each day. Of these 6,500 vehicles, 1,500 are classed as commercial heavy vehicles. These traffic volumes are expected to increase to approximately 7,500 by 2025 and 9,500 by 2040.

RRV have identified the need to upgrade the Western Highway from Ballarat to Stawell to:

- improve road safety at intersections
- improve safety of access to adjoining properties
- enhance road freight efficiency
- reduce travel time
- provide better access to local facilities
- improve roadside facilities.

As part of planning studies commissioned by the Commonwealth and State Governments, bypass route options around the town of Beaufort have been considered to meet the objectives identified by RRV and the National Land Transport Network's Nation Building Program.

The project would include construction of a dual carriageway, connections to major intersecting roads, interchanges to connect Beaufort to the Western Highway at the eastern and western tie-in points, several waterway crossings, an overpass of the Melbourne-Ararat rail line, and intersection upgrades at local roads and provision for service roads as required.

1.2 PROJECT OBJECTIVES

The objectives of the project are to improve:

- road safety and maintain the functionality of Beaufort's road network
- freight movement and efficiency across the road network
- Beaufort's amenity by removing heavy vehicles
- access to markets and the competitiveness of local industries.

2 PROJECT DESCRIPTION

The project would comprise of an 11 km freeway standard bypass to the north of the township of Beaufort, connecting the two recently duplicated sections of the Western Highway to the east and west of Beaufort. The project would be constructed under a Design and Construct or Construct contract administered by a superintendent at RRV/Major Road Project Victoria (MRPV), following a competitive tender process. Department of Transport would manage and maintain the asset.

2.1 FREEWAY STANDARD BYPASS

The project would connect the duplicated sections of the Western Highway to the east and west of Beaufort via the Option C2 bypass to the north of Beaufort that avoids Snowgums Bushland Reserve and cuts through Camp Hill. The bypass would include the following key components:

- designed as a freeway standard bypass
- approximately 11 km long
- designed to 120 km/hr and sign posted to 110 km/hr for its entirety
- two tie-in interchanges
- one road over rail bridge
- waterway crossings
- diamond interchange to connect with the local road network
- four overpass bridge structures over the local road network.

2.2 INTERCHANGES

The project would have interchanges at the following locations:

- tie-in points to existing Western Highway at the eastern and western ends of the bypass
- diamond interchange at existing local road network connection (Beaufort-Lexton Road).

2.3 BRIDGES AND CULVERTS

The route option would have bridge structures at the following locations:

- road over rail bridge structure for the Melbourne-Ararat rail line
- several waterway bridge structures over Yam Holes Creek
- overpass bridge structures for the existing local road network:
  - Main Lead Road
  - Beaufort-Lexton Road (diamond interchange)
  - Racecourse Road
  - Back Raglan Road.

2.4 ALIGNMENT DESCRIPTIONS

Four alignment options, referred to as Options A0, A1, C0 and C2, were assessed in order to identify a preferred bypass (see Figure 2.1). Following extensive community consultation and technical assessments, Option C2 was selected as the preferred route.

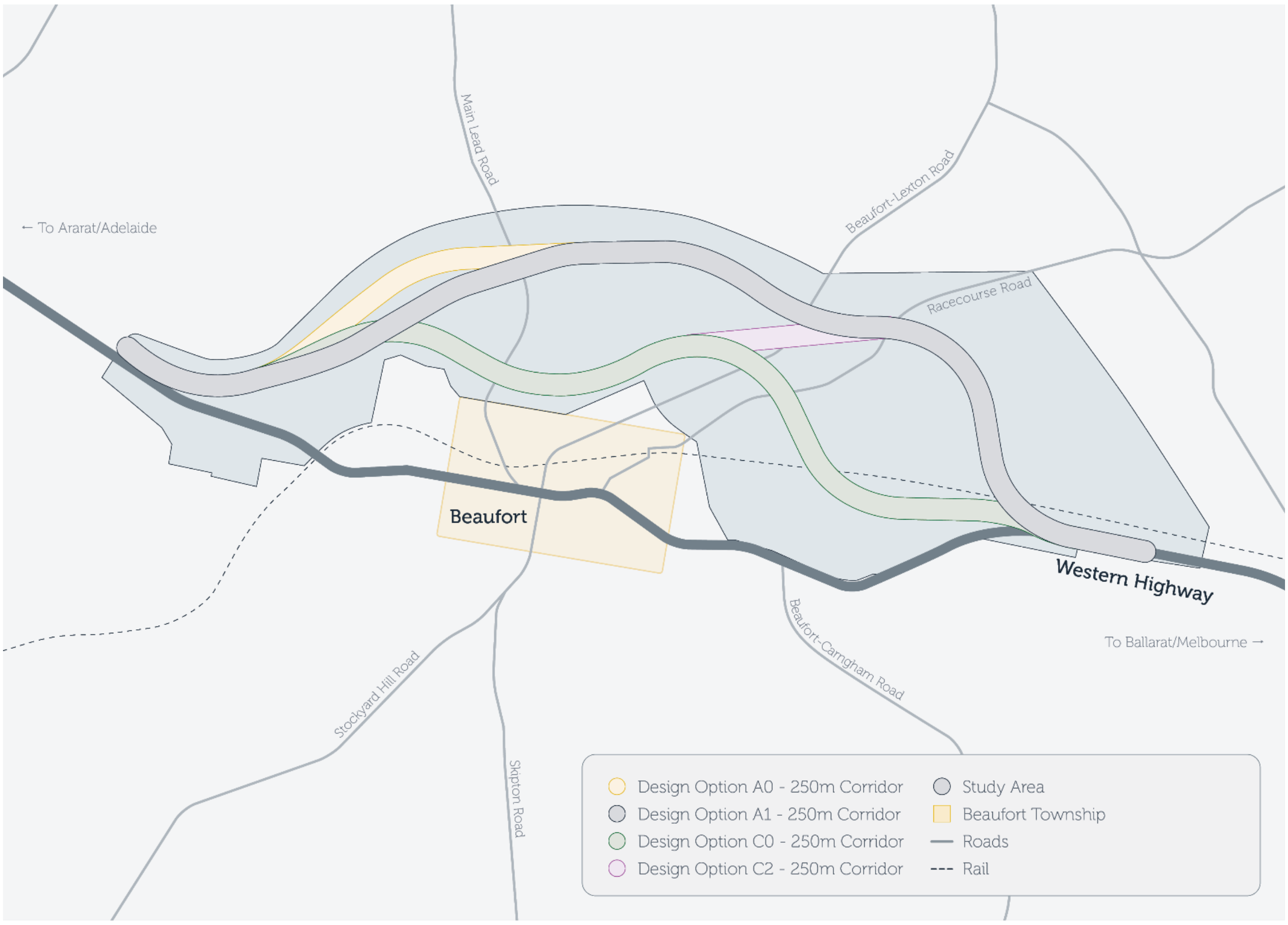

Figure 2.1 Beaufort Bypass alignment options and study area

2.4.1 OPTIONS ASSESSED

2.4.1.1 OPTION A0

The A0 bypass alignment is 11.2 km in length and is the northern most bypass option (see Figure 2.2). From the western tie-in point, approximately 3 km from the Beaufort township, this alignment curves north – north east, where there will be a west-facing, half diamond interchange to maintain access to private properties and the township via the existing Western Highway. The alignment passes over Main Lead Road then climbs through the State Forest north of Camp Hill. From here it descends to a full diamond interchange at Beaufort-Lexton Road, which will provide access to the north and south of the township, before re-joining the Western Highway at its eastern extent, approximately 4.5 km from Beaufort. An outbound exit ramp at the eastern interchange will allow for eastern access to Beaufort via the existing Western Highway. Bridges will pass over Main Lead and Racecourse Roads, as well as over the Melbourne-Ararat rail line. The main areas of fill occur at bridge and interchange locations with a large cut section north of Camp Hill.

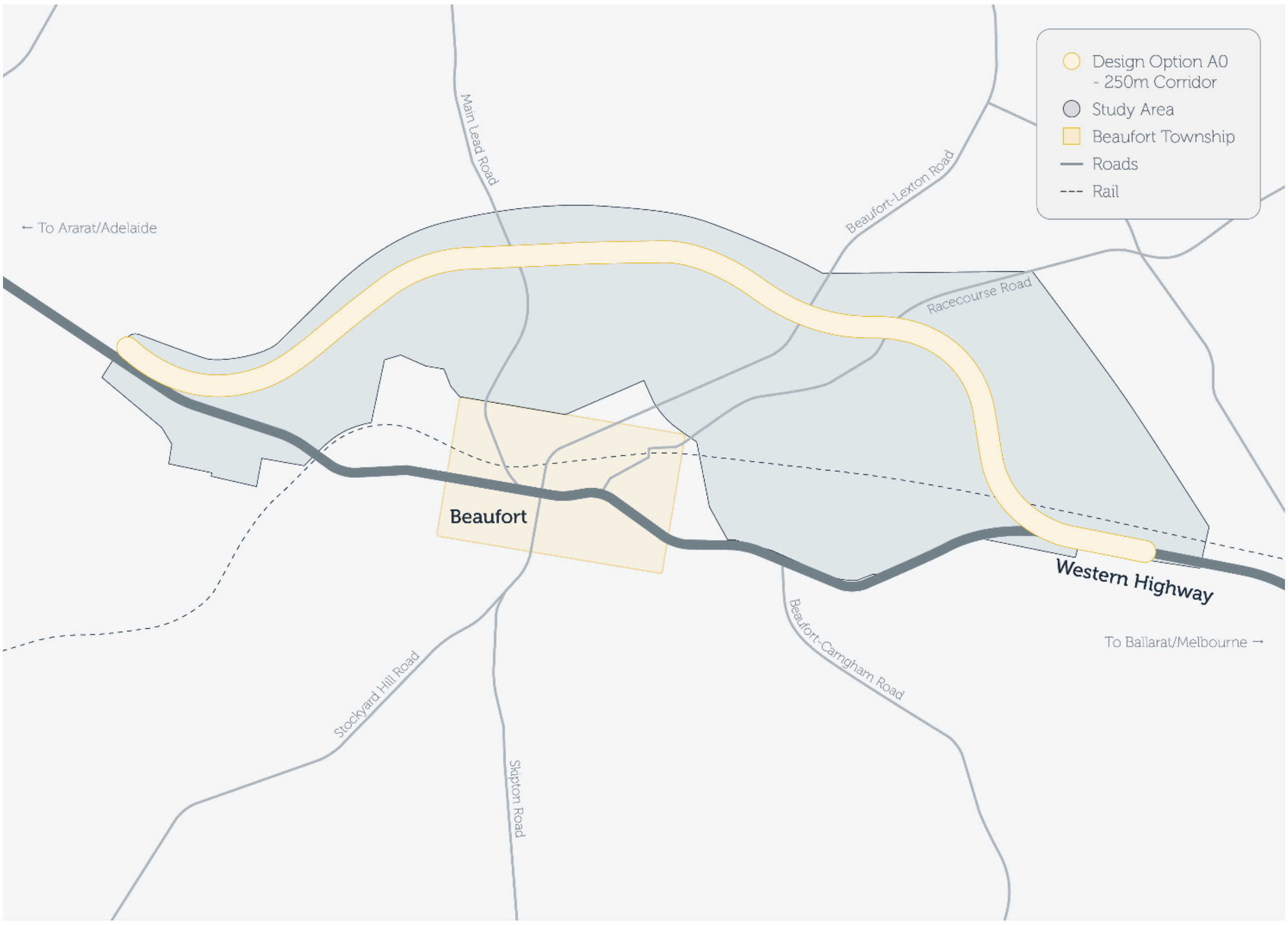

Figure 2.2 Beaufort Bypass A0 alignment option

2.4.1.2 OPTION A1

The A1 bypass alignment option is 11.1 km in length (see Figure 2.3). Approximately 3 km from the Beaufort township, this alignment deviates north-east from the Western Highway, staying slightly south of option A0 until a point east of Main Lead Road, where it re-joins the A0 alignment. There will be a west-facing, half diamond interchange at the western tie-in to maintain access to private properties and the township of Beaufort via the existing Western Highway, and a full diamond interchange at Beaufort-Lexton Road to maintain north-south access. The A1 alignment will re-join the Western Highway approximately 4.5 km to the east of the township. An outbound exit ramp at the eastern interchange will allow for eastern access to Beaufort via the existing Western Highway. Bridges will pass over Main Lead and Racecourse Roads, as well as over the Melbourne-Ararat rail line. The main areas of fill occur at bridge and interchange locations, with cuts north-east of Back Raglan Road, and north of Camp Hill.

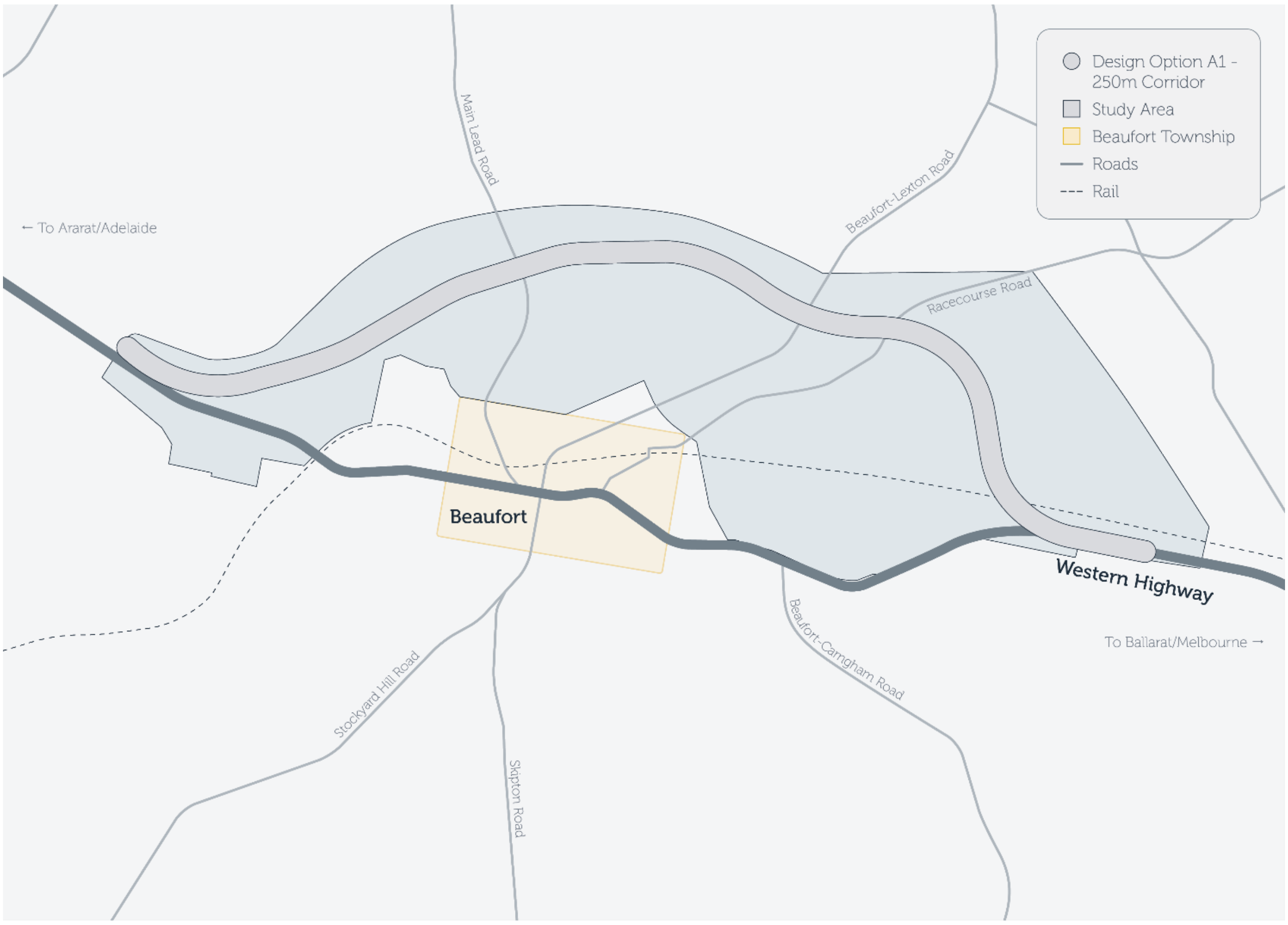

Figure 2.3 Beaufort Bypass A1 alignment option

2.4.1.3 OPTION C0

The southernmost option, C0, is approximately 10.6 km in length from the west to east tie-in points of the Western Highway (see Figure 2.4). Access to the Beaufort township via the existing Western Highway will be maintained by a west facing, half diamond interchange in the west. The C0 option follows the A0 option from the western tie-in point, approximately 3 km from the Beaufort township, before deviating at Back Raglan Road in a more easterly direction almost parallel to the existing Western Highway. This option passes close to the north of Camp Hill, with some cut and fill required in this section, before curving south-east to a full diamond interchange at Beaufort-Lexton Road, providing north-south access. The C0 alignment will re-join the Western Highway approximately 4.5 km to the east of the township. Bridges will pass over Main Lead and Racecourse Roads, as well as over the Melbourne-Ararat rail line. The main areas of fill occur at bridge and interchange locations, with the largest cut and fill areas north and north-east of Camp Hill.

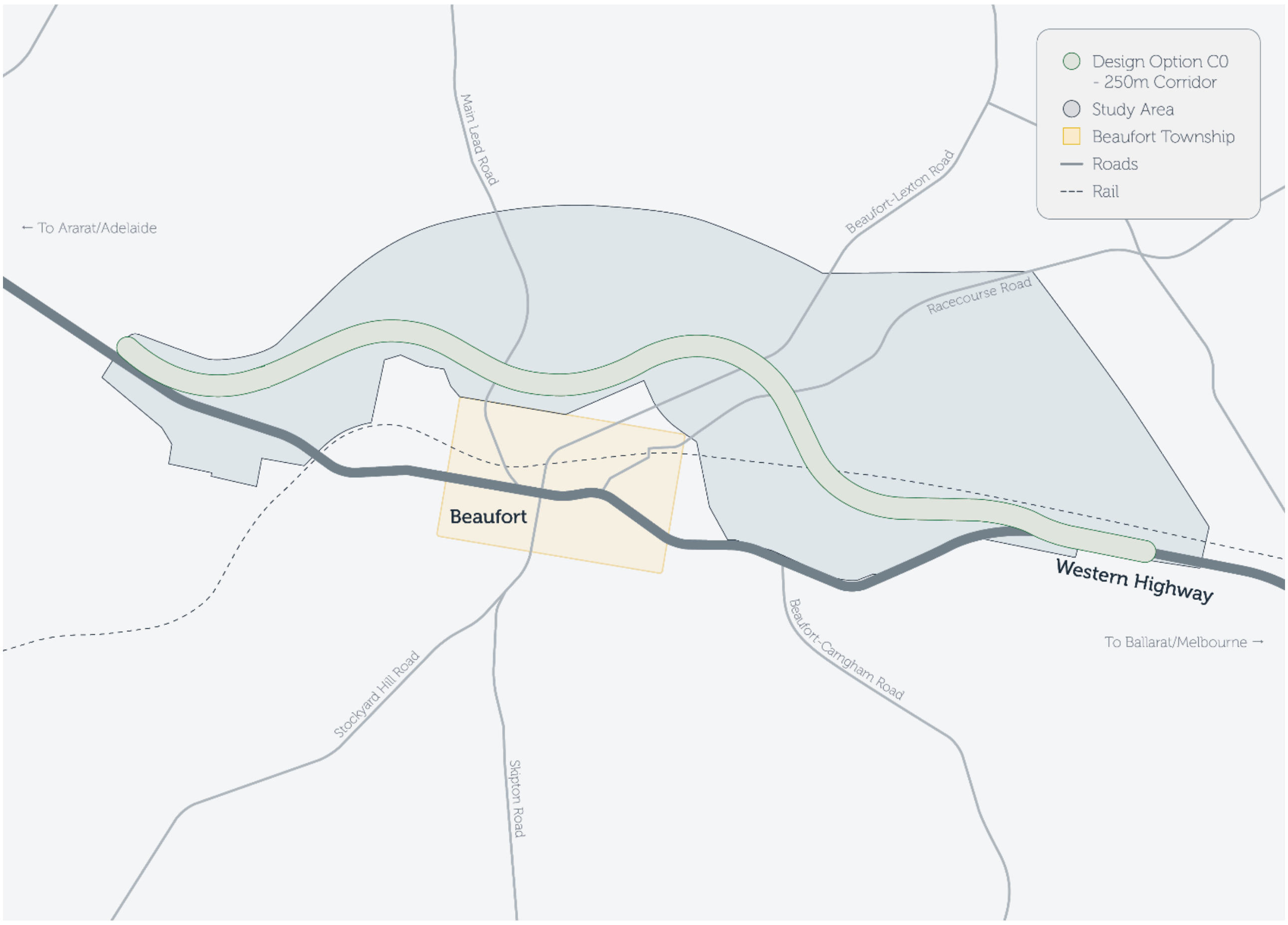

Figure 2.4 Beaufort Bypass C0 alignment option

2.4.2 PREFERRED ALIGNMENT

2.4.2.1 OPTION C2

Option C2 is 11 km in length and is a hybrid between the A0 and the C0 options (see Figure 2.5). It follows the C0 option from the western tie-in point (approximately 3 km from the Beaufort township) until Beaufort-Lexton Road, where it continues in an easterly direction and joins the A0 alignment near Racecourse Road.

The C2 alignment will re-join the existing Western Highway at the eastern tie-it point, approximately 4.5 km from the township. At the western extent, access to Beaufort via the existing Western Highway will be maintained by a half diamond interchange, and there will be a full diamond interchange over Beaufort-Lexton Road. Access to Beaufort via the existing Western Highway at the eastern approach will be maintained by an outbound exit ramp at the eastern interchange. Again, bridges will pass over Main Lead and Racecourse Roads, as well as over the Melbourne-Ararat rail line. The main areas of fill occur at bridge and interchange locations, with the largest cut and fill areas north and north east of Camp Hill.

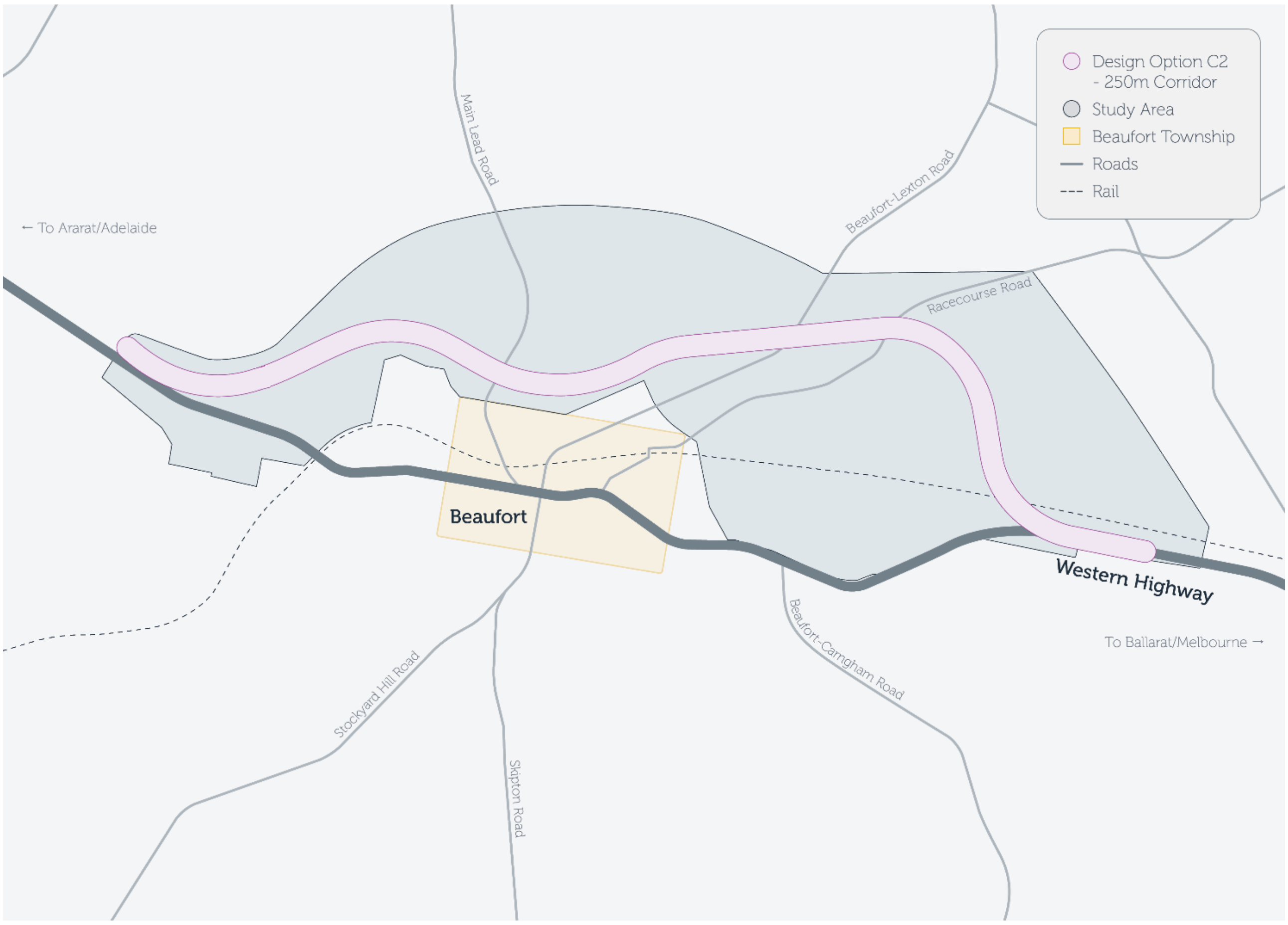

Figure 2.5 Beaufort Bypass C2 alignment option

2.5 PROJECT CONSTRUCTION

The following construction sub-sections describe the construction activities for the project. Construction of the bypass is expected to take two years and commence once construction funding and approvals are obtained.

2.5.1 *CONSTRUCTION ACTIVITIES*

Construction activities would include:

- preconstruction site delineation and compound setup, which may include (but not be limited to) tree clearance and vegetation lopping/removal, and establishment of construction site(s) and access tracks
- establishment of environmental and traffic controls
- route clearance and relocation and/or protection of utilities
- channel realignments to maintain existing flow paths
- construction drainage and sediment and erosion control mitigation
- general earthworks:
  - excavation of a cut including stripping of topsoil and placement of fill
  - import, export and stockpiling of fill
  - treatment of contaminated soil or removal of hazardous material, if required
- development of structures, interchanges, batters, drainage and pavement
- development of ancillary infrastructure:
  - noise barriers
  - lighting
  - safety barriers
  - line marking
- landscaping and site reinstatement.

2.6 OPERATIONS AND MAINTENANCE

Operations and maintenance of the project would be consistent with current practices and standards, including the VicRoads' *Roadside Management Strategy* (2011). Key objectives include:

- asset management of:
  - landscaped areas
  - stormwater drains
  - bridges and culverts
  - road pavement
  - signage
  - barriers
  - line marking
- enhancement of transport safety, efficiency and access
- protection of environmental and cultural heritage values
- management of fire risk
- preservation and enhancement of roadside amenity
- routine and life cycle maintenance activities throughout operations
- monitoring and management of areas of environmental sensitivity such as water bodies and wildlife corridors.

3 EES SCOPING REQUIREMENTS

The *Scoping Requirements for Beaufort Bypass Project Environment Effects Statement* (Department of Environment, Land, Water and Planning (DELWP) 2016) (Scoping Requirements) have been prepared by DELWP on behalf of the Minister for Planning. The Scoping Requirements set out the specific environmental matters to be investigated and documented in the EES, which informs the scope of the EES technical studies.

The following matters of the Scoping Requirements are relevant to the soils and geology impact assessment:

DRAFT EES EVALUATION OBJECTIVE

Catchment values and hydrology: To protect catchment values, surface water and groundwater quality, stream flows and floodway capacity, and avoid impacts on protected beneficial uses.

