CHAPTER 9

Land Resources

GOWRIE TO HELIDON ENVIRONMENTAL IMPACT STATEMENT

IR_1536

The Australian Government is delivering Inland Rail through the Australian Rail Track Corporation (ARTC), in partnership with the private sector.

Contents

9.	**LAND RESOURCES**	**9-1**
9.1	**Summary**	**9-1**
9.2	**Scope of chapter**	**9-2**
9.3	**Terms of Reference requirements**	**9-2**
9.4	**Legislation, policy, standards and guidelines**	**9-3**
9.5	**Methodology**	**9-6**
9.5.1	Land resources study area	9-6
9.5.2	Data sources	9-7
9.5.3	Geotechnical and soil investigations	9-7
9.5.4	Laboratory testing	9-8
9.5.5	Contamination assessment	9-9
9.5.6	Impact assessment methodology	9-9
9.6	**Description of existing land resources**	**9-11**
9.6.1	Geological and topographical setting	9-11
9.6.2	Surface water	9-18
9.6.3	Groundwater	9-18
9.6.4	Soil	9-19
9.6.5	Agricultural land	9-46
9.6.6	Contaminated land	9-48
9.7	**Potential impacts**	**9-80**
9.7.1	Permanent change to landform and topography	9-80
9.7.2	Waste rock	9-81
9.7.3	Loss of soil resources	9-82
9.7.4	Degradation of soil resources through invasive flora and fauna	9-83
9.7.5	Acid sulfate soils	9-83
9.7.6	Salinity hazard	9-84
9.7.7	Disturbance of existing contaminated land	9-85
9.7.8	Creation of contaminated land	9-89
9.8	**Mitigation measures**	**9-90**
9.8.1	Design considerations	9-90
9.8.2	Proposed mitigation measures	9-91
9.9	**Impact assessment**	**9-101**
9.10	**Cumulative impacts**	**9-104**
9.11	**Conclusions**	**9-107**

Figures

Figure 9.1:	Soil sampling sites	9-10
Figure 9.2:	Topographical cross-section of the Project	9-12
Figure 9.3:	Diagrammatic cross section of typical ridge on the eastern side of the Toowoomba Range, showing the locations of slides and stability zones (Willmott 1983)	9-12
Figure 9.4:	Topography	9-13
Figure 9.5:	Geology	9-16
Figure 9.6:	Schematic distribution of the main geological units between Toowoomba and Kagaru	9-17
Figure 9.7:	Australian soils classification	9-24
Figure 9.8:	Acid Sulfate Soils	9-31
Figure 9.9:	Inherent salt store	9-35
Figure 9.10:	Potential expression area: Basalt and sandstone contact	9-37
Figure 9.11:	Potential expression area: Catena form	9-39
Figure 9.12:	Potential expression area: Roads	9-41
Figure 9.13:	Potential expression area: Confluence of streams	9-43
Figure 9.14:	Overall salinity hazard	9-45
Figure 9.15:	Important agricultural areas	9-47
Figure 9.16:	Sites currently listed on the EMR in the land resources study area	9-52
Figure 9.17a–e:	Aurecon (2020) preliminary site investigation sampling locations	9-71
Figure 9.18a–c:	Golder (2020) contamination assessment soil sampling locations	9-77
Figure 9.19:	Strategy for the assessment and investigation of contaminated land in the Project disturbance footprint	9-100

Tables

Table 9.1: Terms of Reference requirements 9-2

Table 9.2: Regulatory Context 9-3

Table 9.3: Geological units 9-14

Table 9.4: Soil chemistry investigation results 9-20

Table 9.5: Summary of geotechnical analysis relevant to land resources 9-22

Table 9.6: Summary of historical soil survey data obtained from the SALI database 9-25

Table 9.7: Summary of soil descriptions and limitations from land management manuals for soils within the Project disturbance footprint 9-26