Table 3.1 EES scoping requirements – Soils and geology

SCOPING REQUIREMENTS SUB-SECTION	MATTER TO BE ADDRESSED	RELEVANT ASSESSMENT	ADDRESSED IN THIS ASSESSMENT
Key issues	Potential changes to the extent and severity of floodwaters in the area, that could have an effect on Beaufort or other significant locations.	Surface water impact assessment	EES Chapter 11: Catchment values and hydrology
	Potential adverse effects on the functions and values of existing waterways during construction and operation.	Surface water impact assessment	EES Chapter 11: Catchment values and hydrology
	Potential for unsuitable soil conditions to support the proposed bypass, including the potential for acid sulfate and contaminated soils.	Soils and geology impact assessment	✓
	Potential for effects on surface water quality, stream flows and ground water, on protected beneficial uses.	Surface water impact assessment	EES Chapter 11: Catchment values and hydrology
		Groundwater impact assessment	EES Chapter 11: Catchment values and hydrology
	Potential for increased salinity, and related impacts on vegetation, soil and habitat values.	Groundwater impact assessment	EES Chapter 11: Catchment values and hydrology
		Flora and fauna impact assessment	EES Chapter 9: Biodiversity and habitat

SCOPING REQUIREMENTS SUB-SECTION	MATTER TO BE ADDRESSED	RELEVANT ASSESSMENT	ADDRESSED IN THIS ASSESSMENT
Priorities for characterising the existing environment	Undertake a hydrology assessment of the study area for the proposed project consistent with outcomes of the Glenelg Hopkins Catchment Management Authority (GHCMA) catchment and modelling study of Beaufort.	Surface water impact assessment	EES Chapter 11: Catchment values and hydrology
	Identify and characterise surface water environments, ground water, salinity and floodplain environments that could be affected by relevant alternatives, including an analysis of drainage features and flood behaviour.	Surface water impact assessment	EES Chapter 11: Catchment values and hydrology
		Groundwater impact assessment	EES Chapter 11: Catchment values and hydrology
	Undertake a geotechnical assessment to identify soil types and structures in the study area and to identify the potential for unsuitable soil conditions to support the bypass, and potential location of acid sulfate, contaminated soils and fill.	Soils and geology impact assessment	✓
Design and mitigation measures	Undertake assessment (modelling) of the hydrology of the study area to inform concept design(s) to minimise the impacts of the proposed project.	Surface water impact assessment	EES Chapter 11: Catchment values and hydrology
	Identify potential and proposed design alternatives and mitigation measures which could avoid or minimise effects on catchment functions and values, for creeks and other surface water environments.	Surface water impact assessment	EES Chapter 11: Catchment values and hydrology
	Identify the potential risks at waterway crossings, and the potential for soil erosion, soil stability, aquifers, acid sulfate, cut and fill and storage of topsoil in flood plains.	Surface water impact assessment	EES Chapter 11: Catchment values and hydrology
		Soils and geology impact assessment	✓
		Groundwater impact assessment	EES Chapter 11: Catchment values and hydrology
	Identify potential and proposed design alternatives and mitigation measures which have the least environmental, social and economic impact.	Interdisciplinary	✓
Assessment of likely effects	Identify potential effects of alternatives on surface water environments especially in relation to run-off impacts on water quality and flood flows.	Surface water impact assessment	EES Chapter 11: Catchment values and hydrology
	Assess the potential for effects of alignment alternatives on groundwater and for effects of groundwater on the proposed project, as a result of intersection works with the groundwater.	Groundwater impact assessment	EES Chapter 11: Catchment values and hydrology

SCOPING REQUIREMENTS SUB-SECTION	MATTER TO BE ADDRESSED	RELEVANT ASSESSMENT	ADDRESSED IN THIS ASSESSMENT
	Assess the potential effects associated with the exposure and disposal of any waste including acid sulfate and contaminated soils	Soils and geology impact assessment	✓
	Identify the potential risks of saline discharges and discharge impacts to soil, vegetation and habitat.	Groundwater impact assessment	EES Chapter 11: Catchment values and hydrology
		Flora and fauna impact assessment	EES Chapter 9: Biodiversity and habitat
	Confirm which alignment alternatives have the greatest risk from a geotechnical perspective and the relative cost implications of each alignment alternative.	Soils and geology impact assessment	✓
Approach to manage performance	Identify proposed principles or approach for managing risks associated with excavation spoil, areas of contaminated land and other waste management.	Soils and geology impact assessment	✓
		Surface water impact assessment	EES Chapter 11: Catchment values and hydrology
	Identify an approach to manage risk and impacts associated with construction and operation.	Interdisciplinary	✓
	Include identified measures in the Environmental Management Framework (EMF).	Interdisciplinary	✓

4 METHODOLOGY

4.1 STUDY AREA

The terminology utilised throughout the current technical assessment relating to the study area and alignment options is defined below.

Study area: The study area for the Beaufort Bypass EES project includes approximately 1,800 ha of land north of the Beaufort township, which contains the four bypass options assessed in this report. During the development stages of the alignment options, the study area was assessed to determine potential environmental impacts and constraints to individual alignment options.

Alignment options: Alignment options (A0, A1, C0 and C2) refer to the four selected bypass options assessed within the study area. Each alignment option consists of a 250 m corridor in which the specific bypass option has been designed. Each alignment option, unless otherwise stipulated, is the area assessed for direct and indirect impacts resulting from the construction, operation and maintenance of the project.

4.2 EXISTING CONDITIONS ASSESSMENT

The soil and geology existing conditions have been established through a combination of a desktop review and preliminary geotechnical investigation.

4.2.1 DESKTOP REVIEW

The desktop study consisted of a review of the following:

- published geology maps
- aerial photographs to identify pre-existing landslides
- historical borehole and groundwater data
- heritage geology database
- Environment Protection Authority (EPA) Victoria environmental audit database and EPA Priority Sites Register
- areas of potential contamination
- acid sulfate soils (ASS) maps on the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Australian Soil Resource Information System (ASRIS).

Salinity has been assessed in the hydrogeology report and aggressivity testing has been conducted as part of the preliminary geotechnical investigation. The key findings relating to salinity are presented in EES Appendix D: *Groundwater impact assessment* (WSP 2021) and historical land uses are also discussed within EES Appendix E: *Historic heritage impact assessment* (Archaeology at Tardis 2021).

The following previous geotechnical study reports were reviewed as part of this report:

- Beaufort Bypass Geotechnical Desktop Study (Halcrow 2011)
- *Geotechnical Desktop Study and Risk Register, Western Highway Beaufort Bypass* (VicRoads 2016a) (Report No: GR158-06.01 PRE.Rev0). Study included a review of:
  - Western Highway Duplication, Burrumbeet to Beaufort, Western End – Box's Track to Carngham Rd, Section 1C, Site Conditions Information (SCI), CN8164, July 2011
  - Western Highway Duplication Project, Beaufort to Buangor, Section 2A, Site Conditions Information (SCI), CN8612, September 2013.

4.2.2 GEOTECHNICAL INVESTIGATION

A preliminary geotechnical investigation was conducted in January 2018. The investigation aims were to provide information on:

- subsurface and groundwater conditions along the proposed alignments at targeted locations based on areas of significant cut or fill, including depth to and condition of rock (if encountered) and thickness of alluvial deposits
- dispersion potential of encountered materials
- settlement potential beneath fill embankments
- suitability of excavated material for reuse as engineered fill
- subgrade suitability
- permanent batter slopes angles for areas of cut.

The fieldwork comprised the drilling of 16 boreholes at locations shown on Figure 6.1. The borehole locations were chosen based on the mapped geology and areas of greatest cut or fill. Three standpipe piezometers were installed in select borehole locations at the completion of drilling to allow for longer term groundwater monitoring.

Several laboratory tests were undertaken on selected samples recovered. The borehole logs from this investigation are included in Appendix A.

4.3 RISK ASSESSMENT

An environmental risk assessment (ERA) has been utilised in the Beaufort Bypass EES to identify environmental impacts associated with the construction and operation phases of the project. The risk assessment process is consistent with the guidance provided in Sections 3.1 and 4 of the *Scoping Requirements for the Beaufort Bypass Project EES* (DELWP 2016) and the *Ministerial guidelines for assessment of the environmental effects under the Environment Effects Act 1978* (Department of Sustainability and Environment (DSE) 2006).

The purpose of the ERA was to provide a systematic approach to the identification and further assessment of potential impacts resulting from the project, whether they be environmental, social or economic. The ERA articulates the probability of an incident with environmental, social or economic effects occurring and the consequence of that impact to the environment. Identified potential impacts with a medium or higher initial risk are subject to detailed impact assessment and mitigation treatments, detailed within each discipline impact assessment

RRV defines risk and impact as:

- The project adopts the definition of environmental risk proposed by the Ministerial guidelines, that: "e*nvironmental risk reflects the potential for negative change, injury or loss with respect to environmental assets*". This approach correlates with ISO 31000: 2018, which defines risk as "*the effect of uncertainty of [environmental] objectives*". Both definitions reflect the fact that risk is normally expressed in terms of the likelihood of a change occurring and the consequence of that change.
- Environmental impact is described as any change to the environment as a result of a project activities.

The risk assessment is a critical part of the EES process as it guides the level and range of impact assessment for the EES and facilitates a consistent approach to risk assessment across the various disciplines.

4.3.1 RISK ASSESSMENT PROCESS

The ERA has guided the environmental impact assessment for the project. The objectives of the ERA are to:

- identify primary environmental risks that relate to the construction and operation of the project
- guide the level and extent of investigation and data gathering necessary for accurately characterising the existing environment and assessing the project's environmental impact
- help identify mitigation measures to avoid, minimise and mitigate environmental risks
- inform assessment of likely residual effects that are expected to be experienced after standard controls and proposed mitigations have been implemented.

The risk assessment process for the EES adopts a risk management framework as detailed in the VicRoads Environmental Sustainability toolkit. The process includes:

- an approach to environmental management which is aligned with ISO 31000: 2018
- systems used to manage environmental risk and protect the environment, and how these are implemented at different stages of road construction, operation and maintenance
- tools and reporting requirements which provide guidance in managing environmental issues throughout the project.

The ERA identifies impact events for each relevant element of the environment, details the primary risks and has informed the level and range of technical reporting required to address predicted impacts. The ERA utilises a risk matrix approach where the likelihood and consequence of an event occurring are considered (Table 4.1, Table 4.2 and Table 4.3). All risks are reassessed at regular intervals during all phases of the project, from the development of the EES to operation and maintenance, to ensure they are still applicable, that controls are appropriate and effective, and that they reflect most recent outcomes of specialist technical studies.

Table 4.1 Risk assessment matrix

			LIKELIHOOD				
	Risk categories		**Rare (A)**	**Unlikely (B)**	**Possible (C)**	**Likely (D)**	**Almost Certain (E)**
CONSEQUENCE	**Catastrophic**	**5**	Medium	High	High	Extreme	Extreme
	Major	**4**	Medium	Medium	High	High	Extreme
	Moderate	**3**	Low	Medium	Medium	High	High
	Minor	**2**	Negligible	Low	Low	Medium	Medium
	Insignificant	**1**	Negligible	Negligible	Negligible	Low	Low

Based on the project objectives and context, a draft set of project-specific and appropriate assessment, likelihood and consequence criteria were developed.

The likelihood categories and consequence descriptions are used as a guide for evaluating risk and are shown below in Table 4.2 and Table 4.3.

Table 4.2 Likelihood categories

RARE (A)	**UNLIKELY (B)**	**POSSIBLE (C)**	**LIKELY (D)**	**ALMOST CERTAIN (E)**
Less than once in 12 months OR 5% chance of recurrence during course of the contract.	About once in 6 months OR 10% chance of recurrence during course of the contract.	About once in 4 months OR 30% chance of recurrence during course of the contract.	About once in 2 months OR 50% chance of recurrence during course of the contract.	About once in a month OR 100% chance of recurrence during course of the contract.
The event may occur only in exceptional circumstances.	The event could occur but is not expected.	The event could occur.	The event will probably occur in most circumstances.	The event is expected to occur in most circumstances.
It has not happened in Victoria but has occurred on other road projects in Australia.	It has not happened regionally but has occurred on other road projects in Victoria.	It has happened in the Beaufort region.	It has happened on an adjoining section of the Western Highway	It has happened on more than one of the adjoining Western Highway projects OR It has happened multiple times on an adjoining Western Highway project.

Consequence criteria have been developed for the project in consultation with technical specialists. The result is a discipline and aspect-specific set of consequence descriptors used to define what would be considered an Insignificant, Minor, Moderate, Major and Catastrophic consequence associated with a risk event.

Table 4.3 Soils and geology ERA consequences descriptors

ASPECT	**INSIGNIFICANT**	**MINOR**	**MODERATE**	**MAJOR**	**CATASTROPHIC**
Land Contamination (historic, construction and operations)	Insignificant risk of encountering historic land contamination during construction or contaminating land through construction or operation	Potential for minor land contamination, but minimal risk to sensitive receptors.	Potential for moderate land contamination, some risk to sensitive receptors.	Potential for gross land contamination, confined to a localised area. Significant risk to sensitive receptors, health.	Potential for gross and widespread land contamination. Significant risk to sensitive receptors, health.

ASPECT	INSIGNIFICANT	MINOR	MODERATE	MAJOR	CATASTROPHIC
Acid Sulfate Soils	Insignificant risk of encountering ASS	Potential for encountering ASS with net acidity <0.03 (PASS) but at depth and not affecting the construction works.	Potential for encountering ASS with net acidity <0.03% (PASS) and construction activity likely to excavate ASS requiring management.	Potential for encountering ASS with net acidity >0.03% (actual ASS) and construction activity likely to excavate actual ASS requiring management.	
Erosion/sediment generation potential	Negligible potential	Potential for erosion and sediment mobilisation in small isolated locations along the alignment.	Potential for erosion and sediment mobilisation in multiple locations along the alignment.	Potential for erosion and sediment mobilisation along most of the alignment.	Potential significant erosion, sediment generation or land instability along most of the alignment.
Soil settlement due to poor (compressible) ground conditions leading to inundation.	No potential	Potential for significant soil settlement in small isolated locations along the alignment resulting in isolated or marginal change to waterway flow regime or floodplain function.	Potential for significant soil settlement in multiple locations along the alignment resulting in marginal changes to waterway flow regime or floodplain function at several localised areas.	Potential for significant soil settlement along many sections of the alignment resulting in a significant change of waterway or floodplain function at several localised areas.	Potential for significant soil settlement along most of the alignment resulting in extensive impact to waterway flow regime or floodplain function throughout the catchment.
Land instability	No risk of land instability	Potential for land instability in small isolated locations along the alignment.	Potential for land instability in multiple locations along the alignment.	Potential for land instability along many sections of the alignment.	Potential for land instability along most of the alignment.

The risk assessment was undertaken for each discrete alignment option as each option had a distinct profile, type and extent of environmental impacts. The assessment of these impacts is detailed within Sections 7 and 9 of this report.

See Appendix B for outcomes of the ERA process.

4.4 IMPACT ASSESSMENT

The impact assessment for the project has utilised the ERA to inform the areas for further investigation. Impacts assessed within this assessment have typically been identified as having a medium or higher initial risk within the risk assessment when standard controls were applied. Impact assessments were prepared in two stages, initially to inform the options assessment and following the selection of the preferred alignment, impact assessment was revised to report impacts and mitigations specifically on the preferred alignment. The technical report describes and assesses impacts in terms of the following:

- description of impact
- identification of whether impacts are direct or indirect
- prediction of the magnitude, extent and duration of impact
- overall rating of impact (without mitigation)
- residual rating of impact (with mitigation).

The impact assessment considers the impact of the proposed bypass on the soils and geology through the following parameters.

4.4.1 IMPACT PATHWAYS

Several impact pathways were identified. These pathways are the cause and effect pathway or relationship that exists between a project activity and the soil and geology. For each impact pathway, an impact on the soil and geology is described.

4.4.2 IMPACT EVALUATION

The impact of each of the alignment options on the soil and geology has been evaluated based on the evaluation objectives outlined in Section 3. Assessment criteria have been developed for each alignment in consultation with RRV for different sub-objectives. Results of the impact assessment are provided in Section 7 of this report.

4.5 MITIGATION

Mitigations for identified impacts were developed by discipline specialists in consultation with RRV. All identified mitigations developed for the project have been informed by specialist experience with proven feasible control measures for major civil infrastructure projects, industry best practice measures and regulatory measures defined by State, Commonwealth and International standards and agreements.

Mitigations for the project were developed throughout the impact assessment process to inform the residual impacts of the preferred alignment defined in Section 11.

4.6 OPTIONS ASSESSMENT

The alignment refinement for the Beaufort Bypass has been undertaken in three distinct phases since project inception. These are discussed in EES Attachment IV: *Options assessment* as:

- Phase 1 – Concept alignment development
- Phase 2 – Option development and assessment
- Phase 3 – Identification of preferred alignment.

This options assessment method section considers the Phase 3 assessment and details the process for selection of the preferred alignment.

The Phase 3 assessment considered four alignment options to select the preferred alignment, utilising a customised comparative options assessment to rank each option against the following areas:

- biodiversity
- catchment values and hydrology
- cultural heritage (Aboriginal and historic)
- social and community
- amenity
- landscape and visual.

Multiple scoring scenarios and sensitivity testings were undertaken against each option to ensure the environmental, social, heritage and economic assessment criteria aligned with the EES evaluation objectives. The scoring framework developed sought to ensure a wholistic decision-making process was undertaken, and that no single scoring or sensitivity scenario would be the primary determining factor in the identification and selection of the preferred alignment.

Weightings for the assessment included the application of six scenarios and sensitivity tests to eliminate bias of specific environmental constraints. These scenarios included:

- Scenario 1: Apply a score of 1 to 4 from least to highest impact.
- Scenario 2: Alignment with highest number of least impact scores.
- Scenario 3: Apply a score of 1 to the highest impact and the subtract the percentage difference between alignments.
- Scenario 4: Apply a score of 1 to least impact and then add the percentage difference between remaining alignments.
- Scenario 5: As per Scenario 3, but minus criteria that can be mitigated.
- Scenario 6: As per Scenario 4, but minus criteria that can be mitigated.

The sensitivity tests included:

- Scoring sensitivity scenario 1:
  - Options with the lowest impact and other options within 5% of the lowest impact are apportioned a score of one point and a green light.
  - Options within 5–20% of the lowest impact option are apportioned a score of zero points and an amber light.
  - Options with an impact of 20% or greater than the lowest impact option are apportioned a score of minus one and a red light.
- Scoring sensitivity scenario 2:
  - Options with the lowest impact and other options within 5% of the lowest impact are apportioned a score of one point and a green light.
  - Options within 5–25% of the lowest impact option are apportioned a score of zero points and an amber light.
  - Options with an impact of 25% or greater than the lowest impact option is apportioned a score of minus one and a red light.

- Scoring sensitivity scenario 3:
  - Options with the lowest impact and other options within 5% of the lowest impact are apportioned a score of one point and a green light.
  - Options within 5–15% of the lowest impact option are apportioned a score of zero points and an amber light.
  - Options with an impact of 15% or greater than the lowest impact option is apportioned a score of minus one and a red light.

The assessment process included an iterative process with RRV, the Technical Reference Group (TRG), legal and discipline specialists to refine the assessment environmental risk workshops and develop a customised assessment matrix. The suite of assessment criteria is detailed within EES Attachment IV: *Options assessment* (RRV 2019).

5 LEGISLATION

This section assesses the project against the Commonwealth and State legislation, policies and guidelines relevant to the soil and geology assessment.

5.1 COMMONWEALTH LEGISLATION

The National Environment Protection Council (NEPC) provides guidance to establish nationally consistent approach to the assessment of site contamination to ensure sound environmental management practises by the community which includes regulators, site assessors, environmental auditors, landowners, developers and industry. The *National Environment Protection (Assessment of Site Contamination) Measure, 1999 Amendment 2013* (NEPM 2013) guidelines aim to provide adequate protection of human health and the environment where site contamination has occurred, through the development of an efficient and effective national approach to the assessment of the site contamination.

The NEPM 2013 is made under the *National Environment Protection Council Act 1994* and is given effect by individual legislation and guidelines in each state and territory. The NEPM 2013 provides site assessment criteria for soil, groundwater and vapour for several beneficial uses of the land and groundwater.

5.2 STATE LEGISLATION, REGULATION AND POLICY

Key State legislation, policies, standards and best practice guidelines are outlined in Table 5.1 below.

Table 5.1 Key State legislation, policies and guidelines

LEGISLATION / POLICY / GUIDELINE	DESCRIPTION	PROJECT RELEVANCE
Environmental Effects Act 1978	Assessment of the potential environmental, cultural and social impacts of proposed public works in Victoria may be required before works can proceed. This assessment process is done through the preparation of an EES guided by the *Environment Effects Act 1978*. The process aims to identify negative impacts and develop mitigation measures to suit the local environment.	On 22 July 2015, the Minister for Planning determined that an EES was required for the project due to the potential for significant effects.
Environment Protection Act 1970	The *Environment Protection Act 1970* (EP Act) aims to prevent pollution and environmental damage by setting environmental quality objectives and establishing programs to meet them. The EP Act establishes the powers, duties and functions of the EPA. These include the administration of the Act and any regulations and orders made pursuant to it, recommending State Environment Protection Policies (SEPPs), issuing works approvals, licences, permits, pollution abatement notices and implementing National Environment Protection Measures.	The EP Act is the overarching legislation for environment protection and is applicable to all projects.

LEGISLATION / POLICY / GUIDELINE	DESCRIPTION	PROJECT RELEVANCE
Environment Protection Amendment Act 2018	The *Environment Protection Amendment Act 2018* will take effect in 2021 and provides the foundation for the transformation of Victoria's environment protection laws and the EPA. This Act focuses on preventing waste and pollution impacts rather than managing those impacts after they have occurred. New guidelines are under development by EPA and will be released following implementation of the *Environment Protection Amendment Act 2018*. Central to the Environment Protection Amendment Act is the general environmental duty (GED). Under the GED businesses must understand the risk from their activities and how to address them. The extent of measures undertaken depends on how much risk the business' activities pose to human health and the environment.	The EPA Act will instruct the legislative changes for environmental protection.
State Environment Protection Policy (Prevention and Management of Contamination of Land) ('the Land SEPP')	The State Environment Protection Policy (Prevention and Management of Contamination of Land) ('the Land SEPP') sets out the regulatory framework for the prevention and management of contaminated land within the State of Victoria. The framework has been developed around the concept of protecting beneficial uses of land and groundwater.	The SEPP gives limited land-use designations. Given the proposed use of the study area as a road, the most appropriate land use designation under the 'Land SEPP' is 'Recreational/ Open Space', consisting of general open spaces and public access areas. The beneficial uses associated with recreation/open space land use are highlighted in Table 5.2 (Section 5.3) below.
Industrial Waste Resource Guidelines (IWRG) 2009	Under the *Environment Protection Act 1970*, the EPA provides a regulatory framework for the handling, management and disposal of prescribed industrial waste due to the potential risks that soils pose to human health and environment. EPA Publication 621 *Soil Hazard Characterisation and Management* provides analytical criteria to categorise the soil into Category A, B, C or Fill Material to determine disposal or management options.	Governs the disposal requirements where soil disposal is required within the study area.
Acid Sulfate Soil and Rock Publication 655.1 (July 2009)	The *Acid Sulfate Soil and Rock Publication 655.1* provides guidance to landowners, developers, consultants and other people involved in the disturbance of soil, sediment, rock and/or groundwater about identifying, classifying and managing acid sulfate soils and rock.	The project is likely to require excavation of soil. Soil testing and classification to identify potential ASS is required for spoil management and constructability purposes during construction.

LEGISLATION / POLICY / GUIDELINE	DESCRIPTION	PROJECT RELEVANCE
Industrial Waste Management Policy (Waste Acid Sulfate Soils) 1999 (17 August 1999)	The *Industrial Waste Management Policy (Waste Acid Sulfate Soils) 1999* provides guidelines for the management of waste ASS and rock.	The project is likely to require excavation of soil. Soil testing and classification to identify potential ASS is required for spoil management and constructability purposes during construction.
Landfill Management Guidelines	The EPA (2015) Publication 788.3 *Best Practise Environmental Management – Siting, design, operation and rehabilitation of landfills* provides existing and future operators of landfills, planning authorities and regulating bodies with: — information on potential impacts of landfills on the environment and how these are to be mitigated — a clear statement of environmental performance objectives for each segment of the environment — information on how to avoid or minimise environmental impacts, including suggested measures to meet the objectives.	Potential former or existing landfills could impact on the constructability and on-going management requirements associated with the project.

5.3 GUIDELINES

Given the proposed use of the project will be a road, the most appropriate land use designation under the 'Land SEPP' is 'Recreational/Open Space', consisting of general open spaces and public access areas. The beneficial uses associated with 'Recreation/Open Space' land use are highlighted in Table 5.2 below.

Table 5.2 Protected beneficial uses of land

BENEFICIAL USES	LAND USE						
	Parks and reserves	Agriculture	Sensitive use: High density	Sensitive use: Other	Recreation / open space	Commercial	Industrial
Maintenance of Natural Ecosystems	✓						
Maintenance of Modified Ecosystems	✓	✓		✓	✓		
Highly Modified Ecosystems		✓	✓	✓	✓	✓	✓
Human Health	✓	✓	✓	✓	✓	✓	✓
Buildings and Structures	✓	✓	✓	✓	✓	✓	✓
Aesthetics	✓		✓	✓	✓	✓	
Production of food, flora and fibre	✓	✓		✓			

* The above table is a reproduction of Table 1 from the Land SEPP (June 2002)

Where excavated soil is to be reused within the study area, the Land SEPP requires soil to be assessed against the open space/recreation guidelines specified in the NEPM 2013.

Where soils are to be transported off-site, this process will be managed in line with the requirements of IWRG 2009.

There are no published numeric criteria specific to the assessment of aesthetic impact. However, the Land SEPP states that '*contamination must not cause the land to be offensive to the senses of human being*s. NEPM 2013 also states that site assessment requires balanced consideration of the quantity, type and distribution of foreign materials or odours in relation to the specific land use and its sensitivity. Fundamentally, the soil should not be discoloured, malodorous or of abnormal consistency.

The beneficial use of building and structures will be assessed in accordance with *Australian Standard 2159 -2009 Piling Design and Installations*.

6 EXISTING CONDITIONS

A review of the desktop and historical information was undertaken to understand the existing conditions of the study area relating to soils and geology to assess impacts of construction and operation of the project.

6.1 SETTING

6.1.1 ROUTE ALIGNMENT AND TOPOGRAPHY

The general topography of all four bypass corridor options is undulating, with gently sloping hills to the east and west of Beaufort, and steeper sections through the Camp Hill area (Figure 6.1). The proposed construction approach to undulating environments will include cut through the steeper slopes to depths of about 15 m for all four options. These depths are based on a 1:2 cut batters, with benches every 5 m in height.

The construction approach will also include areas of fill to maximum fill slope heights for each option are about 10 m for all four options. The fill areas are generally associated with crossings of either roads or the railway line, or on the approach to the hill peaks, where it is intended to balance cut and fill. These heights are based on a 1:4 fill batters.