Table 9.8: Erosion risk 9-28

Table 9.9: Soil type and soil salt store 9-34

Table 9.10: Potential expression area: Basalt and sandstone contact 9-36

Table 9.11: Potential expression area of catena form 9-38

Table 9.12: Number of road potential expression areas along land resources study area categories 9-40

Table 9.13: Potential expression area: Confluence of streams 9-42

Table 9.14: Summary of Department of Resources known salinity areas 9-44

Table 9.15: Properties listed in the Environmental Management Register within the land resources study area 9-50

Table 9.16: Historical aerial photographs 9-54

Table 9.17: Potential existing sources and identified contamination risks 9-66

Table 9.18: Summary of soil and sediment sampling methodology relevant to the Project 9-68

Table 9.19: Aurecon (2020) PSI adopted screening criteria 9-69

Table 9.20: Summary of Aurecon (2020) laboratory results that exceeded human health and ecological investigation levels 9-70

Table 9.21: Landforms with salinity formation risk identified during desktop salinity hazard assessment 9-84

Table 9.22: Potential existing contaminated land source, pathway and receptor linkages 9-85

Table 9.23: Aurecon (2020) preliminary conceptual site model for identified EMR properties 9-88

Table 9.24: Potential creation of contaminated land source, pathway and receptor linkages 9-89

Table 9.25: Initial mitigation through design responses 9-91

Table 9.26: Land resources mitigation measures 9-92

Table 9.27: Impact assessment for potential impacts associated with land resources 9-102

Table 9.28: Other projects in the vicinity of the Project disturbance footprint 9-104

Table 9.29: Potential cumulative impacts 9-105

9. Land Resources

9.1 Summary

This chapter provides an assessment of land resources for the Gowrie to Helidon Project (the Project). The existing environment, the risks arising from the disturbance and excavation of land, as well as the disposal of soil has been evaluated. A quantitative and qualitative risk assessment of soil properties, including agricultural and problematic soils, and contaminated land was undertaken. The risk assessment addresses the construction, operation and decommissioning phases of the Project. Mitigation measures to be implemented during the construction and operational phases of the Project are outlined in Chapter 23: Draft Outline Environmental Management Plan (Draft Outline EMP).

The land resources chapter assesses the following land resources aspects:

- Topography
- Geology
- Acid sulfate soils/acid rock (acid sulfate soils (ASS) includes actual acid sulfate soils (AASS) and potential acid sulfate soils (PASS))
- Naturally occurring asbestos (NOA)
- Saline, dispersive and reactive soils
- Erosion risk
- Contaminated land
- Agricultural land
- Unexploded ordnance.

An assessment of land resource features identified several adverse impacts to potentially occur as a result of Project activities. These impacts may occur during the construction and operational phases and include:

- A permanent change in landform and topography in catchments, influencing their ability to retain and move water
- Loss of natural soil resources including Class A and Class B agricultural land, and Important Agricultural Areas (IAAs)
- Unexpected encounter of ASS or acid rock
- Introducing weeds, which may change physical and chemical properties of soil
- Feral animal impedance
- Increased salinity of the landscape causing water table salting, irrigation water salting and erosion scalding
- Disturbance of contaminated land (soil and groundwater)
- Project activities leading to the generation of new contaminated land (soil and groundwater).

The quantitative and qualitative risk assessment identified change to landform and topography, loss of soil resources and disturbance of existing contaminated land during the construction phase of the Project to present a medium residual risk.

The mitigation measures detailed in Section 9.8 will sufficiently manage all identified potential impacts for land resources as a result of Project activities.

This chapter should be read in conjunction with the following components of the draft EIS:

- Appendix X: EMR Search Certificates and Laboratory Certificates
- Appendix W: Geotechnical
- Appendix T: Spoil Management Strategy.

9.2 Scope of chapter

The purpose of this chapter is to provide an assessment of the Project's impact on land resources. This includes an evaluation of the existing environment to identify and assess the risks arising from the disturbance and excavation of land and the disposal of soil. The assessment includes contaminated land, IAAs and soil properties. The existing environment for the Project was investigated through desktop assessment of existing available information, as well as through specific studies undertaken for the Project, including contaminated land sampling and analysis, as well as geotechnical investigations. Field assessments of soil for salinity, ASS, sodic, dispersive and cracking clay soils, were undertaken to provide input to the assessment.

A quantitative compliance risk assessment was undertaken for soil properties, including agricultural and problematic soils. A qualitative risk assessment of contaminated land and any risks that this may present from a construction or operational perspective was also undertaken.

Following the identification and assessment of the potential risks for the Project, appropriate mitigation measures were developed.

9.3 Terms of Reference requirements

This chapter addresses the Terms of Reference (ToR) requirements associated with land resources for the environmental impact statement (EIS) and are detailed in Table 9.1.

TABLE 9.1: TERMS OF REFERENCE REQUIREMENTS

Terms of Reference requirements		Where addressed in the EIS
Existing Environment		
10.4.	Describe and illustrate the topography of the preferred alignment and surrounding area, and highlight any significant features shown on the maps. Include and name all waterways, including watercourses, rivers and creeks. Maps should include a scale and have contours at suitable increments relevant to the scale, location, potential impacts and type of project, shown with respect to Australian Height Datum (AHD) and drafted to GDA94.	Section 9.6.1.1, Figure 9.2 and Figure 9.4
10.5.	Describe and illustrate specific information about the proposed Project including the precise location of the preferred alignment in relation to designated area, such as transport corridors, protected areas and areas of regional interest and agricultural land uses identified in the Queensland Agricultural Land Audit. Consideration should also be given to key resource areas (KRAs), petroleum and gas pipelines, explosive magazines (Storage and manufacturing facilities) abandoned mines and mining (exploration and production) tenures.	Sections 9.7, 9.6.6.1, 9.9 and Figure 9.16
10.6.	Where relevant, describe and map in plan and cross-sections the geology and landforms, including catchments, of the project area. Show geological structures, such as aquifers, faults and economic resources (such as agricultural products and KRAs) that could have an influence on, or be influenced by, the project's activities.	Sections 9.6.1.2, 9.6.2, 9.6.3, Figure 9.5 and Figure 9.6
10.7.	Where relevant, describe, map and illustrate soil types and profiles of the project area at a scale relevant to the proposed project. Identify soils that would require particular management due to wetness, erosivity, depth, acidity, salinity, contamination or other relevant features.	Sections 9.6.4, 9.6.6 and Figure 9.6 to Figure 9.12
11.87.	Identify and investigate areas of salinity, acid sulfate soils, sodic, dispersive and cracking clay soils and potential and actual areas of acid sulfate soils. Where potential areas are identified, further investigations (including field surveys) should be undertaken in accordance with accepted industry guidelines and the requirements of the State Planning Policy—State interests guideline water quality are followed.	Sections 9.6.4.3, 9.6.4.4, 9.6.4.5, and Figure 9.8 to Figure 9.14
11.88.	Provide details, including maps, of the location of project works/infrastructure with respect to soil conservation works (contour banks, waterway discharge points, etc.)	Section 9.6.4.2 Chapter 6: Project Description and Appendix C: Design Drawings
11.89.	Identify activities or operations likely to impact soil conservation property plans approved under the *Soil Conservation Act 1986*.	Section 9.6.4.2