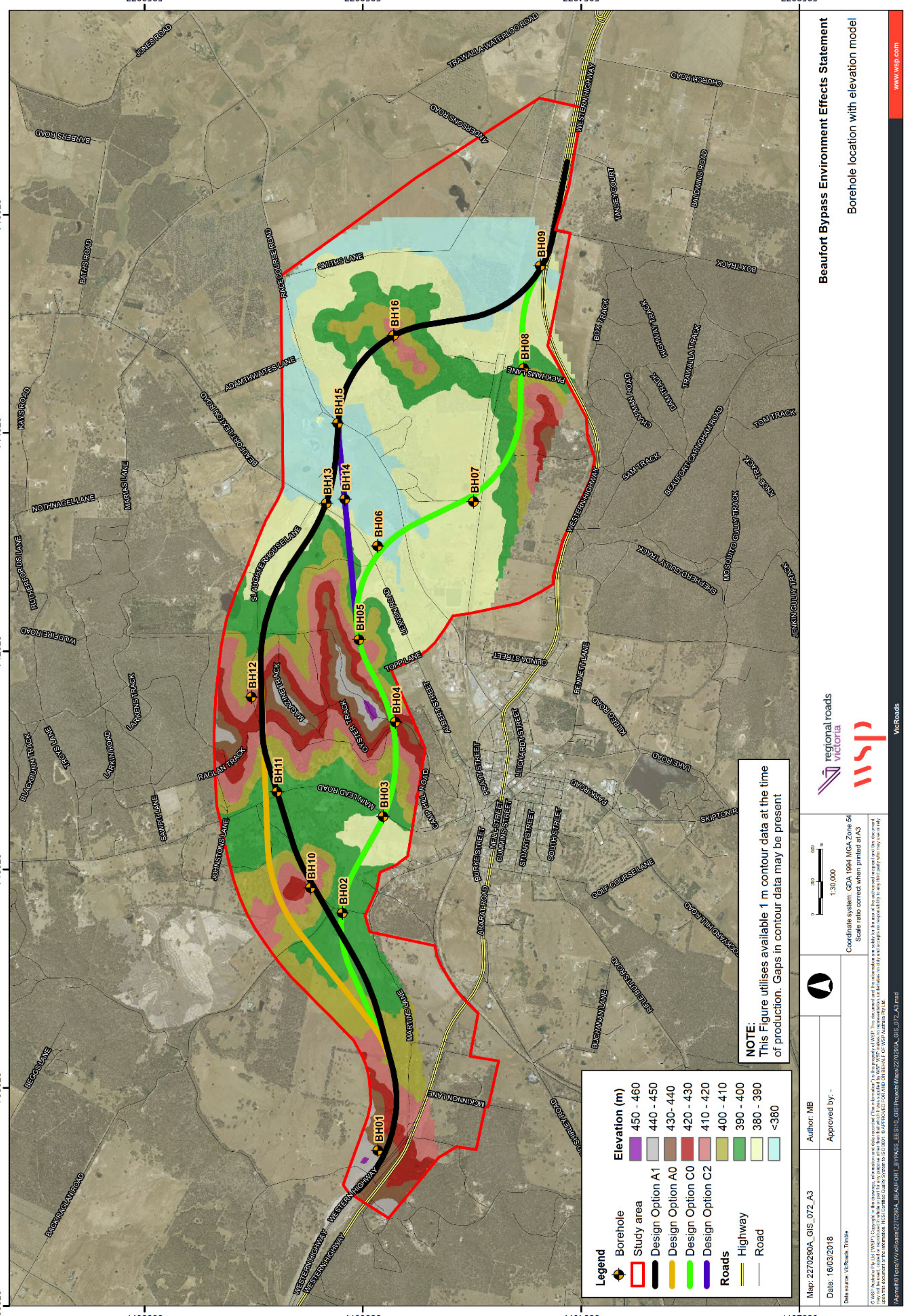

Figure 6.1 Topography

6.2 GEOLOGY DESKTOP ASSESSMENT

6.2.1 REGIONAL GEOLOGY

The published 1:100,000 geology shown on the Department of Jobs, Precincts and Regions, Victoria, Australia GeoVic website, shows the study area is underlain by:

- Alluvium (Qa1): gravel, sand, silt; variably sorted and rounded; generally unconsolidated; includes deposits of low terraces; alluvial floodplain deposits.
- Incised Alluvium (Na): gravel, sand, silt; minor ferricrete; variably incised.
- White Hills Gravel (-Pxh): Vein quartz conglomerate, sand, silt, clay in fluvial braid plain, outwash fan and colluvial deposits; typically compositionally mature, with ubiquitous well-rounded pebbles and cobbles of reef quartz, lesser more angular vein quartz and bedrock clasts; moderately to well sorted, massive to crudely stratified, cross-bedded and channelled; richly auriferous in places; variably ferruginised, silicified or kaolinised.
- Pyrenees Formation (-Cap): Sandstone and mudstone; dominantly sand-rich turbidite facies; moderately to well-rounded quartz with minor feldspar and lithic grains in quartz silt or clay matrix; medium to thick bedded; unfossiliferous; weathered to partly kaolinised; deep marine deposits. Mostly nonmagnetic, but some parts are weakly to moderately magnetic.
- Beaufort Formation (-Cab): Sandstone, mudstone and black shale; sand-poor turbidite facies tectonically modified to phyllite, quartz-mica or graphitic schist; weathered to partly kaolinised; deep marine deposits.

The proposed alignment shown in conjunction with the regional geology map is shown in Figure 6.2.

The sandstones and mudstones of the Pyrenees and Beaufort Formations form the low-lying hills to the north, east and west of Beaufort, while the alluvial deposits and White Hills Gravel are contained within the valleys below the proposed embankments. The more recent Quaternary Alluvium lies above the older Incised Alluvium.

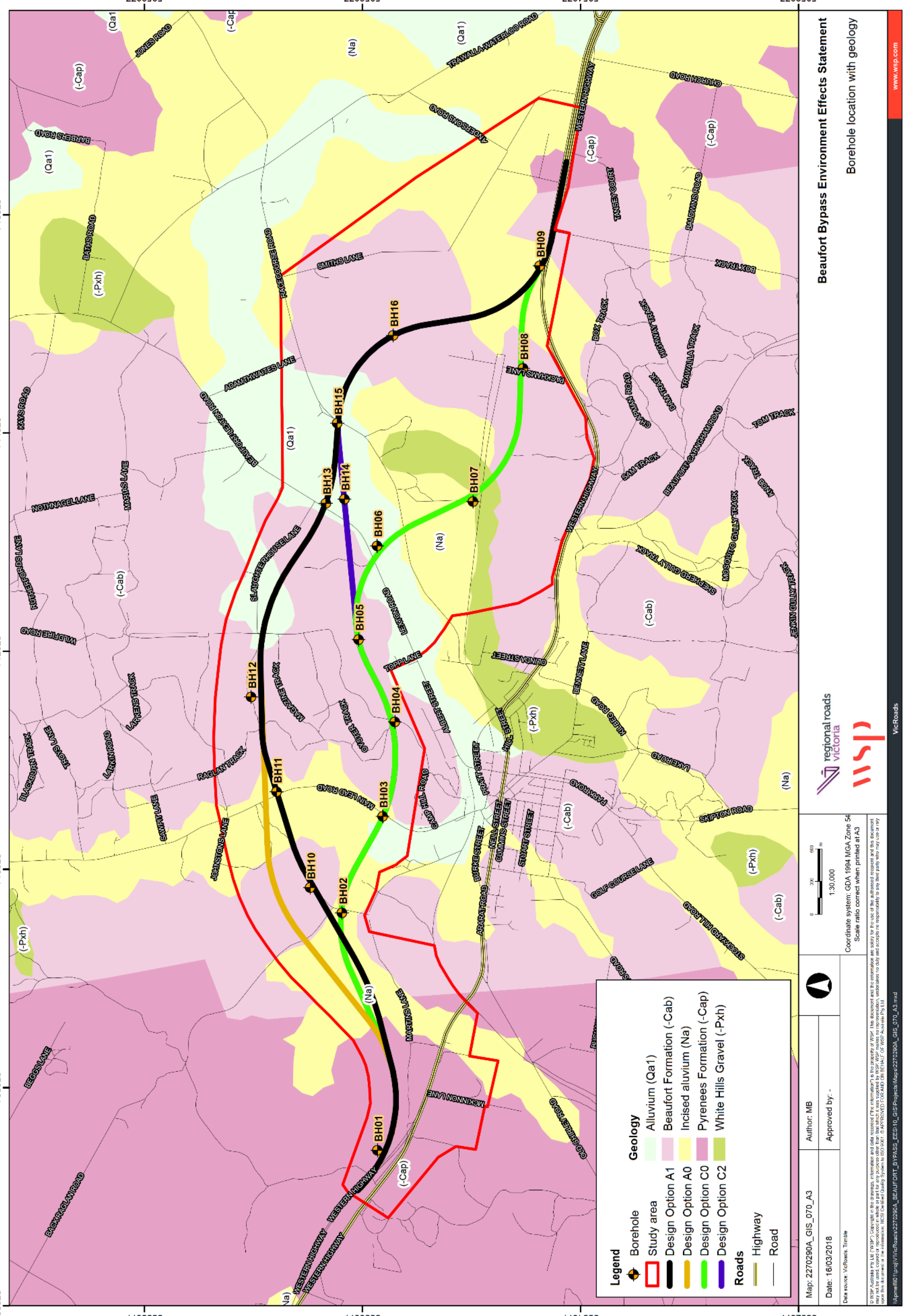

Figure 6.2 Published geology

6.2.2 REVIEW OF PREVIOUS GEOTECHNICAL REPORTS

The following previous geotechnical study reports were reviewed as part of this report as discussed in Section 4.2.1:

6.2.2.1 HALCROW (2011) DESKTOP STUDY

The *Beaufort Bypass Geotechnical Desktop Study* undertaken by Halcrow (2011) studied potential route alignments to the north and south of Beaufort. The report noted the following potential geotechnical constraints:

- potential for small scale slips on low lying hills formed within the Pyrenees Formation and the Beaufort Formation
- compressible soft soils within deposits of colluvium and alluvium and swamp deposits
- basaltic soils with a high shrink-swell potential and high plasticity index (it is noted that these soils lie to the east of the current alignments).

6.2.2.2 VICROADS (2016) DESKTOP STUDY

The VicRoads (2016a) desktop study considered three route alignments to the north of Beaufort.

The report contained information from two Site Conditions Information reports relating to investigations for the Burrumbeet to Beaufort and Beaufort to Buangor Western Highway duplications. The ground investigations for these studies are located close to the ends of the proposed alignments and encountered alluvium (Na) and the Beaufort (-Cab) and the Pyrenees (-Cap) Formations. Locations of the historic investigations have been included on Figure 6.3.

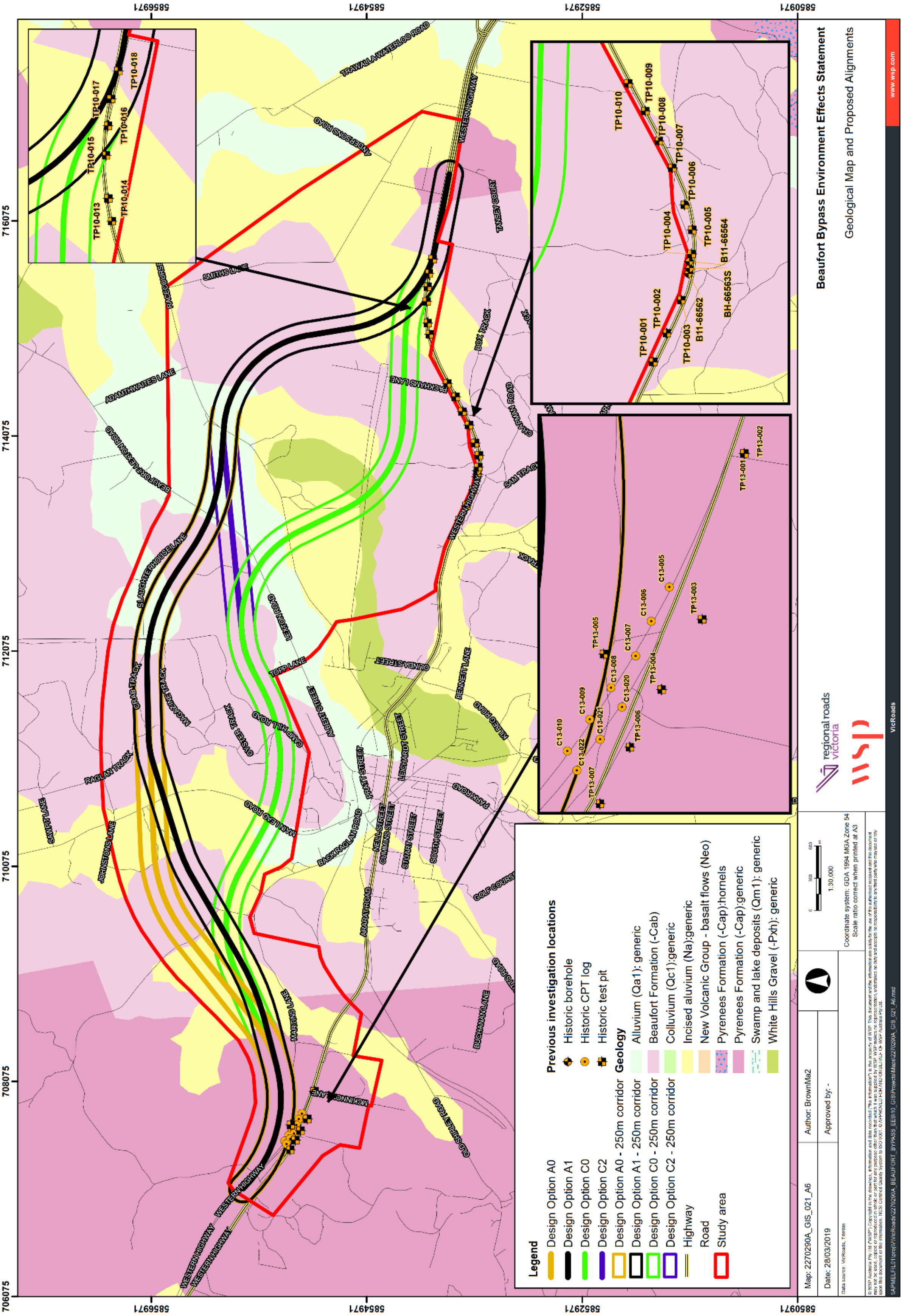

Figure 6.3 Historical borehole locations

BURRUMBEET TO BEAUFORT SCI – BOX'S TRACK TO CARNGHAM ROAD

Investigation works reported for the Burrumbeet to Beaufort Site Conditions Information (SCI) were within the Beaufort Formation and overlying alluvium and included:

- three boreholes with one standpipe piezometer
- 16 test pits
- laboratory testing included:
  - 9 Particle Size Distribution tests
  - 9 Atterberg limits tests with linear shrinkage
  - 16 in-situ moisture content tests
  - 6 Emerson Class tests
  - 5 soaked Californian Bearing Ratio (CBR) tests.

All three boreholes encountered Sandstone/Siltstone at depths ranging between 0.1–1.5 m below existing ground level, which was generally described as distinctly weathered and very low to low strength. The deepest borehole was terminated at 11.5 m.

The laboratory test results for natural soils from these pits are summarised Table 6.1 below:

Table 6.1 Summary of laboratory test results – Burrumbeet to Beaufort SCI

TEST PIT	SAMPLE DEPTH	TEST PIT SOIL DESCRIPTION	RECEIVED MOISTURE CONTENT (%)	FINES CONTENT (%)	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	LINEAR SHRINKAGE (%)	SOAKED CBR	EMERSON CLASS
TP10-002	1.0 m	CLAY, high plasticity, with FM gravel, firm to stiff	29.8	88	63	24	10		Class 3
TP10-004	1.1 m	XW Siltstone (CLAY, low plasticity, hard)	8.8	59	27	17	1	5% CBR 3% swell OMC 13.8%	Class 2
TP10-007	0.6 m	CLAY, medium plasticity, very stiff	20.7	84	39	14	8		
TP10-008	1.5 m	XW Siltstone (CLAY, low plasticity, stiff to very stiff)	14.9	82	32	14	7.5	5% CBR 0.5% swell OMC 16.5%	Class 2
TP10-010	1.6 m	CLAY, medium plasticity, trace sand, stiff to very stiff	21	89	49	16	12.5%		
TP10-013	1.0 m	CLAY, high plasticity, firm to stiff	32.1	93	68	25	17.5%	5% CBR 1.0% swell OMC 30.8%	Class 4

TEST PIT	SAMPLE DEPTH	TEST PIT SOIL DESCRIPTION	RECEIVED MOISTURE CONTENT (%)	FINES CONTENT (%)	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	LINEAR SHRINKAGE (%)	SOAKED CBR	EMERSON CLASS
TP10-015	1.2 m	CLAY, high plasticity, firm to stiff	27.9	93	64	18	12	1% CBR 4.0% swell OMC 24.4%	Class 2
TP10-018	0.3 m	CLAY, high plasticity, stiff to very stiff	33.9	93	91	29	19.5	6% CBR 1.0% swell OMC 33.7%	Class 4

Source: Modified from *VicRoads Site Conditions Information Report, Western Highway Duplication Burrumbeet to Beaufort, Western End – Box's Track to Carngham Rd Section 1C, CN8164, July 2011*

The laboratory test results suggest two different soils have been tested, which mostly match the extents of Beaufort Formation and Incised Alluvium shown on the geology map. Samples from TP10-002, 013, 015 and 018 appear to be alluvial in origin, while samples from TP10-004, 007, 008 and 010 appear to be derived from weathering of the Beaufort Formation.

The alluvial clays tested are of high plasticity with moisture contents up to 10% above the plastic limit. Optimum Moisture Content is 5 to 6% above the plastic limit. Based on the CBR test results, only some of the clays will be suitable as a subgrade without need for a capping layer and/or as a VicRoads Type B fill (soaked CBR >2% and swell <2.5%). Moisture conditioning and compaction of high plasticity clays can present difficulties during construction and further investigation will be required to assess the suitability for reuse of these soils as fill as well as confirming the extent of soils with low soaked CBR and/or high swell. The Emerson Class test results range from 2 to 4 showing some of the soils are dispersive and present a risk of discolouration of stormwater runoff and erosion if exposed to rainfall or flowing water.

The Beaufort Formation clays tested are of medium plasticity with moisture contents ranging from 8% below to 7% above the plastic limit. Optimum Moisture Content is within 3% of the plastic limit. Based on the CBR test results, only some of the clays will be suitable as a subgrade without need for a capping layer and/or as a VicRoads Type B fill (soaked CBR >2% and swell <2.5%). Further investigation will be required to determine the extent of soils with (soaked CBR <2% and swell >2.5%) which may require treatment and/or provision of a capping layer. The Emerson Class test results of 2 show the soils are dispersive and present a risk of discolouration of stormwater runoff and erosion if exposed to rainfall or flowing water.

The SCI Report for Western Highway Duplication, Burrumbeet to Beaufort, Western End - Box's Track to Carngham Road, Section 1C, CN8164 is included as an appendix in the *Geotechnical Desktop Study and Risk Register* (VicRoads 2016a) report.

BEAUFORT TO BUANGOR SCI – SECTION 2A

Investigation works reported for the Beaufort to Buangor SCI were within the Pyrenees Formation and included:

- 9 cone penetration tests (CPT)
- 6 test pits
- laboratory testing included:
  - 2 Particle Size Distribution tests
  - 2 Atterberg Limits tests with linear shrinkage
  - 2 California Bearing Ratio tests
  - 4 in-situ moisture content tests
  - 4 Emerson Class tests.

The CPT results indicated the residual soil from the Pyrenees Formation was typically of high strength with undrained cohesion values more than 130 kPa (greater than very stiff).

Rock was not encountered in the test pits, which extended up to a maximum depth of 3.1 m. Although not noted in the CPT logs, the cone resistance profile indicates that the CPTs were likely terminated near the transition into weathered rock. Termination depths for the CPT tests ranged from 2.03–10.72 m.

The laboratory test results for TP13-003 and TP13-007 are summarised in Table 6.2 below:

Table 6.2 Summary of laboratory test results – Beaufort to Buangor SCI

TEST PIT	SAMPLE DEPTH	TEST PIT SOIL DESCRIPTION	RECEIVED MOISTURE CONTENT (%)	FINES CONTENT (%)	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	LINEAR SHRINKAGE (%)	SOAKED CBR	EMERSON CLASS
TP13-003	1.2 m	CLAY, medium plasticity, very stiff	22.8	96	46	19	10	3% CBR 1.5% swell OMC 22.4%	Class 2
TP13-007	1.5 m	CLAY, medium plasticity, very stiff	14.1	94	46	19	8.5	2.5% CBR 1.5% swell OMC 19.1%	Class 3

Source: Modified from *VicRoads Site Conditions Information Report, Western Highway Duplication Beaufort to Buangor, CN8162, September 2013*

The laboratory test results show that the clays tested are of medium plasticity with moisture contents close to the plastic limit. Optimum Moisture Content is at or just above the plastic limit.

Based on the CBR test results, the clays will be suitable as a subgrade without need for a capping layer and/or as a VicRoads Type B fill (soaked CBR >2% and swell <2.5%). The Emerson Class test results of 2 and 3 show the soils are dispersive and present a risk of discolouration of stormwater runoff and erosion if exposed to rainfall or flowing water.

The SCI report for Beaufort to Buangor, Section 2A, CN8612 is included as an appendix in the *Geotechnical Desktop Study and Risk Register* (VicRoads 2016a) report.

POTENTIAL GEOTECHNICAL CONSTRAINTS

The VicRoads (2016a) Beaufort Bypass desktop study report noted the following potential geotechnical constraints:

- previous mining may have potential impact due to the presence of voids
- groundwater in cut zones may result in construction issues, potential delays and a requirement to design for a long-term strategy to deal with the groundwater inflow
- previous investigations in the vicinity showed soils of high dispersion potential
- deep cuts in the proposed options may encounter deeply weathered rock.

6.2.3 REVIEW OF HISTORICAL GROUNDWATER DATA

A review of historical groundwater data is presented in EES Appendix D: *Groundwater impact assessment* (WSP 2021).

6.2.4 REVIEW OF AERIAL PHOTOGRAPHY

A review of aerial photography supplied by VicRoads (2016) was conducted to identify any pre-existing landslides with respect to the proposed bypass corridor options.

No large-scale pre-existing landslides were identified in this review. However, this will need to be ground truthed while also checking for smaller scale slides that may not be apparent from the aerial photographs during detailed design phase.

6.2.5 REVIEW OF HERITAGE GEOLOGY DATABASE

A review of Australia's National Heritage List (https://www.environment.gov.au/heritage/places/national-heritage-list) was undertaken regarding the study area. No areas of geological significance were listed within the proposed study area.

6.3 PRELIMINARY GEOTECHNICAL ASSESSMENT

6.3.1 GROUND CONDITIONS ENCOUNTERED

The following Table 6.3 and Table 6.4 provide a summary of the materials encountered during the preliminary geotechnical investigation with borehole locations illustrated in Figure 6.4.

Table 6.3 Subsurface profile of hills (Pyrenees and Beaufort Formations) (boreholes BH01, BH04, BH05, BH08, BH10, BH12, BH16)

GROUND TYPE	MATERIAL	ENCOUNTERED SUBSURFACE CONDITIONS	TYPICAL THICKNESS OF UNIT (m)
1	Disturbed soil	SILT: low plasticity, dark brown, brown, pale brown, trace to with roots/rootlets, dry, disturbed by cultural heritage sieving.	0.2 – 0.4
2	Residual soil	SILT / CLAY: low to high plasticity, brown, orange-brown, grey, red, dry, hard, typically friable.	0.25 – 4.6
3	Extremely weathered material	SILT: low plasticity, (pale) orange-brown, (pale) grey, (pale) red-brown, (pale) brown, dry, hard, friable. Observed bedding dips in SPT samples (where possible) ranged between 20° and 60° in BH10, 70° to 80° in BH01, BH04 and BH08. Zones of highly weathered siltstone of very low to low strength was encountered in the extremely weathered material.	>TD

1 This profile was encountered in boreholes located on top on hills.
2 Mapped as mauve and purple on Figure 6.2.
3 >TD (Total depth): Borehole did not penetrate this unit.

Table 6.4 Subsurface profile of low-lying areas (boreholes BH02, BH03, BH06, BH07, BH09, BH11, BH13, BH14, BH15)

GROUND TYPE	MATERIAL	ENCOUNTERED SUBSURFACE CONDITIONS	TYPICAL THICKNESS OF UNIT (m)
1	Disturbed soil	SILT: low plasticity, dark brown, brown, pale brown dry, disturbed by cultural heritage sieving.	0.3 – 0.9
4	Alluvium	GRAVEL / SAND / SILT / CLAY: low to high plasticity clay/silt, fine to coarse grained sand/gravel, brown, orange-brown, grey, red, dark brown, dark red, dry to moist, stiff to hard, medium dense to dense, friable in places. Typically becoming coarser grained with depth.	0.25 – 4.4
2	Residual Soil	SILTY SAND / SILT / CLAY: fine grained sand, low plasticity silt/clay, (pale) grey, orange-brown.	0 – >TD
3	Extremely weathered material	SILT: low plasticity, orange, (pale) grey, red, pale red-brown, dry to moist, stiff to hard, friable. Observed bedding dips in SPT samples (where possible) at 80° in BH13.	>TD

1 This profile was encountered in boreholes located in low-lying areas.
2 Mapped as yellow and grey on Figure 6.2.
3 >TD: Borehole did not penetrate this unit.

Most of the materials encountered are stiff to hard. Limited soft/weak materials were encountered as follows:

- BH06: 2.7–3.5 – possibly disturbed by drilling
- BH11: 0.0–0.9 – surface softening in Alluvium/Topsoil
- BH12: 0.0–0.2 – surface softening in Alluvium/Topsoil.

Groundwater inflows were encountered in boreholes BH03 at a depth of 4.4 m and BH14 at a depth of 1.8 m. Note that existing dams were located within about 10–20 m from the borehole locations.

Three standpipe piezometers were installed into boreholes BH10, BH14 and BH16. These boreholes were measured dry about one to two weeks after borehole completion.

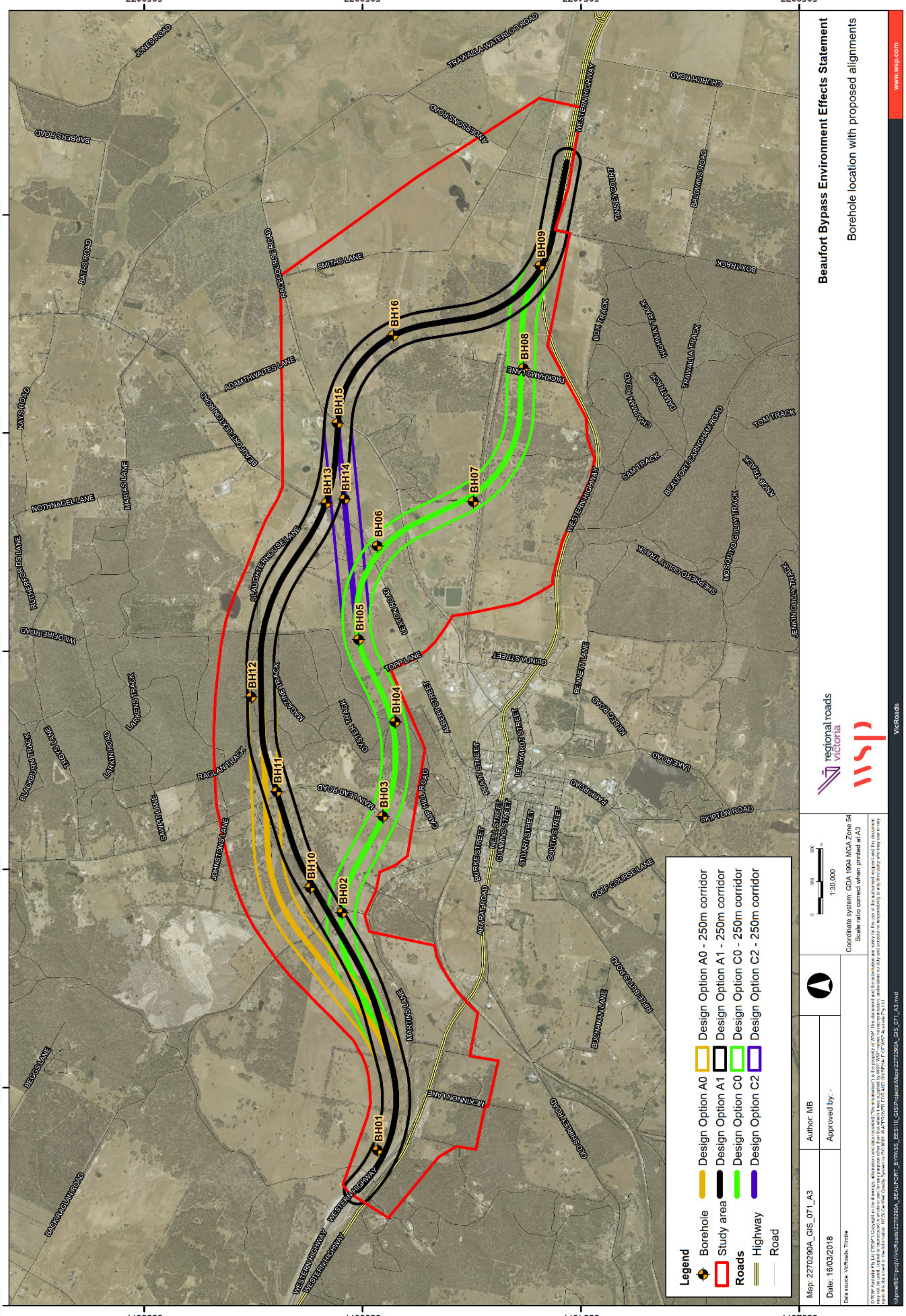

Figure 6.4 Exploratory hole location plan relative to the four alignments

6.3.2 LABORATORY TESTS

Laboratory tests were undertaken on the samples collected from the boreholes to inform the assessment of dispersion, durability, settlement, material reuse, subgrade conditions and batter slopes. The following Table 6.5 and Table 6.6 provide a summary of the results.