Terms of Reference requirements		Where addressed in the EIS
11.157.	Detail any known or potential sources of contaminated land within or adjoining the project area, including the location of any potential contamination identified by landholders. Provide results of searches of the Environmental Management Register (EMR) and/or the Contaminated Land Register (CLR) under the *Environmental Protection Act 1994* for the preferred rail alignment and disturbance areas.	Section 9.6.6 and Figure 9.16 Appendix X: EMR Search Certificates and Laboratory Certificates
11.158.	Describe how any proposed land use may result in land potentially becoming contaminated. Provide a description of the nature and extent of contamination at identified site(s).	Section 9.6.6
11.161.	Describe how the presence of any known potential unexploded ordnance will be identified on maps of an appropriate size and scale and assessed within or adjoining the project area. Describe how any known or potential unexploded ordnance will be managed. Describe any consultation proposed with the Commonwealth Department of Defence.	Sections 9.6.6 and 9.8.2
Impact Assessment		
11.86.	The assessment of impacts on topography, geology and soils will be in accordance with DEHP application requirements for the ERAs with impacts to land (Guideline ESR/2015/1839). Discuss the projects impacts on Important Agricultural Areas as per the SPP – State interest guideline—Agriculture with reference to Agricultural Land Use Categories under the Queensland Agricultural Land Audit methodology (see Appendix 1).	Sections 9.4, 9.7 and 9.9 Chapter 8: Land Use and Tenure
Mitigation Measures		
11.90.	Measures to avoid or mitigate potential impacts of the project on soil values must be described.	Section 9.8
11.159.	Describe the proposed management of any contaminated land either previously identified or encountered during construction activities and the potential for contamination from construction, commissioning, operation and decommissioning.	Sections 9.6.6, 9.7.7, 9.7.8, and 9.8
11.160.	Describe strategies and methods to be used to prevent, manage or remediate any land contamination resulting from the project, including but not limited to the management of any acid generation or management of chemicals and fuels to prevent spills or leaks.	Section 9.8

9.4 Legislation, policy, standards and guidelines

The land resources assessment presented in this chapter was undertaken in accordance with the legislation, policies, standards and guidelines presented in Table 9.2, which are intended to protect and manage land resources. Further information on legislation, policies, standards and guidelines relevant to the Project are provided in Chapter 3: Project Approvals.

TABLE 9.2: REGULATORY CONTEXT

Legislation, policy or guideline	Relevance to the Project
Commonwealth	
National Environment Protection (Assessment of Site Contamination) Measure 1999 (Cth) (ASC NEPM)	The ASC NEPM is the national guidance document for the assessment of site contamination in Australia, which aims to establish a nationally consistent approach to assess site contamination to ensure sound environmental management practices are adopted. The desired outcome of ASC NEPM is to protect human health and the environment. Contaminated land in Queensland is assessed in accordance with the processes and guidance detailed in ASC NEPM. The Project included a Tier 1 desktop assessment of the land resources study area as per ASC NEPM.