Table 6.5 Laboratory test summary – Geotechnical

TEST ID	SPECIMEN DEPTH (m)		SOIL GRADING					SOIL PLASTICITY									
	From	To	Gravel (%)	Sand (%)	Fines (%)	Silt (%)	Clay (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Linear Shrinkage (%)	Emerson Class	Moisture Content (%)	Optimum Moisture Content (%)	Maximum Dry Density (t/m³)	CBR (%)	CBR Swell (%)
BH01	5.0	5.1						30	25	5	2.5		14.9				
BH01	9.0	10.0	8	12		56	24	28	24	4	1.5	2	13.8	18.0	1.72	6.0	1.5
BH02	0.5	0.95						44	14	30	6.5		14.0				
BH02	3.5	3.87	25	35	40								12.6				
BH03	1	1.45						38	13	25	6		14.8				
BH04	11.0	12.0	2	18		62	18	30	20	10	2.0	2	4.5	16.0	1.77	2.0	3.5
BH05	1.5	3.0	7	30		25	38	35	15	19	4.5	2	13.5	17.5	1.71	5.0	2.0
BH05	10.0	11.0	23	25		19	33	37	22	15	4.5		12.3	14.0	1.87	4.5	1.5*
BH05	13.0	14.0	0	8		73	19	37	24	13	4	2	10.4	16.5	1.70	1.0	5.5
BH05	13.0	14.0	0	8		74	18	24	23	1	2.0		13.1	13.0	1.68	1.5	6.0*
BH06	1	1.45						70	22	48	8		24.6				
BH07	1	1.45						57	15	42	5.5		14.5				
BH08	1.5	1.95						50	29	21	4.5		22.9				
BH08	3.0	4.0	22	20		58	0	40	27	13	3.0		14.4	16.5	1.69	1.5	5.0*
BH08	7	8	1	24		45	30	34	22	12	2.5	2	16.6	16.0	1.78	2.5	3.5
BH09	1	1.45						53	18	35	5.5		21.0				
BH10	2	3	1	2		83	14	35	27	8	2	2	8.9	15.5	1.68	1.5	6.0
BH10	7.3	8.5	1	5		79	15	33	25	8	4.5	2	15	16.0	1.65	1.0	5.0
BH10	13.5	14.5	6	14		47	33	36	22	14	3	2	8.5	13.5	1.87	2.0	5.0
BH10	13.5	14.5	16	12		44	28	35	21	14	4.8		11.2	12.5	1.85	5.0	2.0*
BH11	1	1.45						41	16	25	7.5		15.6				
BH12	1.4	1.5						55	24	31	12		12.9				

TEST ID	SPECIMEN DEPTH (m)		SOIL GRADING					SOIL PLASTICITY									
	From	To	Gravel (%)	Sand (%)	Fines (%)	Silt (%)	Clay (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Linear Shrinkage (%)	Emerson Class	Moisture Content (%)	Optimum Moisture Content (%)	Maximum Dry Density (t/m³)	CBR (%)	CBR Swell (%)
BH12	12	13	19	18		41	22	34	26	8	2.5	2	13.1	15.5	1.76	2.0	2.5
BH16	5.0	6.0	22	26		22	30	35	22	13	4.0		11.9	14.0	1.90	2.0	2.0*
BH16	13.5	14.5	9	18		43	30	41	26	15	5.5	2	8.6	16.0	1.74	1.5	5.5

** Indicates sample triple compacted prior to CBR test*

Aggressivity testing was undertaken to identify if there are any soils that would adversely affect the durability of concrete piles. The results were compared to Australian Standard AS 2159-2009 'Piling – Design and installation' for exposure classification applicable to concrete piles. The results of testing, provided in Table 6.6 below, are consistent with an exposure classification for concrete piles of 'Non-aggressive' to 'Mild' and therefore indicative of a low potential to impact on design of concrete pile foundations.

Table 6.6 Aggressivity suite test results

BOREHOLE	DEPTH (m)	FIELD MOISTURE CONTENT (%)	PH	CHLORIDE (mg/kg)	SULFATE AS SO^4 (mg/kg)	RESISTIVITY (OHM-CM)
BH01	9 – 10	11.6	8.6	<10	<10	13,700
BH04	12 – 13	4.2	7.9	110	10	2,910
BH05	1.5 – 3	11.5	4.8	60	100	14,900
BH05	13 – 14	8.6	6.7	520	<10	4,850
BH08	7 – 8	13.6	6.6	880	70	2,380
BH10	2 – 3	7.6	6.1	410	30	4,440
BH10	7.3 – 8.5	19.2	7.4	600	40	3,460
BH10	13.5 – 14.5	7.1	6.4	330	90	5,560
BH12	12 – 13	11.7	7.7	380	20	1,040
BH16	13.5 – 14.5	8.8	6.5	100	100	10,300

6.4 ACID SULFATE SOILS

6.4.1 POTENTIAL ACID SULFATE SOILS

ASS occur naturally in both coastal (tidal) and inland or upland (freshwater) settings. Principally the main metal sulfide of concern is pyrite (FeS_2) and exposure of it to water and oxygen can generate sulfuric acid. This can acidify soil, rock and groundwater, which can adversely affect human health, environmental quality for flora and fauna, corrode concrete and steel and affect agricultural practices.

Potential acid sulfate soils (PASS) are those soils that contain iron sulfides or sulfidic material which have not been exposed to air or oxidised. The field pH of these soils in their undisturbed state can be pH 4 or more and may be neutral or slightly alkaline. However, PASS pose a considerable environmental risk when disturbed, as they can become acidic when exposed to air, and water to form sulfuric acid.

A review of PASS database was conducted on the Australian Soil Resource Information System (ASRIS) website (ASRIS 2017). The database indicated low probability of ASS albeit with very low confidence. As the site is not within a coastal area, encountering coastal ASS during the construction works is unlikely.

Soil samples collected as part of the geotechnical assessment reported pH ranging between 4.8 (BH05) and 8.6 (BH01) within the study area, however no field indicators for the presence of ASS were identified.

6.5 LAND CONTAMINATION DESKTOP ASSESSMENT

6.5.1 EPA VICTORIA AUDIT DATABASE

A search of the EPA Victoria audit database for Statutory Environmental Audits completed in the Pyrenees Shire was undertaken on 3 November 2017. No Statements or Certificates of Environmental Audit were identified within the study area.

6.5.2 EPA PRIORITY SITES REGISTER

Priority Sites are sites for which the EPA Victoria has issued a Clean-up Notice pursuant to Section 62A or a Pollution Abatement Notice (relevant to land and/or groundwater), pursuant to Section 31A or 31B of the Victorian EP Act. Typically, Priority Sites are properties where identified pollution may present an unacceptable risk to human health or to the environment. EPA maintains the Priority Sites Register as a listing of all properties identified by the EPA as requiring assessment and/or clean up.

A search of the EPA Priority Sites Register was undertaken on 3 November 2017. The search did not identify any Priority Sites within the study area.

6.5.3 EPA LICENSED FACILITIES

A review of the EPA licensed premises database was undertaken on 3 November 2017. Relevant information including the EPA Licence (74422) and Annual Performance Statements were reviewed.

An EPA licensed wastewater treatment plant (WTP) operated by Central Highlands Water (CHW) is located at Racecourse Road, Beaufort (Figure 6.5). The contaminants of interest associated with operation of a WTP are heavy metals (aluminium, arsenic, cadmium, chromium, cobalt, lead nickel, zinc), fluoride and lime.

The WTP is operating in compliance with all EPA license requirements. The irrigation areas are receiving water approved by the EPA and is not expected to have gross contamination.

6.5.4 LAND USES ASSOCIATED WITH POTENTIAL SOIL CONTAMINATION

The study area comprises various land uses allowed under the Farming Zone, Rural Conservation Zone, Public Conservation and Resource Zone, Low Density Rural Zone, General Residential Zone, Industrial 1 Zone, Public Use Zone (Transport) and Rural Living Zone. The key land uses that has a potential to cause soil contamination within and surrounding the study area are:

- railway corridor (Melbourne-Ararat rail line)
- commercial/industrial activities – former landfill/Waste Transfer Station, former mining activities, former Council Works Depot, former Beaufort Trotting Training Track, and service stations
- agriculture/grazing activities.

The potential sources of contamination identified during desktop assessment are provided in Figure 6.5.

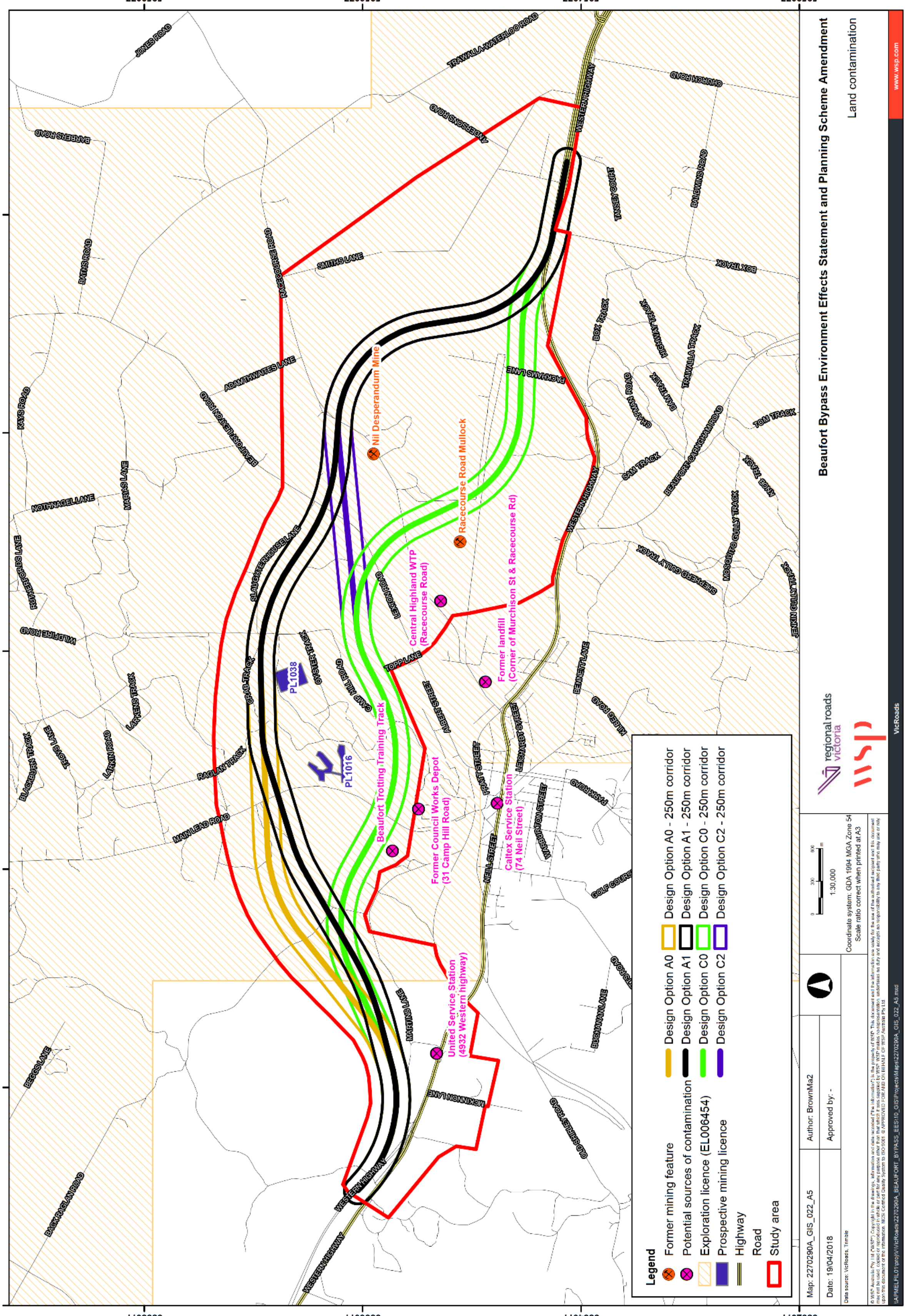

Figure 6.5 Potential sources of contamination within the study area

6.5.4.1 MELBOURNE-ARARAT RAIL LINE

The town of Beaufort is serviced by rail on the Melbourne-Ararat rail line. There is the potential for imported fill to exist within the rail environment which may be contaminated with heavy metals. Localised contamination attributed to diesel and/or oil spills/ leaks may also be present along the rail corridor. In accordance with Australian Standard AS4482.1 *"Guide to the Investigation and sampling of sites with potentially contaminated soil"*, the contaminants that are associated with railway operations are total petroleum hydrocarbons (TRHs), benzene, toluene, ethyl benzene, xylenes (BTEX), polycyclic aromatic hydrocarbons (PAHs), phenols, heavy metals including arsenic, nitrates, and ammonia.

6.5.4.2 FORMER UNLINED LANDFILL AND COUNCIL TRANSFER STATION

An unlined former landfill which received municipal and commercial wastes is located at the corner of Racecourse Road and Murchison Street. The landfill is located outside the study area. Currently the site is operating as a waste transfer station for Pyrenees Shire Council.

The contaminants of interest associated with the former landfill site are alkanes, ammonia, sulphides, heavy metals and organic acids.

As noted in EES Appendix D: *Groundwater impact assessment* (WSP 2021), Total Dissolved Solids (TDS) concentrations indicate that groundwater within the alluvial aquifer ranges in classification from Segment A1 to C triggering all listed beneficial uses. The single TDS concentration within the basalt aquifer falls within Segment B for protected beneficial uses.

A scientific paper by Moreau and Minard (2014) inferred that the nitrate concentrations in the downgradient Yam Holes Creek are because of a mixture of leachate and surrounding agricultural sources. The former landfill and Yam Holes Creek are located outside the study area and are not likely to be impacted from the project construction works.

6.5.4.3 HISTORICAL MINING ACTIVITIES

The review of current and historical mining licenses in the study area was undertaken via the State Government's Earth Resources website (http://earthresources.vic.gov.au/earth-resources/maps-reports-and-data/geovic) identified an exploration license EL006454 and two Prospecting Licenses (PL1016 and PL1038) within the study area.

Gold was discovered in Beaufort between 1852-1854 at Fiery Creek in the study area and there is potential for presence of mine tailings and former mine shafts along the proposed bypass corridors. Contaminants associated with gold mining activities such as arsenic, mercury and lead may be present in soil. However, the contamination from gold mining activities is dependent upon the methods used for mining. EES Appendix E: *Historic heritage impact assessment* (Archaeology at Tardis 2021) reported that puddling and shallow mining was the main mining method used (prevalent between 1855 to 1861), however areas of intensive deep lead mining activities also occurred in the study between 1861 and 1916. Archaeology at Tardis (2021) noted that the likely locations of the shallow mining operations would be adjacent to Yam Holes Creek and its tributaries, and the deep lead operations in proximity to Main Lead north of Beaufort. The shallow mining operations would have a low risk of land contamination.

Mining operations identified by Archaeology at Tardis (2021) are summarised in Table 6.7.

Table 6.7 Identified mining operations and features

ALIGNMENT OPTION	SHALLOW OPERATIONS	DEEP-LEAD OPERATIONS
A0	Camp Hill North Area 1	Slaughterhouse Lane Mullock Heaps Nil Desperandum
A1	Camp Hill North	Slaughterhouse Lane Mullock Heaps Nil Desperandum
C0	Camp Hill South Area 8 Area 7	Slaughterhouse Land Mullock Heaps Racecourse Rd Mullock Heap
C2	Camp Hill South	Nil Desperandum

There are three registered historic archaeological sites within the study area and are listed in Table 6.8 (Archaeology at Tardis 2021).

Table 6.8 Registered heritage sites

SITE NAME AND REGISTRATION NO.	LOCATION	MINING CONTENTS / EQUIPMENT
Nil Desperandum Mine Feature H7523-0071	Racecourse Road 46/5/Beaufort	Deep lead mine. Two large mullock heaps, brick, scatter and sludge pond.
Racecourse Road Mullock Feature 1 H7523-0074	Racecourse Road 1 PS704621	Deep lead mine. Small scale mine comprising five low lying mullock heaps extending in a north-south orientation.
Camp Hill North H7523-0098	Camp Hill State Forest	Water race, infilled gold prospecting pits, remnants of puddling machines and dams.

6.5.4.4 FORMER COUNCIL WORKS DEPOT

A former Pyrenees Council works depot, located at 31 Camp Hill Road, is within the study area. The exact nature of council operations at the depot is unknown, however, it is likely that the depot stored fuels/chemicals, storage of wastes such as bitumen. The contaminants of interest associated with the former depot are TRHs, BTEX, PAHs, phenols, heavy metals, and volatile organic compounds (VOCs).

6.5.4.5 BEAUFORT TROTTING TRAINING TRACK

A former harness racing training track is located within the study area. While the activities undertaken on the facility that may potentially contaminate the soils are unknown, it is likely that activities such as horse washing, fuel/chemical storage and fertiliser/pesticides application were undertaken at the facility. The contaminants of interest associated with these activities are TRH, BTEX, PAHs, heavy metals, nitrates, and pesticides. The soil contamination from the harness racing facility is expected to be minor and localised.

6.5.4.6 FUEL SERVICE STATIONS

Two operational fuel service stations are in the town of Beaufort, which are located outside the study area. The contaminants associated with petroleum service station sites are TRHs, BTEX, PAHs, lead, methyl ter-butyl ether (MTBE), and VOCs. The contamination from the service stations is unlikely to be encountered in the study area.

6.5.4.7 AGRICULTURE AND GRAZING

Most of the study area was and is currently used for farming/grazing purposes and therefore potential contaminants of interest sourced from agriculture/grazing that may be present include nitrates, pesticides, insecticides, fungicides and herbicides.

6.5.5 LAND CONTAMINATION CONCEPTUAL SITE MODEL

Based on the study area, surroundings and available information, a Conceptual Site Model has been developed to consider potential impact pathways associated with land contamination. Table 6.9 outlines the key impact pathways considering the source-pathway-receptor scenarios for the study area.

Table 6.9 Conceptual Site Model

SOURCE	CONTAMINANTS OF INTEREST	EXPOSURE PATHWAY	RECEPTORS	
			Human health	**Environment**
Former mining activities, agriculture/ grazing land use, railway land use, unknown historical fill, service stations, former landfill, WTP, etc.	TRH, BTEX, PAHs, VOCs, MTBE, phenols, pesticides/herbicides, heavy metals, sulphides, organics acids, nitrates, ammonia, alkanes, and fluoride	Dermal contact and ingestion	Construction workers	Ecological receptors such as flora and fauna, groundwater, and buildings and structures
		Air inhalation of vapour and dust	Construction workers, commercial and residential users nearby	
		Volatilisation and enclosed space accumulation	Workers in excavations and trenches	Groundwater
		Leaching and groundwater transport	Groundwater users in and near the study area	Soil, groundwater and surface water

6.5.5.1 ACID SULFATE SOILS

ASS and acid sulfate rock (ASR) can affect land use and development. Disturbance of ASS / ASR can adversely impact land, water and ecosystems by formation of acid and metal sulphides. The following impacts may be realised:

- **environmental quality**: affecting soil quality, surface and groundwater quality, and aquatic habitats
- **agricultural practices**: loss of rural productivity, loss of commercial and recreational fisheries, the cost of additional lime and fertiliser requirements and degradation of drainage systems
- **engineering and landscaping works**: the corrosion of concrete and steel and the design of transport structures (i.e. road or rail), buildings, embankments and drainage systems to avoid impacted areas
- **human health**: skin and eye irritation, contamination of drinking water and occupational health and safety risks.

Some environments may have acid buffering capacity to neutralise effects of ASS / ASR. Acid buffering capacity of soil and water is often limited, so may not provide neutralising capacity in the long term. Depending on the circumstances, acidic discharges may be harmless in one environment, but hazardous in another. The risk and hazard posed must be assessed on a case-by-case basis.

Excavation of ASS may lead to formation of acidic soils, higher disposal costs, corrosion of underground infrastructures and occupational health and safety concerns. As noted above in Section 6.5.3, encountering ASS during construction is unlikely.

6.5.5.2 CONTAMINATED SOILS

Excavation of soils would be required during the construction of the project. Exposure to contaminated soils is known to be associated with potential risk to human health and the environment.

The risks are realised when the source and receptors (human or ecological) are exposed via one of the following pathways:

- dermal contact with skin causing the contaminants to be absorbed into the underlying tissue and blood stream
- ingestion of contaminated soil and water due to adhesion to skin and transfer onto food
- inhalation of vapours from the contaminated soil or groundwater carried by air into the lungs and respiratory systems of the organism
- leaching to groundwater; groundwater transport to extraction bores and surface water
- leaching to drainage systems
- contact with the built environment such as concrete or steel piles.

Apart from these general exposure pathways, contaminated soil poses several other risks to the environment mainly in the form of sediment generation. Therefore, understanding risks associated with these issues is important in planning and implementing an effective environmental management system during the construction and operational phases of the project.

7 IMPACT ASSESSMENT – FOUR ALIGNMENT OPTIONS

This section identifies and describes soils and geology cause and effect pathways associated with the construction and operation of the project, and the impact on all proposed alignments.

7.1 IMPACT PATHWAYS

The following impact pathways for all proposed road alignment options have been identified:

- excavation exposes ASS
- excavation exposes contaminated soils
- excavation causes erosion/sedimentation
- filling causes ground settlement
- construction causes ground instability
- excavation encounters unsuitable soils.

7.1.1 EXCAVATION EXPOSES ACID SULFATE SOILS

ASS when disturbed can oxidise and allow the release of acids to the environment, particularly where surface water transports exposed ASS materials.

The study area is located approximately 160 km from the coastal waters. The potential to have ASS is low for all proposed alignment options, based on the ASRIS database (ASRIS 2017) and Victorian Coastal ASS Maps (DSE 2009), although no analytical data is available to confirm this.

7.1.2 EXCAVATION EXPOSES CONTAMINATED SOIL

7.1.2.1 EPA LICENSED FACILITIES

The EPA licensed WTP, operated by CHW, is located within the study area, however it is not intersected by any of the alignment options. As such, soil from the WTP will not be excavated during the project construction. However, the land where the treated effluent from the WTP is disposed for irrigation is located within the A0, A1 and C2 alignment corridors. As noted in the EPA Annual Performance Statement (EPA 2017) for the WTP, the WTP is operating within the license limits set by the EPA (i.e. meeting discharge criteria). If the WTP continues to operate within the conditions of the licence limits, the potential for contamination during construction is likely to be medium for all alignment options that intersect the site. For the alignment option C0, which does not intersect the irrigation area, the impact of soil contamination during construction from the WTP is considered low.

7.1.2.2 MELBOURNE-ARARAT RAIL LINE

All four alignments options cross the Melbourne-Ararat rail line. Potential local contamination from fuel and oil spills/leaks from trains is expected to be along the rail corridor and at the footprint of the proposed crossing with the railway line. The proposed crossings with the rail corridor is expected to have concrete structures at depth (piles, foundations). The drilling and excavation in the rail corridor during construction is expected to encounter soil contaminated with hydrocarbons, heavy metals, nitrates and ammonia.

7.1.2.3 FORMER UNLINED LANDFILL AND COUNCIL TRANSFER STATION

The former unlined landfill/waste transfer station is not located within the four bypass alignment areas. As such, the material placed in the landfill will not be affected by the construction of the project. Groundwater and surface water impacts associated with the landfill/waste transfer station have been identified at and near the former landfill and are monitored by the Council on a biannual basis. Given the distance to the nearest proposed alignment (>1 km), the potential for contamination to migrate and impact on the construction of the project is low for all of the proposed alignment options.

7.1.2.4 HISTORICAL MINE WORKINGS

EES Appendix E: *Historic heritage impact assessment* (Archaeology at Tardis 2021) identified shallow workings and deep lead workings within the project alignment options. The nature and extent of historic mine workings are approximate and needs to be further explored during the following phases of the project. Shallow mine workings may have been reinstated to a substandard specification and may give rise to unpredictable and inconsistent ground conditions. The potential impact of contamination during construction from deep or shallow mine workings is medium for all proposed alignments.

7.1.2.5 BEAUFORT TROTTING TRAINING TRACK

The Beaufort Trotting Training Track located within the study area, south of the C0 and C2 alignments, may have minor localised contamination sourced from site activities. However, the Trotting Track is located within an area of proposed filling and so the impact of such contamination will be minimal. For alignments C0 and C2, exposure of contamination by construction activity is low. Localised contamination from this source during construction is not considered to impact alignment options A0 and Al and is negligible.

7.1.2.6 FUEL SERVICE STATIONS

The two service stations (United and Caltex) are not within the study area. The potential hydrocarbon contamination beneath these sites will not be excavated during the construction of the project and is not considered to impact any of the proposed alignment options, with the risk of exposure to contamination from construction activity for all alignments considered to be low.

7.1.2.7 AGRICULTURE AND GRAZING

The study area encompasses former and current farmland where near surface soil may be contaminated with fertilisers (nitrates), pesticides/herbicides, etc. The soil excavated during the construction may require off-site disposal if contaminant concentrations exceed human health and ecological assessment criteria. The potential for pesticide contamination of soil during construction is considered medium for all the proposed alignment options.

7.1.3 EXCAVATION CAUSES EROSION/SEDIMENTATION

The geological units encountered for all four proposed alignment options are similar. All alignments cross the sandstones and mudstones of the Pyrenees and Beaufort Formations and the alluvial valley deposits described in Section 6.2.1. Alignment C0 is the only alignment crossing the White Hills Gravel deposit. For all four proposed alignments, cut slopes are required up to a maximum depth of approximately 15 m, with embankments up to a maximum height of approximately 12 m. Because all alignments cross similar geology with similar maximum cut and fill slope heights, the impact from erosion and sedimentation during construction is medium for all alignment options.

Surface water running over cut and fill slopes has the potential to causes slope erosion and sedimentation in watercourses. Emerson Class tests were conducted on samples recovered during the preliminary investigation, from proposed areas of cut along the alignments. The results returned Emerson Class numbers of 2 for the recovered soil, which indicated that the samples displayed some dispersive reaction during testing. Based on the Emerson Class test results, the encountered soils are considered to be dispersive.

Slopes formed in dispersive soils have several potential impacts, including:

- surface water flowing over the slopes has the potential to chemically interact with the dispersive soils resulting in the breakdown of soil particles that can be washed away in solution, resulting in erosion
- steeper slopes have the potential to generate higher velocity surface water runoff which would accelerate the erosion of unprotected dispersive soil slopes compared with shallow slope angles
- slope berms are often used in conjunction with catch drains. Eroded sediments may collect on the berms and within the catch drains creating the need for long term maintenance or produce blockages to the surface drainage systems.

During construction, exposed dispersive soils are susceptible to erosion and sedimentation prior to completion of the permanent protection measures. Unprotected slopes or stockpiles of dispersive soils could potentially result in erosion and cause sediments to enter watercourses unless control measures are implemented.

Erosion and sedimentation mitigation measures used on adjacent sections of the Western Highway duplication included use of shallower 1V:3H vegetated cut slopes. However, because of the cut depths required, using 1V:3H cut slopes in the deeper cuts will create a wide cutting, which will have a significant impact on the existing vegetation, including the Camp Hill State Forest.

An alternative to shallow slopes is to design steep slopes (1H:10V). Such slopes would be supported by use of soil nails and protected by shotcrete. Steeper slopes would reduce land take, particularly through the Camp Hill area.

Soil stockpiles won from excavation have high potential to suffer erosion as they are typically of high batter angles and generally exposed soil surfaces. The location and geometry of any stockpiles, for all proposed alignments, would need to be carefully considered during the detailed design, as local instabilities and excessive erosion may affect nearby environmental features such as waterways and ecosystems.

7.1.4 FILLING CAUSES GROUND SETTLEMENT

The construction of fill over compressible ground will result in settlement. Ground settlement could potentially cause damage to adjacent buildings and infrastructure. Settlement of the embankments after construction has the potential to increase the level of highway maintenance required.

For all proposed alignment options, embankments are proposed to traverse areas of alluvium.

The areas of alluvium investigated in the preliminary geotechnical investigation were found to be between 2–4.4 m thick and comprised of a mixture of clay, silt, sand and gravel. The thickness and composition of the alluvium is likely to vary along all alignment options. There is the potential that thicker alluvial deposits exist.

Based on the soil samples recovered and tested in the preliminary geotechnical investigation, embankment settlements should be manageable through implementation of standard industry practices. The impact of soil settlement outside the footprint of the embankments would be very limited (impacts within 5 m from the embankment toe).

There is no significant difference between the impact of soil settlement on each alignment option, with the risk of settlement impacts during construction and operation considered to be low for all alignment options.

7.1.5 CONSTRUCTION CAUSES GROUND INSTABILITY

No existing landslides were identified along the four proposed alignments from a study of aerial photography. However, excavation into the natural hillsides has the potential to re-activate any existing shallow landslips too small to be seen in the aerial photographs or hidden by vegetation. A walkover survey of the preferred alignment will be required to confirm the natural slopes do not contain existing landslips. The risk of ground instability from hillside construction is low.

Steep cuttings in soil are potentially unstable unless battered back to a safe angle or supported by soil nails or retaining walls. Design of cuttings must consider the local geology, groundwater and existing topography to derive stable slope angles and/or requirements for reinforcement. Cuts though weathered rock may contain relict bedding and joints, which could be angled adversely to the cutting’s alignment. This could lead to one side of the cutting being more unstable than the other. This will also need to be considered during cutting design.

The risk of ground instability from encountering shallow or deep mine workings is low for all four alignment options. Shallow workings may remain open or have been reinstated to a substandard specification and may give rise to unstable ground conditions. The spatial distribution of shallow workings may be difficult to identify as years of vegetation growth may have covered the remnants of disturbance.

Deep lead workings/mine shafts may result in ground subsidence or collapse once subjected to increased loading. Progressive subsidence or collapse of mine workings may occur during or after the project construction activities.

A site walkover of the preferred alignment will be required to map and identify the nature of visible workings. Geophysics may be required to investigate workings hidden below the ground surface.

7.1.6 EXCAVATION ENCOUNTERS UNSUITABLE SOILS

The suitability of soils excavated from the cuts for re-use as fill is a key geotechnical constraint for all alignment options. All alignment options will require a greater volume of fill materials to form embankments than available from excavation of the proposed cuttings. If excavated soils cannot be used to form the fill embankments, further quantities of imported fill materials will be required. Unsuitable soils cannot be compacted directly in the areas of proposed fill. Unsuitable soils will either need treatment to make the soils suitable or the soils will need to be reserved for landscaping, noise mounds and/or removal off-site.

The subgrade left at the base of cuts after excavation also needs to be suitable as a pavement base. If the natural soils are too weak or susceptible to degrading under traffic loading, they will need to be treated or replaced with imported fill materials.

The preliminary geotechnical investigation found the excavated soils of low strength, comprising a high silt content and dispersible. For all alignments, it is considered that the risk of unsuitable soils being encountered during excavation and cuttings is high.

Noting that VicRoads Standard Specification 204 advises that soils with silt content cannot be adopted as Type A or Type B fill material, and in order to minimise the volume of imported fill, earthworks design will need to consider opportunities to treat unsuitable soils for reuse as embankment fill or contain them within zoned embankments. Earthworks design will also need to specify preparation and compaction requirements to ensure stable soils at subgrade level and within embankments.

Preliminary investigations did not find any significant differences between the suitability of soils for each alignment option.

8 OPTIONS ASSESSMENT AND PREFERRED ALIGNMENT SELECTION

The options assessment completed for the project assessed alignment options A0, A1, C0 and C2 against the customised set of criteria summarised in section 4.5. The results of the options assessment and sensitivity testing are detailed in Table 8.1. As well as the score for each alignment under each scenario, a colour coding has been applied to rank the performance of the options under each scenario as follows:

- best performing alignment option: Green
- second performing alignment option: Yellow
- third performing alignment option: Orange
- worst performing alignment option: Red.

Table 8.1 Combined alignment option scenario scoring

SCENARIO	ALIGNMENT A0	ALIGNMENT A1	ALIGNMENT C0	ALIGNMENT C2
Scenario 1	128	123	126	111
Scenario 2	18	22	20	27
Scenario 3	45.85	44.89	50.01	43.95
Scenario 4	81.03	77.59	93.98	74.12
Scenario 5	24.16	22.70	27.03	19.44
Scenario 6	47.74	42.69	56.16	35.49
Sensitivity Scenario 1	-6	-3	-5	9
Sensitivity Scenario 2	-3	2	-4	11
Sensitivity Scenario 3	-11	-6	-9	5

The alignment scoring scenarios outlined in Table 8.1 show that the best performing option is the C2 Alignment, while the worst performing options are the A0 and C0 Alignments. The primary drivers for this outcome were due to the C2 alignment having:

- the lowest amount of total native vegetation clearance
- the least impact on threatened vegetation communities identified under the *Environment Protection and Biodiversity Conservation Act 1999* and *Flora and Fauna Guarantee Act 1988*
- the least impact on wildlife corridors, particularly the core habitat areas
- the lowest amount of native vegetation with high conditions to be removed by Ecological Vegetation Class Conservation Status
- the lowest potential impacts on known or registered sites of Aboriginal and historic heritage significance
- the smallest number of dwellings within 100 m, 200 m and 300 m of the alignment corridor.

Further detail on the options assessment process is provided in the EES Attachment IV: *Options assessment*.

9 IMPACT ASSESSMENT – PREFERRED ALIGNMENT

This section provides a summary of the impact pathways identified in Section 7.1 on the preferred C2 alignment option without the implementation of mitigation measures.

9.1 EXCAVATION EXPOSES ACID SULFATE SOILS

The potential for the preferred C2 alignment to have ASS is low based on the ASRIS database (ASRIS 2017) and Victorian Coastal ASS Maps (DSE 2009), although no analytical data is available to confirm this. The potential to expose ASS would be limited to the construction phase of the project and of low impact.

9.2 EXCAVATION EXPOSES CONTAMINATED SOIL

Based on the current and historical land use activities, the potential for contaminants to be exposed along the preferred alignment is medium, as there have been historical uses within the study area that would give rise to moderate soil contamination (mine workings, rail corridor, farming and grazing). The main impact would be to human health from exposure of construction workers during the construction phase to contaminated materials, dust, vapours, fuels and chemicals during the construction phase, as a direct result of excavation of contaminated ground.

9.3 EXCAVATION CAUSES EROSION/SEDIMENTATION

Emerson Class tests were conducted on soil samples recovered from boreholes BH01, BH04 and BH05 on the preferred C2 alignment, at areas of proposed cutting. All samples tested derived an Emerson Class number of 2, indicating that the samples displayed some dispersive reaction during testing. With respect to erosion and sedimentation, soils on the preferred C2 alignment are therefore considered to be dispersive.

Erosion and sedimentation associated with cut slopes on the preferred C2 alignment has the potential to increase sedimentation rates in Yam Holes Creek, which has many tributaries that cross the preferred alignment. Erosion of any unprotected soil stockpiles located near the creek and its tributaries also have the potential to cause sedimentation through the action of rain and/or flood waters.

It is concluded that the potential for excavation works and erosion causing sediments to enter the environment would have a medium impact, which would occur throughout the construction phase of the project as a direct result of excavation works. There is also the potential for sediments to enter the environment after the construction phase is complete, while reinstatement of vegetation on stripped surfaces re-establish.

9.4 FILLING CAUSES GROUND SETTLEMENT

A significant portion of the preferred C2 alignment requires fill to be placed on unconsolidated alluvial deposits, particularly the section of the alignment between Beaufort-Lexton Road and Racecourse Road and immediately east of Main Lead Road. Boreholes BH02, BH03, BH14 and BH15 have identified alluvial deposits up to 4.4 m thick, comprising of a mixture of clay, silt, sand and gravel. The thickness and composition of the alluvium is likely to vary along the alignment, and potentially thicker deposits may be present elsewhere on the preferred route alignment.

The potential for settlement as a direct result of construction filling is low, where embankments are placed upon alluvial deposits, generally associated with low lying ground and adjacent to watercourses. The duration and extent of settlement can be calculated in the detailed design of the embankments and impacts mitigated through design. Most of the ground settlement will occur during the construction period of the project but has the potential to continue following completion of the project.

9.5 CONSTRUCTION CAUSES GROUND INSTABILITY

No existing landslides were identified along the preferred C2 alignment from a study of aerial photography. It is possible that shallow landslips are present, which are too small to be seen in the aerial photographs, or which may have been hidden by vegetation. The most likely locations for ground instability relating to construction activity on the preferred C2 alignment are at the proposed cut locations within hillsides, at the location of boreholes BH01, BH04, BH05 and BH16.

EES Appendix E: *Historic heritage impact assessment* (Archaeology at Tardis 2021) identified shallow mine workings and deep lead mine workings within the study area, however not specific to the C2 alignment. It is possible that the preferred C2 alignment could encounter currently unknown shallow mine workings or deep lead workings.

The potential for instability of engineered slopes, cut or embankments as a direct result of construction is low. The duration for ground instability will last throughout the construction period of the project and has the potential to exist following completion of the project.

9.6 EXCAVATION ENCOUNTERS UNSUITABLE SOILS

The preferred alignment C2 will require a greater volume of fill material to form embankments than available from excavation of the proposed cuttings. If excavated soils cannot be used to form the fill embankments, then quantities of imported fill materials will be required. The suitability of soils excavated from cuts, for re-use as fill, is therefore a key geotechnical constraint for the preferred C2 alignment. If the natural soils at the base of cuttings are too weak or susceptible to degrading under traffic loading, they will need to be treated or replaced with imported fill.

Preliminary geotechnical investigation results from boreholes along the preferred C2 alignment (BH01, BH02, BH03, BH04, BH05, BH09, BH14, BH15 and BH16) found that excavated soils are generally of low strength, comprising a high silt content, non-aggressive to mildly aggressive and dispersive.

Given the preliminary geotechnical laboratory results and noting that VicRoads Standard 204 advises that soils with silt content cannot be adopted as Type A or Type B fill material, earthworks design will need to consider opportunities to treat unsuitable soils for reuse as embankment fill or contain them within zoned embankments to minimise the volume of imported fill. Preliminary investigation results suggest that it is likely that significant amounts of fill will need to be imported.

The potential for excavations encountering unsuitable soils is high on the preferred C2 alignment. The impact of this is likely to affect the design phase of the project, with respect to reusable materials but could extend into the construction if unexpected ground conditions were encountered.

10 MITIGATION

10.1 STANDARD ENVIRONMENTAL PROTECTION MEASURES

RRV has a set of standard environmental protection measures which are typically required to be complied for construction of major projects like the Beaufort Bypass project. The standard contract conditions that are applicable to soils are:

- VicRoads (2016b), Contract Documents Section 177 Environmental Management (Major).

The proposed measures presented below is a summary of the EMF to manage the environmental performance consistent with VicRoads Section 177 Environmental Management Plan (EMP) and relevant Commonwealth and State Acts, policies and best practice.

- In accordance with Section 177, an EMP is an overarching document describing the EMF for the project. The EMP will have several sub-plans to manage specific impacts and tasks associated with the construction and operation phase of the project.
- Construction environmental management plan (CEMP) to be prepared prior to commencement of construction to manage environmental considerations and roles and responsibilities during the construction phase of the project which will be updated based on progressive investigation methods.
- Spoil management strategy/plan to be prepared prior to commencement of construction based on the soil re-use requirements of the project. All excavated soil is to be appropriately stored prior to disposal off-site to an appropriately licenced facility in accordance with relevant EPA Victoria regulations. Soils stockpiles on-site are placed on plastic and covered to prevent spread of materials via wind and rain. The geometry and location of the stockpile is to be designed to avoid soil erosion and contamination of nearby ecosystems. Prior to re-use or off-site disposal, stockpiles soils or importation of fill are to be assessed in accordance with IWRG 702 and 621 guidelines. If soils are to be reused on site, liaise with EPA to determine soil reuse options in accordance with the SEPP (Prevention and Management of Contaminated Land) No. S95 June 2002. The spoil management strategy to include plans for fill requirements for the project including source locations, type of fill and stockpile management.
- If ASS is identified during detailed design or in the initial intrusive investigation works, the EMP is to include an ASS management plan.
- Prior to the commencement of construction, an area specific or task specific occupational Health and Environment Safety Plan (HESP) be prepared so that risk from specific contaminants can be appropriately managed.
- The EMP will require the CEMP to include erosion and sedimentation controls, established in accordance with EPA best practice guidelines for the treatment of sediment laden run-off. In addition, the EMP will require the amount of exposed surface be limited during construction with progressive protection of exposed surfaces with mulch, erosion control mat and progressive seeding with sterile grass. The EMP will also require use of sedimentation basins as the primary sediment control for the works unless these are found to not be technically feasible for the project.
- Work near waterways will be controlled by VicRoads Section 177 EMP and the SEPP (Waters) and best practice guidelines. Stockpiles will be located away from waterways.
- The effectiveness of control measures will be monitored and cleaned, repaired and augmented as required to maintain effective controls.
- Additional geotechnical investigations along the preferred alignment will be required to inform the detailed design to determine the specific geological conditions and risks for the alignment to be assessed and reduced using best practice design and engineering.

10.2 ADDITIONAL CONTROL

The impact and risk assessments have identified the need for an additional control to minimise environmental impact. This is summarised below:

- As part of detailed design, undertake intrusive soil assessment along the preferred alignment and analysis for relevant contaminants of potential concern in accordance with EPA Victoria Publications IWRG702 and 621. The results of these assessments will inform the detailed design and the soil management strategy for the project.

10.3 MANAGING IDENTIFIED IMPACTS ON THE PREFERRED ALIGNMENT

The following mitigation steps will be taken to reduce the impacts to soil and geology on the preferred alignment, identified in Section 9.

10.3.1 ACID SULFATE SOILS

Additional ground investigation will be undertaken along the preferred alignment, as part of the detailed ground investigation, targeting specific areas relevant to the finalised design and confirming the presence or absence of ASS with laboratory testing. If ASS is identified during detailed design ground investigation the EMP will include a specific ASS management plan in accordance *Industrial Waste Management Policy (Waste Acid Sulfate Soils) 1999* to manage risks to buildings and structures, and the environment.

10.3.2 CONTAMINATED SOIL

If contaminated soils (hydrocarbons, heavy metals, nitrates, ammonia, pesticides, herbicides etc.) are identified from targeted geo-environmental investigation and laboratory testing during the detailed ground investigation, a specific contamination management plan will be included in the EMP.

Prior to the commencement of construction, a CEMP and an area specific or task specific occupational HESP will also be prepared so that risks from specific contaminants can be appropriately managed.

Prior to re-use or off-site disposal, stockpiles of soils or importations of fill will be assessed in accordance with IWRG 702 and 621 guidelines. If soils are to be reused on site, liaison will be carried out with EPA to determine soil reuse options in accordance with the SEPP (Prevention and Management of Contaminated Land) No. S95 June 2002. The spoil management strategy will include plans for fill requirements for the project including source locations, type of fill and stockpile management.

10.3.3 EROSION / SEDIMENTATION

The EMP will require the CEMP to include erosion and sedimentation controls, established in accordance with EPA best practice guidelines for the treatment of sediment laden run-off. In addition, the EMP will require the amount of exposed surface be limited during construction with progressive protection of exposed surfaces with mulch, erosion control mat and progressive seeding with sterile grass. The EMP will also require use of sedimentation basins as the primary sediment control for the works unless these are found to not be technically feasible for the project. Erosion and sediment controls will need to extend into operational phases until revegetation and landscaping of exposed surfaces is established.

Work near waterways, such as Yam Holes Creek, will be controlled by VicRoads Section 177 EMP and the SEPP (Waters) and best practice guidelines.

The effectiveness of control measures will be monitored and cleaned, repaired and augmented as required to maintain effective controls.

As established in the Spoil Management Strategy/Plan, soil stockpiles on-site are placed on plastic and covered to prevent spread of materials via wind and rain. Stockpiles will be positioned outside of flood plains. The geometry and location of the stockpile is to be designed to avoid soil erosion and contamination of nearby ecosystems.

Design alternatives to minimise erosion and sedimentation could be employed, such as, steep cutting slopes (1H:10V) as opposed to shallow slopes. Such slopes would be supported by use of soil nails or retaining structures and protected by shotcrete. Steeper slopes would reduce land take, particularly through the Camp Hill area. Dispersion of excavated soils could potentially be reduced through soil treatment.

10.3.4 GROUND SETTLEMENT

Additional ground investigation will be undertaken at embankment locations along the preferred alignment, as part of the detailed ground investigation, to confirm the thickness and properties of any underlying alluvium, depth to rock head and ground water levels.

Based on the soil samples recovered and tested in the preliminary geotechnical investigation, settlements of the surrounding ground and of the embankment should be manageable through implementation of standard industry practices.

10.3.5 GROUND INSTABILITY

A walkover survey of the preferred alignment will be carried out to confirm the natural slopes do not contain existing landslips. If necessary, geological mapping will be conducted by an Engineering Geologist to determine any potential cut slope instability. Geotechnical investigation may also target cut slope locations with the use of angled boreholes, complete with downhole televiewer data, to understand the dip and dip direction of the geological bedding and jointing.

A walkover survey of the preferred alignment will also be required to determine the potential for mining instability. Geophysics, combined with intrusive investigation, may be required to investigate workings hidden below the ground surface.

10.3.6 UNSUITABLE SOILS

To minimise the quantity of imported fill, earthworks design will need to consider opportunities to treat unsuitable soils for reuse as embankment fill or contain them within zoned embankments. Earthworks design will also need to specify preparation and compaction requirements to ensure stable soils at subgrade level and within embankments.

10.4 SUMMARY OF MITIGATIONS

A summary of mitigations is provided in Table 10.1 and will require incorporation into the EMF for the management of residual impacts.

Table 10.1 Summary of mitigations

NO.	MITIGATION	PROJECT PHASE
SG1	Preparation of an overarching EMP in accordance with Contract Specifications Section 177.	Pre-construction and construction
SG2	Preparation of a CEMP to manage potential erosion, sediment and contamination impacts and define roles and responsibilities during the construction.	Pre-construction, construction and post-construction
SG3	Spoil Management Strategy/Plan to be prepared prior to commencement of construction based on the soil re-use requirements of the project.	Pre-construction and construction
SG4	Prepare an ASS management plan if ASS is identified during detailed design or in the initial intrusive investigation works, in accordance *Industrial Waste Management Policy (Waste Acid Sulfate Soils) 1999*.	Detailed design and pre-construction
SG5	Prepare task specific occupational HESP to manage risk from specific contaminants.	Pre-construction and construction
SG6	Undertake site walkover survey of the preferred alignment to confirm the natural slopes do not contain existing landslips and mining instability.	Detailed design
SG7	Consider opportunities to treat unsuitable soils for reuse as embankment fill or contain them within zoned embankments. Earthworks design will also need to specify preparation and compaction requirements to ensure stable soils at subgrade level and within embankments.	Detailed design, pre-construction and construction

11 RESIDUAL IMPACTS

11.1 ACID SULFATE SOILS

Based on limited data of the existing ground conditions mentioned earlier and the proposed mitigation measures, the potential for ASS to impact the construction and operation of alignment C2 of the project is considered low. Any potential impacts can be further understood through an ASS investigation including laboratory testing and appropriate mitigation and/or management measures adopted as part of the CEMP. The residual impact is considered low.

11.2 CONTAMINATED SOIL

The potential for contamination to impact the alignment C2 of the project and the surrounding environment is considered medium.

Any potential impacts can be further understood through a soil contamination investigation including laboratory testing and appropriate mitigation and/or management measures adopted as part of the CEMP. Once the road alignment is finalised, soil sampling and analysis is required to understand contamination risk/disposal costing/reuse assessment reducing the residual impacts. The residual impact is considered low.

11.3 EROSION / SEDIMENTATION

The potential for excavation works causing sediments to enter waterways is considered to have medium impact.

Through detailed design and suitable construction methodology (CEMP), the risks and impacts to the surrounding environment and waterways can be mitigated during and after construction. The EMP will require the CEMP to include erosion and sedimentation controls, including limiting exposed surfaces during construction, employing sedimentation basins, and ensuring works near waterways are controlled by VicRoads Section 177 EMP, the SEPP (Waters), and best practice guidelines.

With the effectiveness of control measures monitored, cleaned and repaired as works progress, a low residual impact of erosion and sedimentation impacting the environment and waterways during and after construction will remain. The residual impacts will be low.

11.4 GROUND SETTLEMENT

The potential for ground settlement along alignment C2 is considered to have a low residual impact. Ground settlement impacts can be further reduced and mitigated during detailed design phase and through the implementation of standard industry practices.

11.5 GROUND INSTABILITY

Impacts identified around ground instability along alignment C2 are low. Implementation of standard industry design practices during the detailed design phase will ensure low initial impact remain. The residual impact is then considered low.

11.6 UNSUITABLE SOILS

There is a high risk associated with encountering unsuitable soils along alignment C2, such as weak and/or erosion/sedimentation prone soils. These risks can be reduced through further geotechnical investigation, laboratory testing, soil treatment and design solutions to utilise the soils won from cuttings and excavation on site. Use of imported fill will also reduce these impacts. The residual impact is therefore considered low with further investigation and design solutions.

12 CONCLUSION

The DELWP (2016) scoping requirement evaluation objectives relevant to the soils and geology impact assessment were assessed based on a desktop study of existing conditions, the findings of a preliminary ground investigation, risk and impact assessment based on environmental management performance required for the project.

The soils and geology impact assessment concluded that:

- There are no significant differences between the assessed impacts of each of the proposed alignment options.
- Based on the existing conditions and impact assessment noted in this report, a medium impact to the environment will result from contamination due to the construction of the project, without mitigation. This potential impact can be minimised through thorough soil contamination investigations and laboratory testing along the preferred alignment, with appropriate mitigation and/or management measures defined in Section 10.3.2 adopted as part of the CEMP. With implementation of proposed mitigations, the residual impact is considered low.
- Based on the existing conditions reviewed in this report, the potential for ASS from the construction and operation of the project is considered low. Any potential impacts can be further understood through an ASS investigation and laboratory testing for the preferred alignment, with appropriate mitigation and/or management measures adopted as part of the CEMP.
- Construction impacts on the soil and geology within the study area are likely to have only low potential impacts on the protected beneficial uses of the surrounding land. These minor potential impacts could be mitigated for the preferred alignment by minimising the extent of earthworks.
- For all alignment options, there is a high risk associated with encountering unsuitable soils and there is a greater volume of fill material required for embankments than available from excavation of the proposed cuttings. Preliminary geotechnical investigation found that excavated soils are generally of low strength, comprising a high silt content, and dispersive. Earthworks design will need to consider opportunities to treat unsuitable soils for reuse as embankment fill or contain them within zoned embankments to minimise the volume of imported fill. Current findings show that it is likely that significant amounts of fill will need to be imported.
- For all alignment options, a medium impact related to excavation works causing sediments to enter watercourses. This impact can be mitigated and result in low residual impacts through design and the EMP, which will require the CEMP to include erosion and sedimentation controls, including limiting exposed surfaces during construction, employing sedimentation basins, ensuring works near waterways will be controlled by VicRoads Section 177 EMP and the SEPP (Waters) and best practice guidelines. Control measures are recommended to be monitored, reviewed and refined as works progress.
- Ground instability and settlement along the potential alignment options have been identified in this report as low impact. These impacts can be further reduced and mitigated during detailed design and through the implementation of standard industry practices that will result in minimal residual impacts to the environment. The residual impacts to the environment from potential ground instability and settlement resulting from the construction of the project is considered low.

13 LIMITATIONS

13.1 SCOPE OF SERVICES

This soils and geology impact assessment has been prepared in accordance with the scope of services set out in the contract, or as otherwise agreed, between the client and WSP (scope of services). In some circumstances the scope of services may have been limited by a range of factors such as time, budget, access and/or site disturbance constraints.

13.2 RELIANCE ON DATA

In preparing the report, WSP has relied upon data, surveys, analyses, designs, plans and other information provided by the client and other individuals and organisations, most of which are referred to in the report (the data). Except as otherwise stated in the report, WSP has not verified the accuracy or completeness of the data. To the extent that the statements, opinions, facts, information, conclusions and/or recommendations in the report (conclusions) are based in whole or part on the data, those conclusions are contingent upon the accuracy and completeness of the data. WSP will not be liable in relation to incorrect conclusions should any data, information or condition be incorrect or have been concealed, withheld, misrepresented or otherwise not fully disclosed to WSP.

13.3 GEOTECHNICAL INVESTIGATION

Geotechnical engineering is based extensively on judgment and opinion. It is far less exact than other engineering disciplines. Geotechnical engineering reports are prepared to meet the specific needs of individuals. A report prepared for a consulting civil engineer may not be adequate for a construction contractor or even some other consulting civil engineer. This report was prepared expressly for the client and expressly for purposes indicated by the client or his representative. Use by any other persons for any purpose, or by the client for a different purpose, might result in problems. The client should not use this report for other than its intended purpose without seeking additional geotechnical advice.

13.4 THIS GEOTECHNICAL REPORT IS BASED ON PROJECT-SPECIFIC FACTORS

This soils and geology impact assessment is based on a subsurface investigation which was designed for project-specification factors, including the nature of any development, its size and configuration, the location of any development on the site and its orientation, and the location of access roads and parking areas. Unless further geotechnical advice is obtained this soils and geology impact assessment cannot be used:

- when the nature of any proposed development is changed
- when the size, configuration location or orientation of any proposed development is modified.

This soils and geology impact assessment report cannot be applied to an adjacent site.

13.5 THE LIMITATIONS OF SITE INVESTIGATION

In assessing a site from a limited number of boreholes or test pits there is the possibility that variations may occur between test locations. Site exploration identifies specific subsurface conditions only at those points from which samples have been taken. The risk that variations will not be detected can be reduced by increasing the frequency of test locations; however, this often does not result in any overall cost savings for the project. The investigation program undertaken is a professional estimate of the scope of investigation required to provide a general profile of the subsurface conditions. The data derived from the site investigation program and subsequent laboratory testing are extrapolated across the site to form an inferred geological model and an engineering opinion is rendered about overall subsurface conditions and their likely behaviour regarding the proposed development. Despite investigation the actual conditions at the site might differ from those inferred to exist, since no subsurface exploration program, no matter how comprehensive, can reveal all subsurface details and anomalies.

The borehole logs are the subjective interpretation of subsurface conditions at a location, made by trained personnel. The interpretation may be limited by the method of investigation and cannot always be definitive. For example, inspection of an excavation or test pit allows a greater area of the subsurface profile to be inspected than borehole investigation, however, such methods are limited by depth and site disturbance restrictions. In borehole investigation, the actual interface between materials may be more gradual or abrupt than a report indicates.

13.6 SUBSURFACE CONDITIONS ARE TIME DEPENDENT

Subsurface conditions may be modified by changing natural forces or man-made influences. A geotechnical engineering report is based on conditions which existed at the time of subsurface exploration.

Construction operations at or adjacent to the site, and natural events such as floods, or groundwater fluctuations, may also affect subsurface conditions, and thus the continuing adequacy of a soils and geology impact assessment. The project geotechnical engineer should be kept appraised of any such events and should be consulted to determine if additional tests are necessary.

13.7 AVOID MISINTERPRETATION

A geotechnical engineer should be retained to work with other appropriate design professionals explaining relevant geotechnical findings and in reviewing the adequacy of their plans and specifications relative to geotechnical issues.

13.8 BORE/PROFILE LOGS SHOULD NOT BE SEPARATED FROM THE SOILS AND GEOLOGY IMPACT ASSESSMENT

Final bore/profile logs are developed by geotechnical engineers based upon their interpretation of field logs and laboratory evaluation of field samples. Customarily, only the final bore/profile logs are included in geotechnical engineering reports. These logs should not under any circumstances be redrawn for inclusion in architectural or other design drawings. To minimise the likelihood of bore/profile log misinterpretation, contractors should be given access to the complete geotechnical engineering report prepared or authorised for their use. Providing the best available information to contractors helps prevent costly construction problems. For further information on this matter reference should be made to ‘Guidelines for the Provision of Geotechnical Information in Construction Contracts’ published by the Institution of Engineers Australia, National Headquarters, Canberra 1987.

13.9 GEOTECHNICAL INVOLVEMENT DURING CONSTRUCTION

During construction, excavation is frequently undertaken which exposes the actual subsurface conditions. For this reason, geotechnical specialists should be retained through the construction stage, to identify variations if they are exposed and to conduct additional tests which may be required and to deal quickly with geotechnical problems if they arise.

13.10 REPORT FOR BENEFIT OF CLIENT

The report has been prepared for the benefit of the client and no other party. WSP assumes no responsibility and will not be liable to any other person or organisation for or in relation to any matter dealt with or conclusions expressed in the report, or for any loss or damage suffered by any other person or organisation arising from matters dealt with or conclusions expressed in the report (including without limitation matters arising from any negligent act or omission of WSP or for any loss or damage suffered by any other party in relying upon the matters dealt with or conclusions expressed in the report). Other parties should not rely upon the report or the accuracy or completeness of any conclusions and should make their own enquiries and obtain independent advice in relation to such matters.

13.11 OTHER LIMITATIONS

WSP will not be liable to update or revise the report to take into account any events, emergent circumstances or facts occurring or becoming apparent after the date of the report.

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APPENDIX A

BOREHOLE LOGS

Explanatory Notes - Engineering Logs

Engineering logs have been prepared in accordance with AS1726:2017 "Geotechnical Site Investigations" and as defined below.

DRILLING/EXCAVATION METHODS

Symbol	Term
AS	Auger Screwing
EX	Excavation
HA	Hand Auger
NMLC/HMLC	Diamond Core –triple tube
NQ/HQ/PQ	Diamond Core – wireline
PC	Percussion
PCB	Poly Carbonised Diamond Bit
PT	Push Tube
RAB	Rotary Air Blast
RC	Reverse Circulation
S	Sonic drill
VB	Vibrocoring
WB	Washbore with blade
WR	Washbore with roller (tricone)

SUPPORT

C Casing
M Drill mud
Nil No support

WATER

—< Partial water loss   >— Water inflow

◀ Complete water loss

▽ Water level at date shown

NFGWO No Free Groundwater Observed
The observation of groundwater, whether present or not, was not possible due to drilling water, surface seepage or cave in of the borehole/test pit.
NFGWE No Free Groundwater Encountered
The borehole/test pit was dry soon after excavation. Inflow may have been observed had the borehole/test pit been left open for a longer period.

FIELD TEST (Soil borehole and test pit logs)

DM Dilatometer test
HB Hammer bounce
OT Other test (eg. plate load test)
PE Permeability test
PM Pressuremeter test
PP Pocket penetrometer
SPT Standard penetration test
SV Shear vane test

SAMPLE (Soil borehole and test pit logs)

B Bulk disturbed sample
D Disturbed sample
PT Push tube
SPT SPT sample
U50 Undisturbed sample in 50mm diameter tube
U75 Undisturbed sample in 75mm diameter tube

GRAPHIC LOG – see later

TOTAL CORE RECOVERY (Rock logs only)

$$TCR\ (\%) = \frac{\text{Length of core recovered}}{\text{Length of core run}} \times 100$$

ROCK QUALITY DESIGNATION (Rock logs only)

$$RQD\ (\%) = \frac{\sum \text{Length of sound core pieces} > 100\text{mm}}{\text{Length of core run}} \times 100$$

GROUP SYMBOL (Soil borehole and test pit logs)

Soils are classified to reflect their primary and significant secondary component/characteristic using the classification symbols described in AS1726-2017, summarised as follows.

Symbol	Major division	Typical names
GW, GP	GRAVEL	Gravel & gravel-sand mixtures, little/no fines
GM		Gravel-silt & gravel-sand-silt mixtures
GC		Gravel-clay & gravel-sand-clay mixtures
SW, SP	SAND	Sand & gravel-sand mixtures, little/no
SM		Sand-silt mixtures
SC		Sand-clay mixtures
ML	SILT & CLAY (low & medium plasticity)	Inorganic silt/clayey fine sand or silt
CL, CI		Inorganic clay, gravelly clay, sandy clay
OL		Organic silt
MH	SILT & CLAY (high plasticity)	Inorganic silt
CH		Inorganic clay, high plasticity
OH		Organic clay, med-high plasticity, organic silt
Pt	Highly organic soil	Peat, highly organic soil

FIELD DESCRIPTION

Soil and rock materials described to AS1726-2017. The description of percentage of cobbles and boulders in a soil may be limited by sample size.

MOISTURE CONDITION

Coarse grained soils and rocks
Dry (D), Moist (M) or Wet (W).
Estimated based on appearance and feel.

Cohesive soils

MC<PL	Moist, dry of plastic limit
MC≈PL	Moist, near plastic limit
MC>PL	Moist, wet of plastic limit
MC≈LL	Wet, near liquid limit
MC>LL	Wet, wet of liquid limit

Estimated based on judgement

COHESIVE SOILS - CONSISTENCY

The consistency of a cohesive soil is assessed by tactile means or field measurement of undrained shear strength.

A Hand Penetrometer may be used in the field or the laboratory to provide approximate assessment of unconfined compressive strength of cohesive soils (kPa) as follows:

Strength	Symbol	Indicative undrained shear strength (kPa)	Hand Penetrometer Reading (kPa)
Very Soft	VS	≤ 12	< 25
Soft	S	>12 and ≤ 25	25 to 50
Firm	F	> 25 and ≤ 50	50 to 100
Stiff	St	>50 and ≤ 100	100 to 200
Very Stiff	VSt	> 100 and ≤ 200	200 to 400
Hard	H	>200	> 400
Friable	Fr	-	-

COHESIONLESS SOILS - RELATIVE DENSITY

Relative density terms are used to describe silty and sandy material, and these are usually based on resistance to drilling penetration or the Standard Penetration Test (SPT) 'N' values.

The Standard Penetration Test (SPT) is carried out in accordance with AS 1289, 6.3.1. For completed tests the number of blows required to drive the split spoon sampler 300 mm is recorded as the N value. For incomplete tests the number of blows and the penetration beyond the seating depth of 150 mm are recorded. If the 150 mm seating penetration is not achieved the number of blows to achieve the measured penetration is recorded. SPT correlations may be subject to corrections for overburden pressure and equipment type.

Term	Symbol	Density Index	N Value (blows /0.3 m)	DCP (blows /100m
Very Loose	VL	0 to 15	0 to 4	0 to 1
Loose	L	15 to 35	4 to 10	1 to 2
Medium Dense	MD	35 to 65	10 to 30	2 to 5
Dense	D	65 to 85	30 to 50	5 to 10
Very Dense	VD	>85	>50	>10

SOIL STRUCTURE

Soil structure is described to AS 1726-2017 if visible and present.

SOIL / ROCK ORIGIN

The geological origin of the soil or rock is presented as an interpretation of the geological and geomorphological setting. Origin cannot be deduced on the basis of material appearance and properties alone and is therefore limited by the availability of supporting geological information

ROCK MATERIAL WEATHERING

Rock weathering is described mainly using the following abbreviations and definitions used in AS1726.

Term	Symbol	Definition
Residual soil	RS	Material is weathered to such an extent that it has soil properties. Mass structure and material texture and fabric of original rock are no longer visible.
Extremely weathered	XW	Material is weathered to such an extent that it has soil properties. Mass structure and material texture and fabric of original rock are still visible.
Highly weathered	HW	The whole of the rock material is discoloured, usually by iron staining or bleaching to the extent that the colour of the original rock is not recognizable. Rock strength is significantly changed by weathering. Some primary minerals have weathered to clay minerals. Porosity may be increased by leaching, or may be decreased due to deposition of weathering products in pores.
Moderately weathered	MW	The whole of the rock material is discoloured, usually by iron staining or bleaching to the extent that the colour of the original rock is not recognizable, but shows little or no change of strength from fresh rock.
Slightly weathered	SW	Rock is partially discoloured with staining or bleaching along joints but shows little or no change of strength from fresh rock.
Fresh	FR	Rock shows no sign of decomposition of individual minerals or colour changes.

If differentiation between highly and moderately weathered rock is not practicable, then Distinctly Weathered (DW) is used as defined in AS1726:2017.

INFERRED ROCK STRENGTH

Rock strength is inferred based on field assessment, Point Load Index or Uniaxial Compressive Strength as follows:

Term	Symbol	UCS (MPa)	Point Load Index $Is_{(50)}$ (MPa)
Very Low	VL	0.6 to 2	0.03 to 0.1
Low	L	2 to 6	0.1 to 0.3
Medium	M	6 to 20	0.3 to 1
High	H	20 to 60	1 to 3
Very High	VH	60 to 200	3 to 10
Extremely High	EH	>200	>10

● Diametral Point Load Index test

■ Axial Point Load Index test

DEFECT SPACING/BEDDING SPACING (Rock)

Measured at right angles to defects of same set or bedding.

Term	Defect Spacing	Bedding
Extremely closely spaced	<6 mm 6 to 20 mm	Thinly Laminated Laminated
Very closely spaced	20 to 60 mm	Very Thin
Closely spaced	0.06 to 0.2 m	Thin
Moderately widely spaced	0.2 to 0.6 m	Medium
Widely spaced	0.6 to 2 m	Thick
Very widely spaced	>2 m	Very Thick

DEFECT DESCRIPTION (Rock)

Symbol	Term	Symbol	Term
Bg	Bedding	DB	Drill Break
Pt	Parting	Se	Seam
Cn	Contact	SZ	Sheared Zone
Bd	Boundary	CZ	Crushed Zone
Jt	Joint	F	Fault
Fo	Foliation	Vn	Vein
C	Cleavage		

DEFECT ORIENTATION (Rock)

Dip measured relative to the horizontal plane in vertical boreholes and relative to core axis in inclined boreholes.

DEFECT ROUGHNESS AND SHAPE (Rock)

Roughness	Description	Roughness	Description
Sm	Smooth	Po	Polished
Ro	Rough	Sl	Slickensided
VRo	Very Rough		
Shape	**Description**	**Shape**	**Description**
Pl	Planar	Cu	Curved
Un	Undulating	Vu	Vuggy
Ir	Irregular	St	Stepped

COATING OR INFILLING (Rock)

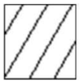
Abbreviation	Description	Abbreviation	Description
Cln	Clean	Co	Coal
Cg	Coating	Cr	Crushed rock
In	infill	Fe	Limonite/ironstone
Sn	Stain	Fl	Feldspar
Vr	Veneer	Gp	Gypsum
Ca	Calcite	Mn	Manganese
Ch	Chlorite	Py	Pyrite
Cl	Clay	Qz	Quartz

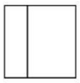
Graphic Symbols — Soils and Rocks

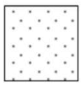
Typical symbols for soils and rocks are as follows. Combinations of these symbols may be used to indicate mixed materials such as clayey sand.

SOIL SYMBOLS

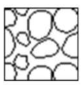
Main components

 CLAY

 SILT

 SAND

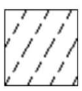
 GRAVEL

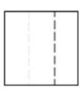
 BOULDERS / COBBLES

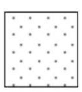
 TOPSOIL

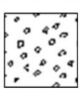
 PEAT

Minor components

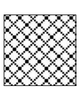
 CLAYEY

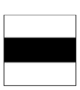
 SILTY

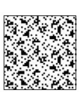
 SANDY

 GRAVELLY

OTHER MATERIAL SYMBOLS

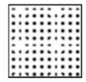
 FILL

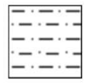
 BITUMEN

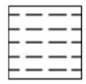
 CONCRETE

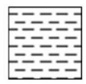
ROCK SYMBOLS

Sedimentary Rocks

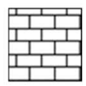
 SANDSTONE

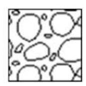
 SILTSTONE

 CLAYSTONE, MUDSTONE

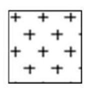
 SHALE

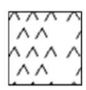
 COAL

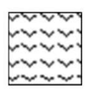
 LIMESTONE

 CONGLOMERATE

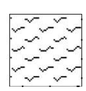
Igneous rocks

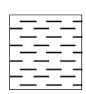
 GRANITE

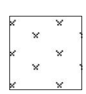
 BASALT

 UNDIFERENTIATED IGNEOUS

Metamorphic rocks

 SLATE, PHYLLITE, SCHIST

 GNEISS

 QUARTZITE

BOREHOLE ENGINEERING LOG

BOREHOLE NO.

BH01

SHEET : 1 OF 2

Client:	**VicRoads**	Date Commenced:	**2-26-18**
Project:	**Beaufort Bypass EES**	Date Completed:	**2-26-18**
Borehole Location:	**Refer to Figure 1**	Recorded By:	**TS**
Project Number:	**2270290A**	Log Checked By:	**CB**

Drill Model/Mounting:	**Boart Longyear LS250/ Track**	Hole Angle:	**-90°**	Surface RL:	**441.8 m AHD**
Borehole Diameter:	**180 mm**	Bearing:	**---**	Co-ords:	**E 707448 N 5855940 MGA94**

Borehole Information | Field Material Description

METHOD	SUPPORT	WATER	RL (m AHD)	DEPTH (m)	FIELD TEST	SAMPLE	GRAPHIC LOG	GROUP SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY (VS S F ST VST H / FB VL L MD D VD)	POCKET PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
S		NFGWE		0.00				ML	SILT; low plasticity, dark brown, brown, trace rootlets.				Top 200mm disturbed by cultural heritage sieving
			441	0.20				ML	SILT; low plasticity, pale orange-brown, trace fine to medium grained, angular gravel.	D			Friable
			440	1.00	SPT 9/80mm N=R	SPT		ML	SILT; low plasticity, pale orange-brown, inferred extremely weathered siltstone.				
				2					becoming dark red, purple, brown, grey, trace fine to coarse grained angular gravel				
			439	3	SPT 7/80mm HB N=R	SPT							
			438 / 437	4	SPT 8/90mm HB N=R	SPT			becoming orange-brown				
			436	5 / 6	SPT 6/30mm HB N=R				with zones of highly weathered siltstone, low strength				
			435 / 434	7									

This Borehole log should be read in conjunction with WSP's accompanying explanatory notes.

BOREHOLE ENGINEERING LOG

BOREHOLE NO.

BH01

Client:	**VicRoads**	Date Commenced:	**2-26-18**
Project:	**Beaufort Bypass EES**	Date Completed:	**2-26-18**
Borehole Location:	**Refer to Figure 1**	Recorded By:	**TS**
Project Number:	**2270290A**	Log Checked By:	**CB**

Drill Model/Mounting:	**Boart Longyear LS250/ Track**	Hole Angle:	**-90°**	Surface RL:	**441.8 m AHD**
Borehole Diameter:	**180 mm**	Bearing:	**---**	Co-ords:	**E 707448 N 5855940 MGA94**

METHOD	SUPPORT	WATER	RL (m AHD)	DEPTH (m)	FIELD TEST	SAMPLE	GRAPHIC LOG	GROUP SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY (VS S F ST VST H / FB VL L MD D VD)	POCKET PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
S		NFGWE		8.00	SPT 8/100mm HB N=R			ML	SILT; low plasticity, orange-brown, inferred extremely weathered siltstone.	D			
			433	9		B							
			432	10	SPT 6/60mm HB N=R								observed bedding dips at 80° (
			431	11									
			430	12	SPT 6/70mm HB N=R				becoming red-brown, brown, highly weathered siltstone zones absent				
			429	13									
			428	14					END OF BOREHOLE AT 14.00 m Target depth				
			427										
			426										

This Borehole log should be read in conjunction with WSP's accompanying explanatory notes.

BOREHOLE ENGINEERING LOG

BOREHOLE NO. **BH02**

SHEET : 1 OF 1

Client:	**VicRoads**	Date Commenced:	**1-16-18**
Project:	**Beaufort Bypass EES**	Date Completed:	**1-16-18**
Borehole Location:	**Refer to Figure 1**	Recorded By:	**TS**
Project Number:	**2270290A**	Log Checked By:	**CB**

Drill Model/Mounting:	**Boart Longyear LS250/ Track**	Hole Angle:	**-90°**	Surface RL:	**393.4 m AHD**
Borehole Diameter:	**120 mm**	Bearing:	**---**	Co-ords:	**E 709624 N 5856265 MGA94**

Borehole Information | **Field Material Description**

METHOD	SUPPORT	WATER	RL (m AHD)	DEPTH (m)	FIELD TEST	SAMPLE	GROUP SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY (VS S F ST VST H / FB VL L MD D VD)	POCKET PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
S	Nil	NFGWE		0.00–0.30			ML	SILT: low plasticity, pale brown				Top 300mm disturbed by cultural heritage sieving
			393	0.30–2.00	SPT 7, 9, 7 N=16	SPT	CH	CLAY: high plasticity, orange-brown, brown becoming mottled orange-brown, grey becoming orange-brown, with fine to coarse grained sand	D - M M D - M		>600 >600	
			391	2.00–2.40	SPT 8/70mm N=R	SPT	GC	CLAYEY GRAVEL: fine to coarse grained, angular, quartz, orange-brown, high plasticity clay with fine to coarse grained sand				
				2.40–3.20		D	SM / ML	SILTY SAND/SANDY SILT: low plasticity silt, fine grained sand, pale grey	M			
			390	3.20–4.20	SPT 7, 12, 10/70mm N=R	SPT	SM	SILTY SAND: fine grained, pale grey, low plasticity silty becoming fine to coarse grained sand becoming orange-brown	M - W			
			389	4.20–5.10			ML	SANDY SILT: low plasticity, grey, orange-brown, fine grained sand	M			
			388	5.10–5.45	SPT 8, 11, 12 N=23	SPT	SM	SILTY SAND: fine to coarse grained, grey, low plasticity silt	M - W			
			387, 386					END OF BOREHOLE AT 5.45 m Target depth				

This Borehole log should be read in conjunction with WSP's accompanying explanatory notes.

BOREHOLE ENGINEERING LOG

BOREHOLE NO.

BH03

SHEET : 1 OF 1

Client:	**VicRoads**	Date Commenced:	**1-24-18**
Project:	**Beaufort Bypass EES**	Date Completed:	**1-24-18**
Borehole Location:	**Refer to Figure 1**	Recorded By:	**TS**
Project Number:	**2270290A**	Log Checked By:	**CB**

Drill Model/Mounting:	**Boart Longyear LS250/ Track**	Hole Angle:	**-90°**	Surface RL:	**389.4 m AHD**
Borehole Diameter:	**120 mm**	Bearing:	**---**	Co-ords:	**E 710507 N 5855893 MGA94**

Borehole Information							Field Material Description						
METHOD	SUPPORT	WATER	RL (m AHD)	DEPTH (m)	FIELD TEST	SAMPLE	GRAPHIC LOG	GROUP SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY (VS S F St VSt H / VL L MD D VD)	POCKET PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
S	Nil		389	0.00				ML	SILT: low plasticity, pale brown becoming dark brown				Top 800mm disturbed by cultural heritage sieving
			388	0.80	SPT 5, 7, 8 N=15	SPT		CL-ML	CLAYEY SILT/Silty CLAY: low plasticity, mottled orange-brown, grey with fine grained sand	D - M M			
			387	2.00	SPT 7, 10/130mm N=R	SPT		SM	SILTY SAND: fine grained, orange-brown, grey becoming fine to coarse grained sand, brown, trace fine-medium grained angular quartz gravel				SPT refusal on quartz layer
			386	3.00				GP	SANDY GRAVEL: fine to medium grained, angular, brown	W			
				3.70				CH	CLAY: high plasticity, mottled orange-brown, grey, trace fine grained sand	M			
		▽	385 384	4.20	SPT 3, 5, 6 N=11 SPT 2, 5, 7 N=12	SPT SPT		ML	CLAYEY SILT: low plasticity, pale grey				Groundwater measured 15 minutes after borehole completion Borehole location 20m from existing dam
			383 382	5.45					END OF BOREHOLE AT 5.45 m Target depth				

This Borehole log should be read in conjunction with WSP's accompanying explanatory notes.

BOREHOLE ENGINEERING LOG

BOREHOLE NO.

BH04

Client:	**VicRoads**	Date Commenced:	**2-27-18**
Project:	**Beaufort Bypass EES**	Date Completed:	**2-27-18**
Borehole Location:	**Refer to Figure 1**	Recorded By:	**TS**
Project Number:	**2270290A**	Log Checked By:	**CB**

Drill Model/Mounting:	**Boart Longyear LS250/ Track**	Hole Angle:	**-90°**	Surface RL:	**389.4 m AHD**
Borehole Diameter:	**180 mm**	Bearing:	**---**	Co-ords:	**E 711375 N 5855781 MGA94**

Borehole Information / **Field Material Description**

METHOD	SUPPORT	WATER	RL (m AHD)	DEPTH (m)	FIELD TEST	SAMPLE	GROUP SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY (VS S F ST VST H / FB VL L MD D VD)	POCKET PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
S	C	NFGWE		0.00–0.20			ML	SILT; low plasticity, dark brown, with roots.	D			
			389	0.20–1.00			CL / CI	CLAY; low to medium plasticity, orange-brown.				Friable
			388	1.00–1.50			ML	SILT; low plasticity, pale orange-brown, grey, inferred extremely weathered siltstone, trace zones of highly weathered siltstone, low strength.				
				1.50	SPT 6/50mm HB N=R	SPT		MIXTURE OF SILT (EXTREMELY WEATHERED SILTSTONE) AND HIGHLY WEATHERED SILTSTONE: low plasticity silt, hard, low strength siltstone, pale brown				observed bedding dips at 80° (from SPT sample)
			387	2								
				3	SPT 4/40mm HB N=R							
			386					becoming dark brown, purple				
			385	4								
			384	5				becoming dark brown, orange-brown, purple				
				6				becoming pale brown, grey, orange-brown				
								rock in mixture becoming highly weathered sandstone, fine grained, low to medium strength				
			383									
			382	7								

This Borehole log should be read in conjunction with WSP's accompanying explanatory notes.

BOREHOLE ENGINEERING LOG

BOREHOLE NO.
BH04

Client:	**VicRoads**	Date Commenced:	**2-27-18**
Project:	**Beaufort Bypass EES**	Date Completed:	**2-27-18**
Borehole Location:	**Refer to Figure 1**	Recorded By:	**TS**
Project Number:	**2270290A**	Log Checked By:	**CB**

Drill Model/Mounting:	**Boart Longyear LS250/ Track**	Hole Angle:	**-90°**	Surface RL:	**389.4 m AHD**
Borehole Diameter:	**180 mm**	Bearing:	**---**	Co-ords:	**E 711375 N 5855781 MGA94**

METHOD	SUPPORT	WATER	RL (m AHD)	DEPTH (m)	FIELD TEST	SAMPLE	GRAPHIC LOG	GROUP SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY (VS S F ST VST H / VL L MD D VD)	POCKET PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
S	C	NFGWE	381	8.00					MIXTURE OF SILT (EXTREMELY WEATHERED SILTSTONE) AND HIGHLY WEATHERED SILTSTONE: low plasticity silt, hard, low strength siltstone, pale brown, grey, orange-brown becoming red-brown becoming dark brown, purple rock in micture becoming highly weathered siltstone, low strength	D			Sample recovered between 8m and 8,5m was inundated with drilling water, sample was not included in box to reduce misinterpretation of moisture condition
			380	9.50				CL	Silty CLAY; low plasticity, pale brown, inferred extremely weathered siltstone, with zones of highly weathered siltstone, low strength.				Sample recovered between 9.3m and 10.7m was inundated with drilling water, sample was not included in box to reduce misinterpretation of moisture condition Friable
			378	11.00		B							
			377	12.00	SPT 3/20mm HB N=R								
			376	13.00					becoming pale red-brown, trace of highly weathered zones				

This Borehole log should be read in conjunction with WSP's accompanying explanatory notes.

BOREHOLE ENGINEERING LOG

BOREHOLE NO.
BH04
SHEET : 3 OF 3

Client:	**VicRoads**	Date Commenced:	**2-27-18**
Project:	**Beaufort Bypass EES**	Date Completed:	**2-27-18**
Borehole Location:	**Refer to Figure 1**	Recorded By:	**TS**
Project Number:	**2270290A**	Log Checked By:	**CB**

Drill Model/Mounting:	**Boart Longyear LS250/ Track**	Hole Angle:	**-90°**	Surface RL:	**389.4 m AHD**
Borehole Diameter:	**180 mm**	Bearing:	**---**	Co-ords:	**E 711375 N 5855781 MGA94**

METHOD	SUPPORT	WATER	RL (m AHD)	DEPTH (m)	FIELD TEST	SAMPLE	GRAPHIC LOG	GROUP SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY (VS S F ST VST H / FB VL L MD D VD)	POCKET PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
S	C	NFGWE	373, 372, 371, 370	16.00, 17, 18, 19				ML	SAND; low plasticity, pale red-brown, inferred extremely weathered siltstone, with zones of highly weathered siltstone, low strength. becoming pale orange-brown (18.0 m)	D	H		
			369, 368, 367, 366	20					END OF BOREHOLE AT 20.00 m Target depth				

This Borehole log should be read in conjunction with WSP's accompanying explanatory notes.

BOREHOLE ENGINEERING LOG

BOREHOLE NO.
BH05

Client:	**VicRoads**	Date Commenced:	**1-22-18**
Project:	**Beaufort Bypass EES**	Date Completed:	**1-23-18**
Borehole Location:	**Refer to Figure 1**	Recorded By:	**TS**
Project Number:	**2270290A**	Log Checked By:	**CB**

Drill Model/Mounting:	**Boart Longyear LS250/ Track**	Hole Angle:	**-90°**	Surface RL:	**411.3 m AHD**
Borehole Diameter:	**180 mm**	Bearing:	**---**	Co-ords:	**E 712130 N 5856113 MGA94**

Borehole Information | **Field Material Description**

METHOD	SUPPORT	WATER	RL (m AHD)	DEPTH (m)	FIELD TEST	SAMPLE	GROUP SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY (VS S F ST VST H / VL L MD D VD FB)	POCKET PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
S	Nil	NFGWE	411	0.00–0.40			ML	SILT: non plastic, pale brown, trace fine grained angular gravel				Top 400mm disturbed by cultural heritage sieving
			410, 409, 408, 407	0.40–5.00	SPT 7, 13, 19 N=32 (1.5–1.95 m); SPT 7, 13, 18 N=31 (3.0–3.45 m)	BS; SPT	CH-MH	CLAYEY SILT/SILTY CLAY: high plasticity, mottled orange-brown, red-brown becoming orange-brown trace fine to medium grained angular quartz gravel becoming orange-brown, pale grey, trace fine to coarse grained sand	D - M			Friable SPT sample recovered
			406, 405	5.00–6.80	SPT 7, 14/140mm, N=R	SPT	CI-CH	CLAY: medium to high plasticity, red-brown, mottled grey, trace fine to coarse grained angular quartz gravel and fine grained siltstone gravel gravel absent	M			Sample recovered moist, driller introduced water for casing, liekly cause of moisture increase
			404	6.80–	SPT 7, 5/30mm HB N=R	SPT	ML	SILT: low plasticity, red-brown, pale brown, inferred extremely weathered siltstone becoming pale brown	D - M			Friable

This Borehole log should be read in conjunction with WSP's accompanying explanatory notes.

BOREHOLE ENGINEERING LOG

BOREHOLE NO.
BH05
SHEET : 2 OF 3

Client:	**VicRoads**	Date Commenced:	**1-22-18**
Project:	**Beaufort Bypass EES**	Date Completed:	**1-23-18**
Borehole Location:	**Refer to Figure 1**	Recorded By:	**TS**
Project Number:	**2270290A**	Log Checked By:	**CB**

Drill Model/Mounting:	**Boart Longyear LS250/ Track**	Hole Angle:	**-90°**	Surface RL:	**411.3 m AHD**
Borehole Diameter:	**180 mm**	Bearing:	**---**	Co-ords:	**E 712130 N 5856113 MGA94**

METHOD	SUPPORT	WATER	RL (m AHD)	DEPTH (m)	FIELD TEST	SAMPLE	GRAPHIC LOG	GROUP SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY (VS S F ST VST H / VL L MD D VD)	POCKET PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
S	Nil	NFGWE	403					ML	SILT: low plasticity, red-brown, pale brown, inferred extremely weathered siltstone	D - M	H		
			402	9					trace fine to coarse grained angular quartz and siltstone gravel				SPT not conducted due to cave in
			401	10	SPT 10/130mm HB N=R	BS							SPT sample recovered
			400	11					becoming pale yellow-brown, gravel absent	D			
			399	12	SPT 9/90mm N=R	SPT							
			398	13		BS			becoming pale red-brown				
			397	14	SPT 9/60mm N=R	SPT			becoming pale orange-brown				
			396	15									

This Borehole log should be read in conjunction with WSP's accompanying explanatory notes.

BOREHOLE ENGINEERING LOG

BOREHOLE NO.
BH05
SHEET : 3 OF 3

Client:	**VicRoads**	Date Commenced:	**1-22-18**
Project:	**Beaufort Bypass EES**	Date Completed:	**1-23-18**
Borehole Location:	**Refer to Figure 1**	Recorded By:	**TS**
Project Number:	**2270290A**	Log Checked By:	**CB**

Drill Model/Mounting:	**Boart Longyear LS250/ Track**	Hole Angle:	**-90°**	Surface RL:	**411.3 m AHD**
Borehole Diameter:	**180 mm**	Bearing:	**---**	Co-ords:	**E 712130 N 5856113 MGA94**

Borehole Information							Field Material Description						
METHOD	SUPPORT	WATER	RL (m AHD)	DEPTH (m)	FIELD TEST	SAMPLE	GRAPHIC LOG	GROUP SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY (VS S F ST VST H / FB VL L MD D VD)	POCKET PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
S	Nil	NFGWE	395	16.00				ML	SILT: low plasticity, pale orange-brown, inferred extremely weathered siltstone	D			Sample recovered between 16m and 17m was inundated with drilling water, sample was not included in box to reduce misinterpretation of moisture condition
			394	17					END OF BOREHOLE AT 17.00 m Target depth				
			393										
			392										
			391										
			390										
			389										
			388										

This Borehole log should be read in conjunction with WSP's accompanying explanatory notes.

BOREHOLE ENGINEERING LOG

BOREHOLE NO.
BH06
SHEET : 1 OF 1

Client:	**VicRoads**	Date Commenced:	**1-22-18**
Project:	**Beaufort Bypass EES**	Date Completed:	**1-22-18**
Borehole Location:	**Refer to Figure 1**	Recorded By:	**TS**
Project Number:	**2270290A**	Log Checked By:	**CB**

Drill Model/Mounting:	**Boart Longyear LS250/ Track**	Hole Angle:	**-90°**	Surface RL:	**379.2 m AHD**
Borehole Diameter:	**120 mm**	Bearing:	**---**	Co-ords:	**E 712989 N 5855943 MGA94**

Borehole Information | **Field Material Description**

METHOD	SUPPORT	WATER	RL (m AHD)	DEPTH (m)	FIELD TEST	SAMPLE	GRAPHIC LOG	GROUP SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY (VS S F ST VST H / VL L MD D VD)	POCKET PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
S	Nil	NFGWE	379	0.00				ML	CLAYEY SILT: low plasticity, grey				Top 500mm disturbed by cultural heritage sieving
				0.50				CI-CH	SILTY CLAY: medium to high plasticity, mottled orange-brown, grey	M	ST		
			378	1	SPT 2, 5, 4 N=9	SPT							
			377	2									Attempted tube sample, no recovery
				2.70				ML	SILT: low plasticity, pale grey		VS		Friable
			376	3									
				3.50				ML	SILT: low plasticity, red, orange, grey, inferred extremely weathered siltstone		VST		
			375	4	SPT 3, 9, 10 N=19	SPT							
			374	5	SPT 4, 9, 14 N=23	SPT							
				5.45					END OF BOREHOLE AT 5.45 m Target depth				
			373										
			372										

This Borehole log should be read in conjunction with WSP's accompanying explanatory notes.

BOREHOLE ENGINEERING LOG

BOREHOLE NO.

BH07

SHEET : 1 OF 1

Client:	**VicRoads**	Date Commenced:	**1-24-18**
Project:	**Beaufort Bypass EES**	Date Completed:	**1-24-18**
Borehole Location:	**Refer to Figure 1**	Recorded By:	**TS**
Project Number:	**2270290A**	Log Checked By:	**CB**

Drill Model/Mounting:	**Boart Longyear LS250/ Track**	Hole Angle:	**-90°**	Surface RL:	**385.7 m AHD**
Borehole Diameter:	**120 mm**	Bearing:	**---**	Co-ords:	**E 713393 N 5855064 MGA94**

Borehole Information							Field Material Description						
METHOD	SUPPORT	WATER	RL (m AHD)	DEPTH (m)	FIELD TEST	SAMPLE	GRAPHIC LOG	GROUP SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY (VS S F ST VST H / FB VL L MD D VD)	POCKET PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
S	Nil	NFGWE		0.00–0.50				ML	SILT: non plastic, dark brown, trace fine to medium grained sub-angular gravel				Top 500mm disturbed by cultural heritage sieving
			385.2	0.50–2.50	SPT 5, 7, 12 N=19 (1.00)	SPT		CH	CLAY: high plasticity, brown mottled red, grey	M	H		
			383.2	2.50–4.40	SPT 7, 8, 9 N=17 (2.50); SPT 3, 7, 7 N=14 (4.00)	SPT; SPT		SM	SILTY SAND: fine grained, orange-brown, grey	M	MD		
			381.3	4.40–5.00				CH	SANDY CLAY: high plasticity, pale blue-grey, fine grained sand		VST		
				5.00					END OF BOREHOLE AT 5.00 m Target depth				

This Borehole log should be read in conjunction with WSP's accompanying explanatory notes.

BOREHOLE ENGINEERING LOG

BOREHOLE NO. **BH08**

SHEET : 1 OF 2

Client:	**VicRoads**	Date Commenced:	**1-23-18**
Project:	**Beaufort Bypass EES**	Date Completed:	**1-23-18**
Borehole Location:	**Refer to Figure 1**	Recorded By:	**TS**
Project Number:	**2270290A**	Log Checked By:	**CB**

Drill Model/Mounting:	**Boart Longyear LS250/ Track**	Hole Angle:	**-90°**	Surface RL:	**396.4 m AHD**
Borehole Diameter:	**180 mm**	Bearing:	**---**	Co-ords:	**E 714616 N 5854604 MGA94**

Borehole Information | **Field Material Description**

METHOD	SUPPORT	WATER	RL (m AHD)	DEPTH (m)	FIELD TEST	SAMPLE	GROUP SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY (VS S F ST VST H / VL L MD D VD)	POCKET PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
S	C	NFGWE		0.00			ML	SILT: non plastic, dark brown				Top 300mm disturbed by cultural heritage sieving
			396	0.30			CH	CLAY: high plasticity, brown	M	H		
				1.00			MH	Clayey SILT: high plasticity, orange-brown, trace tree roots		H		Friable
			395	1.30			ML	SILT: low plasticity, pale grey, pale brown, inferred extremely weathered siltstone	D - M	VST		
				~1.5	SPT 5, 7, 11 N=18	SPT						inferred bedding dips at 70° to 80° (from SPT sample)
				2				becoming red-brown, trace fine grained angular siltstone gravel		H		
			394									gravel could be cobble size pieces broken by sonic vibration
			393	3	SPT 11, 14, 5/20mm HB N=R	BS						SPT sample recovered
			392	4								
			391	5	SPT 8/60mm HB N=R	SPT		with zoners of highly weathered siltstone, very low strength				
			390	6								
				~6.5	SPT 7/60mm HB N=R	SPT						
			389	7		BS		becoming red-brown, grey, trace highly weathered zones				

This Borehole log should be read in conjunction with WSP's accompanying explanatory notes.

BOREHOLE ENGINEERING LOG

BOREHOLE NO.
BH08

Client:	**VicRoads**	Date Commenced:	**1-23-18**
Project:	**Beaufort Bypass EES**	Date Completed:	**1-23-18**
Borehole Location:	**Refer to Figure 1**	Recorded By:	**TS**
Project Number:	**2270290A**	Log Checked By:	**CB**

Drill Model/Mounting:	**Boart Longyear LS250/ Track**	Hole Angle:	**-90°**	Surface RL:	**396.4 m AHD**
Borehole Diameter:	**180 mm**	Bearing:	**---**	Co-ords:	**E 714616 N 5854604 MGA94**

Borehole Information							Field Material Description						
METHOD	SUPPORT	WATER	RL (m AHD)	DEPTH (m)	FIELD TEST	SAMPLE	GRAPHIC LOG	GROUP SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY (VS S F ST VST H / FB VL L MD D VD)	POCKET PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
S	C	NFGWE	388	8.00				ML	SILT: low plasticity, red-brown, inferred extremely weathered siltstone	D - M			
			387	8.50 9	SPT 7/50mm N=R	SPT			MIXTURE OF HIGHLY WEATHERED SILTSTONE AND SILT: low plasticity silt, very low to low strength siltstone, red-brown, silt is extremely weathered siltstone				
			386 385 384 383 382 381	10					END OF BOREHOLE AT 10.00 m Target depth				

This Borehole log should be read in conjunction with WSP's accompanying explanatory notes.

BOREHOLE ENGINEERING LOG

BOREHOLE NO.

BH09

SHEET : 1 OF 1

Client:	**VicRoads**	Date Commenced:	**1-23-18**
Project:	**Beaufort Bypass EES**	Date Completed:	**1-23-18**
Borehole Location:	**Refer to Figure 1**	Recorded By:	**TS**
Project Number:	**2270290A**	Log Checked By:	**CB**

Drill Model/Mounting:	**Boart Longyear LS250/ Track**	Hole Angle:	**-90°**	Surface RL:	**377.9 m AHD**
Borehole Diameter:	**180 mm**	Bearing:	**---**	Co-ords:	**E 715556 N 5854152 MGA94**

Borehole Information							Field Material Description						
METHOD	SUPPORT	WATER	RL (m AHD)	DEPTH (m)	FIELD TEST	SAMPLE	GRAPHIC LOG	GROUP SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY (VS S F ST VST H / FB VL L MD D VD)	POCKET PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
S	Nil	NFGWE		0.00				ML	SILT: non plastic, dark brown, trace fine grained angular gravel				Top 400mm disturbed by cultural heritage sieving
				0.40				CH	CLAY: high plasticity, orange-brown, pale brown				Friable
			377	1	SPT 6, 9, 12 N=21	SPT			becoming mottled dark brown, dark grey	D - M			
			376	2					trace fine to medium grained angular gravel				
			375		SPT 3, 9/130mm HB N=R	SPT			becoming orange-brown, grey, trace fine to coarse grained sand				
				3.10				MH	Clayey SILT: high plasticity, orange-brown, grey, trace fine grained sand	M		450	
			374	4					trace fine to medium grained angular gravel			>600	tube attempted, sample recovered was cave in
				4.20				CH	CLAY: high plasticity, grey, mottled orange-brown			310, 340, 330	Pocket penetrometer tests undertaken on sonic sample
			373	5		U63			trace fine to coarse grained angular gravel			320, 310 - 330	
			372, 371, 370						END OF BOREHOLE AT 5.17 m Target depth				

This Borehole log should be read in conjunction with WSP's accompanying explanatory notes.

BOREHOLE ENGINEERING LOG

BOREHOLE NO.
BH10
SHEET : 1 OF 3

Client:	**VicRoads**	Date Commenced:	**1-16-18**
Project:	**Beaufort Bypass EES**	Date Completed:	**1-17-18**
Borehole Location:	**Refer to Figure 1**	Recorded By:	**TS**
Project Number:	**2270290A**	Log Checked By:	**CB**

Drill Model/Mounting:	**Boart Longyear LS250/ Track**	Hole Angle:	**-90°**	Surface RL:	**416.3 m AHD**
Borehole Diameter:	**180 mm**	Bearing:	**---**	Co-ords:	**E 709856 N 5856559 MGA94**

METHOD	SUPPORT	WATER	RL (m AHD)	DEPTH (m)	FIELD TEST	SAMPLE	GRAPHIC LOG	GROUP SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY (VS S F ST VST H / FB VL L MD D VD)	POCKET PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
S	C	NFGWE		0.00–0.20				ML	SILT: non plastic, dark brown, trace rootlets				Top 550mm disturbed by cultural heritage sieving
			416	0.20–0.55				ML	Clayey SILT: low plasticity, brown, trace fine to coarse grained, angular quartz gravel				
				0.55				ML	SILT: low plasticity, pale brown, pale grey, inferred extremely weathered siltstone	D			Friable
			415	1		D							
					SPT 8, 12/100mm HB N=R	SPT			trace fine to coarse grained angular siltstone gravel				
			414	2		BS							most gravel sized pieces shown in photo can be broken down to silt with hand pressure
			413	3	SPT 3, 13, 6/50mm HB N=R	SPT							
			412	4	SPT 12 HB N=R	SPT			becoming pale grey, white				inferred bedding angle 50° to 60° (from SPT sample)
			411	5									
			410	6	SPT 8/120mm HB N=R	SPT							
				7					becoming pale red-brown				
			409		SPT 3, 5 HB N=R	BS SPT			gravel absent	M			Moisture could be from introduced drilling water for casing and would be dry in situ SPT sample recovered

This Borehole log should be read in conjunction with WSP's accompanying explanatory notes.

BOREHOLE ENGINEERING LOG

Client:	**VicRoads**	Date Commenced:	**1-16-18**
Project:	**Beaufort Bypass EES**	Date Completed:	**1-17-18**
Borehole Location:	**Refer to Figure 1**	Recorded By:	**TS**
Project Number:	**2270290A**	Log Checked By:	**CB**

Drill Model/Mounting:	**Boart Longyear LS250/ Track**	Hole Angle:	**-90°**	Surface RL:	**416.3 m AHD**
Borehole Diameter:	**180 mm**	Bearing:	**---**	Co-ords:	**E 709856 N 5856559 MGA94**

Borehole Information | **Field Material Description**

METHOD	SUPPORT	WATER	RL (m AHD)	DEPTH (m)	FIELD TEST	SAMPLE	GRAPHIC LOG	GROUP SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY (VS S F ST VST H / VL L MD D VD FB)	POCKET PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
S	C	NFGWE		8.00				ML	SILT: low plasticity, pale grey, pale yellow, pale red-brown, inferred extremely weathered siltstone	M			
			408			BS							
									becoming pale grey, pale orange-brown				
				9		U63			becoming pale brown				tube pushed at commencement of day, soil has been effected by introduced water for casing purposes sample is moist to almost wet, have kept sample for reference
			407									450 - 400	
									trace fine to coarse grained angular siltstone gravel				
				10					becoming pale brown, red-brown				
			406						with gravel				
									trace gravel, becoming orange-brown	D - M			
				11					gravel absent	D			gravel sized pieces in photo can be broken down to silt
			405										
				12	SPT 7, 6/50mm HB N=R	SPT			becoming red-brown, trace fine to coarse grained angular highly weathered siltstone gravel	M			inferred bedding dips at 20° to 30° (from SPT sample) soil moist from drilling fluid, likely to be dry in-situ
			404						becoming orange-brown, with gravel				
				13									
			403		SPT 7 HB N=R	SPT							
				14		BS			becoming pale red-brown, with pockets of highly weathered siltstone, very low strength				
			402										
				15	SPT 6, 7/60mm HB N=R	SPT							
			401										

This Borehole log should be read in conjunction with WSP's accompanying explanatory notes.

BOREHOLE ENGINEERING LOG

BOREHOLE NO.

BH10

Client:	**VicRoads**	Date Commenced:	**1-16-18**
Project:	**Beaufort Bypass EES**	Date Completed:	**1-17-18**
Borehole Location:	**Refer to Figure 1**	Recorded By:	**TS**
Project Number:	**2270290A**	Log Checked By:	**CB**

Drill Model/Mounting:	**Boart Longyear LS250/ Track**	Hole Angle:	**-90°**	Surface RL:	**416.3 m AHD**
Borehole Diameter:	**180 mm**	Bearing:	**---**	Co-ords:	**E 709856 N 5856559 MGA94**

METHOD	SUPPORT	WATER	RL (m AHD)	DEPTH (m)	FIELD TEST	SAMPLE	GRAPHIC LOG	GROUP SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY (VS S F ST VST H / FB VL L MD D VD)	POCKET PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
S	C	NFGWE	400	16.00				ML	SILT: low plasticity, ehite, mottled red-brown, inferred extremely weathered siltstone	M			
			399, 398, 397, 396, 395, 394, 393	17					END OF BOREHOLE AT 17.00 m Target depth				PIEZOMETER INSTALLATION Standpipe comprises: 0-8m: 50mm PVC Solid 8-17m: 50mm PVC machine slotted Backfill comprises: Flush mounted gatic cover 0-5m: cement 5-6m: bentonite 6-17m: 7mm scoria gravel

This Borehole log should be read in conjunction with WSP's accompanying explanatory notes.

BOREHOLE ENGINEERING LOG

BOREHOLE NO.

BH11

SHEET : 1 OF 1

Client:	**VicRoads**	Date Commenced:	**1-24-18**
Project:	**Beaufort Bypass EES**	Date Completed:	**1-24-18**
Borehole Location:	**Refer to Figure 1**	Recorded By:	**TS**
Project Number:	**2270290A**	Log Checked By:	**CB**

Drill Model/Mounting:	**Boart Longyear LS250/ Track**	Hole Angle:	**-90°**	Surface RL:	**394 m AHD**
Borehole Diameter:	**120 mm**	Bearing:	**---**	Co-ords:	**E 710734 N 5856866 MGA94**

Borehole Information							Field Material Description						
METHOD	SUPPORT	WATER	RL (m AHD)	DEPTH (m)	FIELD TEST	SAMPLE	GRAPHIC LOG	GROUP SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY (VS S F ST VST H / FB VL L MD D VD)	POCKET PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
S	Nil	NFGWE						ML	SILT: non plastic, dark brown				Top 300mm disturbed by cultural heritage sieving
				0.30				CL-ML	CLAYEY SILT/SILTY CLAY: low plasticity, pale yellow-brown	D			
			393	1	SPT 5, 5, 8 N=13	SPT				D - M			
			392	2					becoming dark brown, trace fine grained sand				
					SPT 4, 7, 6/70mm HB N=R	SPT			trace fine to medium grained angular quartz gravel	M			
			391	3									
				3.50				SM	SILTY SAND: fine grained, orange-brown, grey				
			390	4.00 4				ML	SILT: low plasticity, grey	D - M			
					SPT 9, 15, 16 N=31	SPT							
			389	5	SPT 4, 7, 9 N=16	SPT							
				5.30					SILT: low plasticity, orange-brown, grey, inferred extremely weathered siltstone				
									END OF BOREHOLE AT 5.45 m Target depth				
			388										
			387										

This Borehole log should be read in conjunction with WSP's accompanying explanatory notes.

BOREHOLE ENGINEERING LOG

BOREHOLE NO.

BH12

SHEET : 1 OF 2

Client:	**VicRoads**	Date Commenced:	**2-26-18**
Project:	**Beaufort Bypass EES**	Date Completed:	**2-27-18**
Borehole Location:	**Refer to Figure 1**	Recorded By:	**TS**
Project Number:	**2270290A**	Log Checked By:	**CB**

Drill Model/Mounting:	**Boart Longyear LS250/ Track**	Hole Angle:	**-90°**	Surface RL:	**415.4 m AHD**
Borehole Diameter:	**180 mm**	Bearing:	**---**	Co-ords:	**E 711604 N 5857100 MGA94**

Borehole Information | **Field Material Description**

METHOD	SUPPORT	WATER	RL (m AHD)	DEPTH (m)	FIELD TEST	SAMPLE	GRAPHIC LOG	GROUP SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY (VS S F ST VST H / FB VL L MD D VD)	POCKET PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
S		NFGWE		0.00–0.20				ML	SILT; low plasticity, pale brown, trace rootlets.	D	VS		
			415, 414, 413	0.20–3.10	SPT 9, 14/110mm HB N=R	D, SPT		CI	CLAY; medium plasticity, ornage-brown, red, grey. trace slickensided surfaces in clay		H		Friable between 0.2m and 1m
			412, 411, 410	3.10–6.00	SPT 7, 11, 13 N=24 SPT 9/110mm HB N=R	SPT SPT		ML	SILT; low plasticity, pale grey, pale orange-brown, with zones of extremely weathered siltstone (soil properties).		D / H		Friable
			409, 408	6.00–	SPT 5/50mm HB N=R SPT 6/70mm HB N=R	SPT		ML	SILT; low plasticity, pale orange-brown, grey, inferred extremely weathered siltstone, with zones of highly weathered siltstone, very low to low strength.		H		

This Borehole log should be read in conjunction with WSP's accompanying explanatory notes.

BOREHOLE ENGINEERING LOG

BOREHOLE NO.

BH12

SHEET : 2 OF 2

Client:	**VicRoads**	Date Commenced:	**2-26-18**
Project:	**Beaufort Bypass EES**	Date Completed:	**2-27-18**
Borehole Location:	**Refer to Figure 1**	Recorded By:	**TS**
Project Number:	**2270290A**	Log Checked By:	**CB**

Drill Model/Mounting:	**Boart Longyear LS250/ Track**	Hole Angle:	**-90°**	Surface RL:	**415.4 m AHD**
Borehole Diameter:	**180 mm**	Bearing:	**---**	Co-ords:	**E 711604 N 5857100 MGA94**

Borehole Information | **Field Material Description**

METHOD	SUPPORT	WATER	RL (m AHD)	DEPTH (m)	FIELD TEST	SAMPLE	GRAPHIC LOG	GROUP SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY (VS S F ST VST H / FB VL L MD D VD)	POCKET PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
S		NFGWE	407			D		ML	SILT; low plasticity, pale orange-brown, grey, inferred extremely weathered siltstone, with zones of highly weathered siltstone, very low to low strength.	D	H		
			406	9.00 / 9	SPT 7/50mm HB N=R				SILTSTONE; highly weathered, dark grey, low strength, with zones of extremely weathered siltstone (soil properties)				
			405	10	SPT 5/30mm HB N=R				becoming dark brown				
			404	11									
				11.70				ML	SILT; low plasticity, pale orange-brown, pale grey, inferred extremely weathered siltstone, trace zones of highly weathered siltstone, very low to low strength.	D	H		Friable
			403	12		B							
			402	13									
			401	14					becoming pale grey, pale brown				
			400	15									Sample recovered between 15m and 17m was inundated with drilling water, sample was not included in box to reduce misinterpretation of moisture condition

END OF BOREHOLE AT 16.00 m
Target depth

This Borehole log should be read in conjunction with WSP's accompanying explanatory notes.

BOREHOLE ENGINEERING LOG

BOREHOLE NO.

BH13

SHEET : 1 OF 1

Client:	**VicRoads**	Date Commenced:	**1-22-18**
Project:	**Beaufort Bypass EES**	Date Completed:	**1-22-18**
Borehole Location:	**Refer to Figure 1**	Recorded By:	**TS**
Project Number:	**2270290A**	Log Checked By:	**CB**

Drill Model/Mounting:	**Boart Longyear LS250/ Track**	Hole Angle:	**-90°**	Surface RL:	**377.6 m AHD**
Borehole Diameter:	**120 mm**	Bearing:	**---**	Co-ords:	**E 713380 N 5856413 MGA94**

METHOD	SUPPORT	WATER	RL (m AHD)	DEPTH (m)	FIELD TEST	SAMPLE	GROUP SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY (VS S F ST VST H / FB VL L MD D VD)	POCKET PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
S	Nil	NFGWE	377	0.00			CL / ML	SILTY CLAY/CLAYEY SILT: low plasticity, dark grey, trace fine grained sand	M			Top 900mm disturbed by cultural heritage sieving
				1.00	SPT 3, 4, 4 N=8	SPT	CH	CLAY: high plasticity, mottled dark grey, grey, brown, trace fine grained sand				
			376	1.40			SM	SILTY SAND: fine grained, dark-brown, grey				
			375	2.00	SPT 10/130mm N=R	SPT	ML	SILT: low plasticity, pale red-brown, mottled pale grey, inferred extremely weathered siltstone	D			Friable
			374	4	SPT 11 N=R	SPT		becoming orange-brown, grey				inferred bedding dips at 80° (from SPT sample)
			373					becoming red-brown, grey				
			372	5				END OF BOREHOLE AT 5.00 m Target depth				PIEZOMETER INSTALLATION: Standpipe comprises 0-2m: 50mm PVC solid 2-5m: 50mm PVC machine slotted Backfill comprises Flush mounted gatic cover 0-1m: concrete 1-1.5m: bentonite 1.5-5m 7mm scoria gravel
			371									
			370									

This Borehole log should be read in conjunction with WSP's accompanying explanatory notes.

BOREHOLE ENGINEERING LOG

BOREHOLE NO.
BH14
SHEET : 1 OF 1

Client:	**VicRoads**	Date Commenced:	**1-22-18**
Project:	**Beaufort Bypass EES**	Date Completed:	**1-22-18**
Borehole Location:	**Refer to Figure 1**	Recorded By:	**TS**
Project Number:	**2270290A**	Log Checked By:	**CB**

Drill Model/Mounting:	**Boart Longyear LS250/ Track**	Hole Angle:	**-90°**	Surface RL:	**378.2 m AHD**
Borehole Diameter:	**120 mm**	Bearing:	**---**	Co-ords:	**E 713416 N 5856244 MGA94**

Borehole Information / **Field Material Description**

METHOD	SUPPORT	WATER	RL (m AHD)	DEPTH (m)	FIELD TEST	SAMPLE	GROUP SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY	POCKET PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
S	Nil		378	0.00 – 0.40			ML	SILT: low plasticity, pale grey				Top 400mm disturbed by cultural heritage sieving
			377	0.40 – 1.20			CH	CLAY: high plasticity. orange-brown, brown	D - M	H		
		▽	376	1.20 – 2.70	SPT 2, 4, 3 N=7	SPT	CI-CH	Silty CLAY: medium to high plasticity, pale brown, grey, trace fine grained sand	M	ST		Groundwater measured 15 minutes after the completion of drilling Borehole location about 10m from existing dam
			375	2.70 – 3.50		U63	SM / ML	Silty SAND/Sandy SILT: fine grained sand, low plasticity silt, orange-brown, grey		MD		
				3.50 – 4.00			SM	SILTY SAND: fine to coarse grained, orange-brown, with fine to medium grained angular quartz gravel		MD		
			374	4.00 – 5.30	SPT 1, 2, 4 N=6	SPT	CH	CLAY: high plasticity, orange, trace fine grained angular gravel, trace fine to coarse grained sand		ST		Water recovered in sample
			373					becoming orange-brown, grey		VST	210 250 210	Pocket penetrometer tests undertaken on sonic sample
			372 371	5.30				END OF BOREHOLE AT 5.30 m				

This Borehole log should be read in conjunction with WSP's accompanying explanatory notes.

BOREHOLE ENGINEERING LOG

BOREHOLE NO.

BH15

SHEET : 1 OF 1

Client:	**VicRoads**	Date Commenced:	**1-24-18**
Project:	**Beaufort Bypass EES**	Date Completed:	**1-24-18**
Borehole Location:	**Refer to Figure 1**	Recorded By:	**TS**
Project Number:	**2270290A**	Log Checked By:	**CB**

Drill Model/Mounting:	**Boart Longyear LS250/ Track**	Hole Angle:	**-90°**	Surface RL:	**377 m AHD**
Borehole Diameter:	**120 mm**	Bearing:	**---**	Co-ords:	**E 714112 N 5856309 MGA94**

METHOD	SUPPORT	WATER	RL (m AHD)	DEPTH (m)	FIELD TEST	SAMPLE	GROUP SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY	STRUCTURE AND ADDITIONAL OBSERVATIONS
S	Nil	NFGWE		0.00–0.30			ML	SILT: non plastic, dark brown			Top 300mm disturbed by cultural heritage sieving
				0.30–0.80			CI	CLAY: medium plasticity, brown, grey, with fine to coarse grained sand	M	ST	
			376	0.80–1.45	SPT 8, 11, 10 N=21	SPT	CH	CLAY: high plasticity, dark brown, dark grey; becoming orange-brown, grey	D; M	H	
			375	1.45–2.50			SP	SAND: fine to coarse grained, brown, with silt, trace fine to medium grained angular gravel	M - W	VD	
			374	2.50–3.50	SPT 3, 4, 7 N=11	SPT	CH	CLAY: high plasticity, orange-brown, grey, trace fine to coarse grained sand	M	VST	
				3.50–3.70			CI	Gravelly CLAY: medium plasticity, red-brown, orange-brown, fine to medium grained angular gravel		VST	
			373, 372	3.70–5.45	SPT 4, 7, 8 N=15; SPT 4, 6, 9 N=15	SPT; SPT	ML	SILT: low plasticity, pale grey		ST	
			371, 370					END OF BOREHOLE AT 5.45 m Target depth			

This Borehole log should be read in conjunction with WSP's accompanying explanatory notes.

BOREHOLE ENGINEERING LOG

BOREHOLE NO.

BH16

SHEET : 1 OF 3

Client:	**VicRoads**	Date Commenced:	**1-23-18**
Project:	**Beaufort Bypass EES**	Date Completed:	**1-24-18**
Borehole Location:	**Refer to Figure 1**	Recorded By:	**TS**
Project Number:	**2270290A**	Log Checked By:	**CB**

Drill Model/Mounting:	**Boart Longyear LS250/ Track**	Hole Angle:	**-90°**	Surface RL:	**411 m AHD**
Borehole Diameter:	**180 mm**	Bearing:	**---**	Co-ords:	**E 714917 N 5855796 MGA94**

Borehole Information							Field Material Description						
METHOD	SUPPORT	WATER	RL (m AHD)	DEPTH (m)	FIELD TEST	SAMPLE	GRAPHIC LOG	GROUP SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY (VS S F ST VST H / FB VL L MD D VD)	POCKET PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
S	Nil	NFGWE		0.00				ML	SILT: non plastic, dark brown, trace rootlets				Top 250mm disturbed by cultural heritage sieving
				0.25				MH	Clayey SILT: high plasticity, red-brown	D			Friable
				0.50				ML	SILT: low plasticity, pale orange-brown, grey, inferred extremely weathered siltstone				
			410	1									
					SPT 10/130mm HB N=R	SPT			trace fine to coarse grained angular, highly weathered siltstone gravel				
			409	2									
			408	3									
					SPT 8/30mm HB N=R	SPT			with zones of highly weathered siltstone, very low to low strength				
			407	4									
						D							
			406	5									
			405	6	SPT 5/10mm N=R	SPT			highly weathered siltstone bands absent, with fine to coarse grained siltstone gravel				
									trace fine to coarse grained angular quartz gravel				
			404	7									
									with quartz gravel				

This Borehole log should be read in conjunction with WSP's accompanying explanatory notes.

BOREHOLE ENGINEERING LOG

BOREHOLE NO.
BH16
SHEET : 2 OF 3

Client:	**VicRoads**	Date Commenced:	**1-23-18**
Project:	**Beaufort Bypass EES**	Date Completed:	**1-24-18**
Borehole Location:	**Refer to Figure 1**	Recorded By:	**TS**
Project Number:	**2270290A**	Log Checked By:	**CB**

Drill Model/Mounting:	**Boart Longyear LS250/ Track**	Hole Angle:	**-90°**	Surface RL:	**411 m AHD**
Borehole Diameter:	**180 mm**	Bearing:	**---**	Co-ords:	**E 714917 N 5855796 MGA94**

Borehole Information | **Field Material Description**

METHOD	SUPPORT	WATER	RL (m AHD)	DEPTH (m)	FIELD TEST	SAMPLE	GRAPHIC LOG	GROUP SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY (VS S F ST VST H / FB VL L MD D VD)	POCKET PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
		NFGWE						ML	SILT: low plasticity, pale orange-brown, grey, inferred extremely weathered siltstone trace quartz gravel	D			
			402	9	SPT 9/130mm HB N=R	SPT			siltstone and quartz gravel absent				
			401	10									
			400	11									
									becoming pale grey, white, pale orange-brown				
			399	12	SPT 8/50mm N=R	SPT			becoming red-brown				
									becoming pale yellow-brown, orange-brown				
									trace fine to coarse grained angular siltstone gravel				
			398	13									
			397	14		BS							
			396	15	SPT 7/50mm N=R	SPT							
									gravel absent				

This Borehole log should be read in conjunction with WSP's accompanying explanatory notes.

BOREHOLE ENGINEERING LOG

BOREHOLE NO.

BH16

Client:	**VicRoads**	Date Commenced:	**1-23-18**
Project:	**Beaufort Bypass EES**	Date Completed:	**1-24-18**
Borehole Location:	**Refer to Figure 1**	Recorded By:	**TS**
Project Number:	**2270290A**	Log Checked By:	**CB**

Drill Model/Mounting:	**Boart Longyear LS250/ Track**	Hole Angle:	**-90°**	Surface RL:	**411 m AHD**
Borehole Diameter:	**180 mm**	Bearing:	**---**	Co-ords:	**E 714917 N 5855796 MGA94**

Borehole Information							Field Material Description						
METHOD	SUPPORT	WATER	RL (m AHD)	DEPTH (m)	FIELD TEST	SAMPLE	GRAPHIC LOG	GROUP SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY (VS S F ST VST H / FB VL L MD D VD)	POCKET PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
		NFGWE		16.00				ML	SILT: low plasticity, pale yellow-brown, orange-brown, inferred extremely weathered siltstone	D	H		
			394	17					END OF BOREHOLE AT 17.00 m Target depth				PIEZOMETER INSTALLATION Standpipe Comprises 0m-8m: 50mm PVC solid 8m-17m: 50mm PVC machine slotted Backfill Comprises Flush mounted gatic 0m-5m: cement 5m-6m: bentonite 6m-17m: 7mm scoria gravel
			393										
			392										
			391										
			390										
			389										
			388										

This Borehole log should be read in conjunction with WSP's accompanying explanatory notes.

APPENDIX B

RISK ASSESSMENT TABLES

A0 ALIGNMENT

Table B.1 Soil and geology, contaminated land and acid sulfate soils environmental risk assessment register – A0 alignment

RISK ID	IMPACT PATHWAY	RISK DESCRIPTION	STANDARD CONTROLS	INITIAL RISK			ADDITIONAL MITIGATION / CONTROLS	RESIDUAL RISK		
				Consequence	Likelihood	Rating		Consequence	Likelihood	Rating
SG1a	Erosion/soil instability	Areas of cut may intersect groundwater levels and result in potential slope instability, face seepage and groundwater drawdown.	In sections of the proposed alignments where significant cut is required, it is recommended that boreholes are drilled to confirm the geology and depth to the groundwater table. Standpipe installation is recommended to allow the monitoring of groundwater fluctuation over time to inform the design of the proposed cut slopes. Samples from each strata encountered in the borehole should be taken to allow geotechnical laboratory testing to be undertaken to allow the derivation of geotechnical parameters which will further inform the concept design of the proposed cut slopes. Samples should also be assessed for dispersion potential.	Minor	Possible	Low	Not required	Minor	Possible	Low

RISK ID	IMPACT PATHWAY	RISK DESCRIPTION	STANDARD CONTROLS	INITIAL RISK			ADDITIONAL MITIGATION / CONTROLS	RESIDUAL RISK		
				Consequence	Likelihood	Rating		Consequence	Likelihood	Rating
SG2a	Encounters weak grounds	Embankments constructed over areas of alluvial deposits are likely to settle as a result of the compressible soils below.	In sections of the proposed alignments where softer ground is anticipated (i.e. alluvium deposits), it is recommended that boreholes are drilled to confirm the depth and nature of the soft ground to allow a preliminary estimation of anticipated settlement. The magnitude and time for completion of settlement should be reviewed as part of the design phase. Areas of softer ground may be encountered in areas associated with alluvial deposits and waterways. Structures are likely to require the use of piles to increase bearing capacity and reduce the impact of settlement.	Minor	Possible	Low	Not required	Minor	Possible	Low
SG3a	Design encounters erosion/soil instability	Previous reports have noted potential for dispersive soils. Dispersive nature of soils needs to be investigated adjacent to cut areas. Runoff from dispersive soils may pose an environmental hazard.	Emerson class testing should be carried out during the design phase.	Minor	Likely	Medium	Not required	Minor	Likely	Medium

RISK ID	IMPACT PATHWAY	RISK DESCRIPTION	STANDARD CONTROLS	INITIAL RISK			ADDITIONAL MITIGATION / CONTROLS	RESIDUAL RISK		
				Consequence	Likelihood	Rating		Consequence	Likelihood	Rating
SG4a	Construction encounters erosion/soil instability	Previous reports have noted potential for dispersive soils. Dispersive nature of soils needs to be investigated adjacent to cut areas. Runoff from dispersive soils may pose an environmental hazard.	Erosion and sediment control as per Section 177. Revegetation appropriate to the nature of the soils.	Minor	Likely	Medium	Not required	Minor	Possible	Low
SG5a	Operation/ maintenance encounters erosion/soil instability	Previous reports have noted potential for dispersive soils. Dispersive nature of soils needs to be investigated adjacent to cut areas. Runoff from dispersive soils may pose an environmental hazard.	Erosion and sediment control as per Section 177. Revegetation appropriate to the nature of the soils.	Minor	Possible	Low	Not required	Minor	Possible	Low
CLM1a	Contamination of soil during construction	Cleaning/Construction vehicles/mini fuel tankers causing land contamination through fuel/chemical spills/ discharges. Increased waste disposal cost, potential project delays.	Implement S177.G1 Fuels and Chemicals.	Moderate	Rare	Low	Not required	Moderate	Rare	Low

RISK ID	IMPACT PATHWAY	RISK DESCRIPTION	STANDARD CONTROLS	INITIAL RISK			ADDITIONAL MITIGATION / CONTROLS	RESIDUAL RISK		
				Consequence	Likelihood	Rating		Consequence	Likelihood	Rating
CLM2a	Construction uncovers contaminated land (including landfill)	Discovery of contaminated soils requiring management and potential off-site disposal.	Implement S177.E Contaminated Soils and Materials. No Environmental Audits or EPA Priority Sites within the alignment. No landfill identified within the alignment. Potential for metals contamination from historical gold mining activities (mine tailings) is medium – low on the proposed alignment, however no data is available to verify this. Other potential contamination sources are localised and not within the proposed alignment. Potential localised soil impacts at two service stations in the town centre (outside of alignment). Potential health risk to construction workers where contaminated soil is exposed.	Moderate	Unlikely	Medium	Once the road alignment is finalised soil sampling and analysis is required to understand contamination risk/disposal costing/reuse assessment. Update EMP and Occupation Health and Safety Plan based on contaminants found.	Moderate	Rare	Low

RISK ID	IMPACT PATHWAY	RISK DESCRIPTION	STANDARD CONTROLS	INITIAL RISK			ADDITIONAL MITIGATION / CONTROLS	RESIDUAL RISK		
				Consequence	Likelihood	Rating		Consequence	Likelihood	Rating
CLM3a	Construction uncovers contaminated land (including landfill)	Contaminated groundwater/perched water encountered requiring dewatering for piling. Potential contaminated groundwater adjacent to service stations (outside of alignment). Potential metals (arsenic) contamination from former mine workings/shafts. Depth to groundwater/perched water is unknown.	Implement S177.B2 Groundwater.	Moderate	Unlikely	Medium	Install groundwater monitoring wells to assess groundwater depth and quality to manage any potential contamination issues during construction (piling)/ operations.	Moderate	Rare	Low

RISK ID	IMPACT PATHWAY	RISK DESCRIPTION	STANDARD CONTROLS	INITIAL RISK			ADDITIONAL MITIGATION / CONTROLS	RESIDUAL RISK		
				Consequence	Likelihood	Rating		Consequence	Likelihood	Rating
ASS1a	Exposure of acid sulfate soils during development	Earthworks cause Acid Sulfate Soils (ASS) to be exposed and require treatment or special construction measures. Low potential for encountering ASS, however limited data available. Potential for occurrence along water ways and alluvial geology. Based on topographic elevation (<100 m above sea level), considered low likelihood. Low potential for metal sulfides to exist within rock.	Implement S177.E Contaminated Soils and Materials.	Minor	Unlikely	Low	Not required	Minor	Unlikely	Low

A1 ALIGNMENT

Table B.2 Soil and geology, contaminated land and acid sulfate soils environmental risk assessment register – A1 alignment

RISK ID	IMPACT PATHWAY	RISK DESCRIPTION	STANDARD CONTROLS	INITIAL RISK			ADDITIONAL MITIGATION / CONTROLS	RESIDUAL RISK		
				Consequence	Likelihood	Rating		Consequence	Likelihood	Rating
SG1b	Erosion/soil instability	Areas of cut may intersect groundwater levels and result in potential slope instability, face seepage and groundwater drawdown.	In sections of the proposed alignments where significant cut is required, it is recommended that boreholes are drilled to confirm the geology and depth to the groundwater table. Standpipe installation is recommended to allow the monitoring of groundwater fluctuation over time to inform the design of the proposed cut slopes. Samples from each strata encountered in the borehole should be taken to allow geotechnical laboratory testing to be undertaken to allow the derivation of geotechnical parameters which will further inform the concept design of the proposed cut slopes. Samples should also be assessed for dispersion potential.	Minor	Possible	Low	Not required	Minor	Possible	Low

RISK ID	IMPACT PATHWAY	RISK DESCRIPTION	STANDARD CONTROLS	INITIAL RISK			ADDITIONAL MITIGATION / CONTROLS	RESIDUAL RISK		
				Consequence	Likelihood	Rating		Consequence	Likelihood	Rating
SG2b	Encounters weak grounds	Embankments constructed over areas of alluvial deposits are likely to settle as a result of the compressible soils below.	In sections of the proposed alignments where softer ground is anticipated (i.e. alluvium deposits), it is recommended that boreholes are drilled to confirm the depth and nature of the soft ground to allow a preliminary estimation of anticipated settlement. The magnitude and time for completion of settlement should be reviewed as part of the design phase. Areas of softer ground may be encountered in areas associated with alluvial deposits and waterways. Structures are likely to require the use of piles to increase bearing capacity and reduce the impact of settlement.	Minor	Possible	Low	Not required	Minor	Possible	Low
SG3b	Design encounters erosion/soil instability	Previous reports have noted potential for dispersive soils. Dispersive nature of soils needs to be investigated adjacent to cut areas. Runoff from dispersive soils may pose an environmental hazard.	Emerson class testing should be carried out during the design phase.	Minor	Likely	Medium	Not required	Minor	Likely	Medium

RISK ID	IMPACT PATHWAY	RISK DESCRIPTION	STANDARD CONTROLS	INITIAL RISK			ADDITIONAL MITIGATION / CONTROLS	RESIDUAL RISK		
				Consequence	Likelihood	Rating		Consequence	Likelihood	Rating
SG4b	Construction encounters erosion/soil instability	Previous reports have noted potential for dispersive soils. Dispersive nature of soils needs to be investigated adjacent to cut areas. Runoff from dispersive soils may pose an environmental hazard.	Erosion and sediment control as per Section 177. Revegetation appropriate to the nature of the soils.	Minor	Likely	Medium	Not required	Minor	Possible	Low
SG5b	Operation/ maintenance encounters erosion/soil instability	Previous reports have noted potential for dispersive soils. Dispersive nature of soils needs to be investigated adjacent to cut areas. Runoff from dispersive soils may pose an environmental hazard.	Erosion and sediment control as per Section 177. Revegetation appropriate to the nature of the soils.	Minor	Possible	Low	Not required	Minor	Possible	Low
CLM1b	Contamination of soil during construction	Cleaning/Construction vehicles/mini fuel tankers causing land contamination through fuel/chemical spills/ discharges. Increased waste disposal cost, potential project delays	Implement S177.G1 Fuels and Chemicals.	Moderate	Rare	Low	Not required	Moderate	Rare	Low

RISK ID	IMPACT PATHWAY	RISK DESCRIPTION	STANDARD CONTROLS	INITIAL RISK			ADDITIONAL MITIGATION / CONTROLS	RESIDUAL RISK		
				Consequence	Likelihood	Rating		Consequence	Likelihood	Rating
CLM2b	Construction uncovers contaminated land (including landfill)	Discovery of contaminated soils requiring management and potential off-site disposal.	Implement S177.E Contaminated Soils and Materials. No Environmental Audits or EPA Priority Sites within the alignment. No landfill identified within the alignment. Potential for metals contamination from historical gold mining activities (mine tailings) is medium – low on the proposed alignment, however no data is available to verify this. Other potential contamination sources are localised and not within the proposed alignment. Potential localised soil impacts at two service stations in the town centre (outside of alignment). Potential health risk to construction workers where contaminated soil is exposed.	Moderate	Unlikely	Medium	Once the road alignment is finalised soil sampling and analysis is required to understand contamination risk/disposal costing/reuse assessment. Update EMP and Occupation Health and Safety Plan based on contaminants found.	Moderate	Rare	Low

RISK ID	IMPACT PATHWAY	RISK DESCRIPTION	STANDARD CONTROLS	INITIAL RISK			ADDITIONAL MITIGATION / CONTROLS	RESIDUAL RISK		
				Consequence	Likelihood	Rating		Consequence	Likelihood	Rating
CLM3b	Construction uncovers contaminated land (including landfill)	Contaminated groundwater/perched water encountered requiring dewatering for piling. Potential contaminated groundwater adjacent to service stations (outside of alignment). Potential metals (arsenic) contamination from former mine workings/shafts. Depth to groundwater/perched water is unknown.	Implement S177.B2 Groundwater.	Moderate	Unlikely	Medium	Install groundwater monitoring wells to assess groundwater depth and quality to manage any potential contamination issues during construction (piling)/ operations.	Moderate	Rare	Low

RISK ID	IMPACT PATHWAY	RISK DESCRIPTION	STANDARD CONTROLS	INITIAL RISK			ADDITIONAL MITIGATION / CONTROLS	RESIDUAL RISK		
				Consequence	Likelihood	Rating		Consequence	Likelihood	Rating
ASS1b	Exposure of acid sulfate soils during development	Earthworks cause Acid Sulfate Soils (ASS) to be exposed and require treatment or special construction measures. Low potential for encountering ASS, however limited data available. Potential for occurrence along water ways and alluvial geology. Based on topographic elevation (<100 m above sea level), considered low likelihood. Low potential for metal sulfides to exist within rock.	Implement S177.E Contaminated Soils and Materials.	Minor	Unlikely	Low	Not required	Minor	Unlikely	Low

C0 ALIGNMENT

Table B.3 Soil and geology, contaminated land and acid sulfate soils environmental risk assessment register – C0 alignment

RISK ID	IMPACT PATHWAY	RISK DESCRIPTION	STANDARD CONTROLS	INITIAL RISK			ADDITIONAL MITIGATION / CONTROLS	RESIDUAL RISK		
				Consequence	Likelihood	Rating		Consequence	Likelihood	Rating
SG1c	Erosion/soil instability	Areas of cut may intersect groundwater levels and result in potential slope instability, face seepage and groundwater drawdown.	In sections of the proposed alignments where significant cut is required, it is recommended that boreholes are drilled to confirm the geology and depth to the groundwater table. Standpipe installation is recommended to allow the monitoring of groundwater fluctuation over time to inform the design of the proposed cut slopes. Samples from each strata encountered in the borehole should be taken to allow geotechnical laboratory testing to be undertaken to allow the derivation of geotechnical parameters which will further inform the concept design of the proposed cut slopes. Samples should also be assessed for dispersion potential.	Minor	Possible	Low	Not required	Minor	Possible	Low

RISK ID	IMPACT PATHWAY	RISK DESCRIPTION	STANDARD CONTROLS	INITIAL RISK			ADDITIONAL MITIGATION / CONTROLS	RESIDUAL RISK		
				Consequence	Likelihood	Rating		Consequence	Likelihood	Rating
SG2c	Encounters weak grounds	Embankments constructed over areas of alluvial deposits are likely to settle as a result of the compressible soils below.	In sections of the proposed alignments where softer ground is anticipated (i.e. alluvium deposits), it is recommended that boreholes are drilled to confirm the depth and nature of the soft ground to allow a preliminary estimation of anticipated settlement. The magnitude and time for completion of settlement should be reviewed as part of the design phase. Areas of softer ground may be encountered in areas associated with alluvial deposits and waterways. Structures are likely to require the use of piles to increase bearing capacity and reduce the impact of settlement.	Minor	Possible	Low	Not required	Minor	Possible	Low
SG3c	Design encounters erosion/soil instability	Previous reports have noted potential for dispersive soils. Dispersive nature of soils needs to be investigated adjacent to cut areas. Runoff from dispersive soils may pose an environmental hazard.	Emerson class testing should be carried out during the design phase.	Minor	Likely	Medium		Minor	Likely	Medium

RISK ID	IMPACT PATHWAY	RISK DESCRIPTION	STANDARD CONTROLS	INITIAL RISK			ADDITIONAL MITIGATION / CONTROLS	RESIDUAL RISK		
				Consequence	Likelihood	Rating		Consequence	Likelihood	Rating
SG4c	Construction encounters erosion/soil instability	Previous reports have noted potential for dispersive soils. Dispersive nature of soils needs to be investigated adjacent to cut areas. Runoff from dispersive soils may pose an environmental hazard.	Erosion and sediment control as per Section 177. Revegetation appropriate to the nature of the soils.	Minor	Likely	Medium		Minor	Possible	Low
SG5c	Operation/ maintenance encounters erosion/soil instability	Previous reports have noted potential for dispersive soils. Dispersive nature of soils needs to be investigated adjacent to cut areas. Runoff from dispersive soils may pose an environmental hazard.	Erosion and sediment control as per Section 177. Revegetation appropriate to the nature of the soils.	Minor	Possible	Low	Not required	Minor	Possible	Low
CLM1c	Contamination of soil during construction	Cleaning/Construction vehicles/mini fuel tankers causing land contamination through fuel/chemical spills/ discharges. Increased waste disposal cost, potential project delays.	Implement S177.G1 Fuels and Chemicals.	Moderate	Rare	Low	Not required	Moderate	Rare	Low

RISK ID	IMPACT PATHWAY	RISK DESCRIPTION	STANDARD CONTROLS	INITIAL RISK			ADDITIONAL MITIGATION / CONTROLS	RESIDUAL RISK		
				Consequence	Likelihood	Rating		Consequence	Likelihood	Rating
CLM2c	Construction uncovers contaminated land (including landfill)	Discovery of contaminated soils requiring management and potential off-site disposal.	Implement S177.E Contaminated Soils and Materials. No Environmental Audits or EPA Priority Sites within the alignment. No landfill identified within the alignment. Potential for metals contamination from historical gold mining activities (mine tailings) is medium - low on the proposed alignment, however no data is available to verify this. Other potential contamination sources are localised and not within the proposed alignment. Potential localised soil impacts at two service stations in the town centre (outside of alignment). Potential health risk to construction workers where contaminated soil is exposed.	Moderate	Unlikely	Medium	Once the road alignment is finalised soil sampling and analysis is required to understand contamination risk/disposal costing/reuse assessment. Update EMP and Occupation Health and Safety Plan based on contaminants found.	Moderate	Rare	Low

RISK ID	IMPACT PATHWAY	RISK DESCRIPTION	STANDARD CONTROLS	INITIAL RISK			ADDITIONAL MITIGATION / CONTROLS	RESIDUAL RISK		
				Consequence	Likelihood	Rating		Consequence	Likelihood	Rating
CLM3c	Construction uncovers contaminated land (including landfill)	Contaminated groundwater/perched water encountered requiring dewatering for piling. Potential contaminated groundwater adjacent to service stations (outside of alignment). Potential metals (arsenic) contamination from former mine workings/shafts. Depth to groundwater/perched water is unknown.	Implement S177.B2 Groundwater.	Moderate	Unlikely	Medium	Install groundwater monitoring wells to assess groundwater depth and quality to manage any potential contamination issues during construction (piling)/ operations.	Moderate	Rare	Low

RISK ID	IMPACT PATHWAY	RISK DESCRIPTION	STANDARD CONTROLS	INITIAL RISK			ADDITIONAL MITIGATION / CONTROLS	RESIDUAL RISK		
				Consequence	Likelihood	Rating		Consequence	Likelihood	Rating
ASS1c	Exposure of acid sulfate soils during development	Earthworks cause Acid Sulfate Soils (ASS) to be exposed and require treatment or special construction measures. Low potential for encountering ASS, however limited data available. Potential for occurrence along water ways and alluvial geology. Based on topographic elevation (<100 m above sea level), considered low likelihood. Low potential for metal sulfides to exist within rock.	Implement S177.E Contaminated Soils and Materials.	Minor	Unlikely	Low	Not required	Minor	Unlikely	Low

C2 ALIGNMENT

Table B.4 Soil and geology, contaminated land and acid sulfate soils environmental risk assessment register – C2 alignment

RISK ID	IMPACT PATHWAY	RISK DESCRIPTION	STANDARD CONTROLS	INITIAL RISK			ADDITIONAL MITIGATION / CONTROLS	RESIDUAL RISK		
				Consequence	Likelihood	Rating		Consequence	Likelihood	Rating
SG1d	Erosion/soil instability	Areas of cut may intersect groundwater levels and result in potential slope instability, face seepage and groundwater drawdown.	In sections of the proposed alignments where significant cut is required, it is recommended that boreholes are drilled to confirm the geology and depth to the groundwater table. Standpipe installation is recommended to allow the monitoring of groundwater fluctuation over time to inform the design of the proposed cut slopes. Samples from each strata encountered in the borehole should be taken to allow geotechnical laboratory testing to be undertaken to allow the derivation of geotechnical parameters which will further inform the concept design of the proposed cut slopes. Samples should also be assessed for dispersion potential.	Minor	Possible	Low	Not required	Minor	Possible	Low

RISK ID	IMPACT PATHWAY	RISK DESCRIPTION	STANDARD CONTROLS	INITIAL RISK			ADDITIONAL MITIGATION / CONTROLS	RESIDUAL RISK		
				Consequence	Likelihood	Rating		Consequence	Likelihood	Rating
SG2d	Encounters weak grounds	Embankments constructed over areas of alluvial deposits are likely to settle as a result of the compressible soils below.	In sections of the proposed alignments where softer ground is anticipated (i.e. alluvium deposits), it is recommended that boreholes are drilled to confirm the depth and nature of the soft ground to allow a preliminary estimation of anticipated settlement. The magnitude and time for completion of settlement should be reviewed as part of the design phase. Areas of softer ground may be encountered in areas associated with alluvial deposits and waterways. Structures are likely to require the use of piles to increase bearing capacity and reduce the impact of settlement.	Minor	Possible	Low	Not required	Minor	Possible	Low
SG3d	Design encounters erosion/soil instability	Previous reports have noted potential for dispersive soils. Dispersive nature of soils needs to be investigated adjacent to cut areas. Runoff from dispersive soils may pose an environmental hazard.	Emerson class testing should be carried out during the design phase.	Minor	Likely	Medium		Minor	Likely	Medium

RISK ID	IMPACT PATHWAY	RISK DESCRIPTION	STANDARD CONTROLS	INITIAL RISK			ADDITIONAL MITIGATION / CONTROLS	RESIDUAL RISK		
				Consequence	Likelihood	Rating		Consequence	Likelihood	Rating
SG4d	Construction encounters erosion/soil instability	Previous reports have noted potential for dispersive soils. Dispersive nature of soils needs to be investigated adjacent to cut areas. Runoff from dispersive soils may pose an environmental hazard.	Erosion and sediment control as per Section 177. Revegetation appropriate to the nature of the soils.	Minor	Likely	Medium		Minor	Possible	Low
SG5d	Operation/ maintenance encounters erosion/soil instability	Previous reports have noted potential for dispersive soils. Dispersive nature of soils needs to be investigated adjacent to cut areas. Runoff from dispersive soils may pose an environmental hazard.	Erosion and sediment control as per Section 177. Revegetation appropriate to the nature of the soils.	Minor	Possible	Low	Not required	Minor	Possible	Low
CLM1d	Contamination of soil during construction	Cleaning/Construction vehicles/mini fuel tankers causing land contamination through fuel/chemical spills/ discharges. Increased waste disposal cost, potential project delays.	Implement S177.G1 Fuels and Chemicals.	Moderate	Rare	Low	Not required	Moderate	Rare	Low

RISK ID	IMPACT PATHWAY	RISK DESCRIPTION	STANDARD CONTROLS	INITIAL RISK			ADDITIONAL MITIGATION / CONTROLS	RESIDUAL RISK		
				Consequence	Likelihood	Rating		Consequence	Likelihood	Rating
CLM2d	Construction uncovers contaminated land (including landfill)	Discovery of contaminated soils requiring management and potential off-site disposal.	Implement S177.E Contaminated Soils and Materials. No Environmental Audits or EPA Priority Sites within the alignment. No landfill identified within the alignment. Potential for metals contamination from historical gold mining activities (mine tailings) is medium - low on the proposed alignment, however no data is available to verify this. Other potential contamination sources are localised and not within the proposed alignment. Potential localised soil impacts at two service stations in the town centre (outside of alignment). Potential health risk to construction workers where contaminated soil is exposed.	Moderate	Unlikely	Medium	Once the road alignment is finalised soil sampling and analysis is required to understand contamination risk/disposal costing/reuse assessment. Update EMP and Occupation Health and Safety Plan based on contaminants found.	Moderate	Rare	Low

RISK ID	IMPACT PATHWAY	RISK DESCRIPTION	STANDARD CONTROLS	INITIAL RISK			ADDITIONAL MITIGATION / CONTROLS	RESIDUAL RISK		
				Consequence	Likelihood	Rating		Consequence	Likelihood	Rating
CLM3d	Construction uncovers contaminated land (including landfill)	Contaminated groundwater/perched water encountered requiring dewatering for piling. Potential contaminated groundwater adjacent to service stations (outside of alignment). Potential metals (arsenic) contamination from former mine workings/shafts. Depth to groundwater/perched water is unknown.	Implement S177.B2 Groundwater.	Moderate	Unlikely	Medium	Install groundwater monitoring wells to assess groundwater depth and quality to manage any potential contamination issues during construction (piling)/ operations.	Moderate	Rare	Low

RISK ID	IMPACT PATHWAY	RISK DESCRIPTION	STANDARD CONTROLS	INITIAL RISK			ADDITIONAL MITIGATION / CONTROLS	RESIDUAL RISK		
				Consequence	Likelihood	Rating		Consequence	Likelihood	Rating
ASS1d	Exposure of acid sulfate soils during development	Earthworks cause Acid Sulfate Soils (ASS) to be exposed and require treatment or special construction measures. Low potential for encountering ASS, however limited data available. Potential for occurrence along water ways and alluvial geology. Based on topographic elevation (<100 m above sea level), considered low likelihood. Low potential for metal sulfides to exist within rock.	Implement S177.E Contaminated Soils and Materials.	Minor	Unlikely	Low	Not required	Minor	Unlikely	Low

ABOUT US

WSP is one of the world's leading engineering professional services consulting firms. We are dedicated to our local communities and propelled by international brainpower. We are technical experts and strategic advisors including engineers, technicians, scientists, planners, surveyors, environmental specialists, as well as other design, program and construction management professionals. We design lasting Property & Buildings, Transportation & Infrastructure, Resources (including Mining and Industry), Water, Power and Environmental solutions, as well as provide project delivery and strategic consulting services. With 43,600 talented people in more than 550 offices across 40 countries, we engineer projects that will help societies grow for lifetimes to come.