Legislation, policy or guideline	Relevance to the Project
Guidelines for Surveying Soil and Land Resources (McKenzie et al., 2008)	The *Guidelines for Surveying Soil and Land Resources* aims to promote the development and implementation of consistent methods for conducting soil and land resource surveys in Australia. The guideline provides information on how to best undertake field surveys to identify, describe, map and evaluate various soils or land resources. The Project considered the guidelines during the assessment of the land resources study area.
Australian Soil and Land Survey Field Handbook (National Committee on Soil and Terrain, 2009)	The *Australian Soil and Land Survey Field Handbook* provides specific methods and terminology for soil and land surveys. It is widely used throughout Australia to provide one reference set of definitions for the characterisation of landforms, vegetation, land surface, soil and substrate. The Project considered information provided in the handbook during the assessment of the land resources study area.
State	
Environmental Protection Act 1994 (Qld) (EP Act)	The EP Act aims to protect Queensland's environment by legislating activities relevant to land resources, including: ▸ Contaminated land/soil management processes (including disposal permit to remove and treat or dispose of contaminated soil) ▸ Grounds for including land on environmental registers.
Environmental Protection Regulation 2019 (Qld)	The Environmental Protection Regulation 2019 regulates activities relevant to the land resources, including: ▸ Regulatory requirement for activities involving acid sulfate soils (ASS) and acid producing rock ▸ Prescribed management of contaminants and contaminated land.
Soil Conservation Act 1986 (Qld)	The *Soil Conservation Act 1986* (Qld) governs the conservation of soil resources and the implementation of soil conservation measures by landholders for the mitigation of soil erosion. Under the Act, the Project will need to meet the requirements of the legislation with respect to soil conservation. Approved soil conservation plans (property or project) are not present within the land resources study area.
Soil Conservation Guidelines for Queensland (Department of Science, Information Technology and Innovation (DSITI), 2015b)	These guidelines provide information on soil degradation and practical tools for its prevention from water-based erosion. They also provide tools and techniques to remediate degraded areas.
State Planning Policy—State Interest Guidance: Agriculture (SPP) (Department of Infrastructure, Local Government and Planning (DILGP), 2017c)	The SPP was established by the Queensland Government to define specific matters of State interest in land use planning and development. Agriculture is identified as a State interest within the SPP. The purpose of the guidance material is to inform the drafting of planning instruments so that they appropriately integrate the Agriculture state interest. Audit information has been used to support the identification and mapping of IAAs, and Agricultural Land Class A and B, which intersect the land resources study area.
Queensland Acid Sulfate Soil Technical Manual: Soil Management Guidelines 2014 (Dear et al., 2014)	The manual provides risk-based management measures, with a variety of 'preferred' or 'high risk' strategies that can be used to manage documented ASS. If ASS is disturbed directly or indirectly during Project activities, an ASS Management Plan is required to be prepared. The technical manual was considered during the assessment of the land resources study area.
Salinity Management Handbook, 2nd edition (Department of Environment and Resource Management (DERM), 2011)	The Salinity Management Handbook provides a guide to salinity processes, investigating salinity risks within landscapes, and developing integrated management strategies should saline soils be encountered. The handbook was considered during the assessment of the land resources study area. Additionally, the modelling and assessment of salinity risks was undertaken in accordance with the handbook.
Guidelines for Soil Survey along Linear Features (Soil Science Australia, 2015)	The guideline addresses soil survey techniques required for linear features, which are generally considered 10 to 100 m wide and include rail. The guideline identifies varying scales of soil mapping are required for different stages of a project. The guidelines recommend soil information for an EIS to require a scale of 1:250,000, while for the construction stage of a project, a scale of 1: 5,000 is considered more appropriate. The Project considered the scale of mapping required under the guideline for the assessment of soil within the land resources study area, at the current Project stage (i.e. EIS).

Legislation, policy or guideline	Relevance to the Project
Environmental Impact Statement Information Guideline—Land (Department of Environment and Heritage Protection (DEHP), 2016b)	The Queensland EIS guideline for land describes information required to support applications for statutory approvals concerning land-related matters. The guideline describes the information required for an EIS (generally tailored towards resources projects) for land-related aspects such as topography, geology and geomorphology, and description of soil, which are relevant to this Project. The guideline was considered and applied in the drafting of this section of the EIS. This guideline was superseded in August 2020, by the Department of Environment and Science 2020, Land—EIS information guideline which has a similar purpose to above.
Environmental Impact Statement Information Guideline—Contaminated Land (DEHP, 2016b)	The Queensland EIS guideline for contaminated land describes the information required to support the EIS (generally tailored towards resources projects), including: ▸ Existing contamination, potential impacts and management measures to be implemented during the Project ▸ The extent to which Project activities would cause soil contamination and how that would be managed ▸ The risks to human health and the environment posed by existing and potential soil contamination. The guideline also prescribes the information required should ASS be encountered during the Project. The guideline was considered and applied in the drafting of this section of the EIS. This guideline was superseded in August 2020, by the Department of Environment and Science 2020, Contaminated Land—EIS information guideline which has a similar purpose to above.
Guidelines for Soil Survey along Linear Features (Soil Science Australia, 2015)	The guidelines prescribe soil survey techniques required for linear features, which are generally considered to be 10–100 m wide and include rail. The guidelines identify varying scales of soil mapping are required for different stages of a project. The guidelines recommend soil information for an EIS to require a scale of 1:250,000, while for the construction stage of a project, a scale of 1:5,000 is considered more appropriate. The mapping scale/intensity etc. defined in Tables 1, 2 and 3 of the Guidelines are for a project with a defined disturbance footprint and an alignment width of less than 100 m. The Project footprint for the Border to Gowrie Project is subject to confirmation through the detail design process but will be, in several locations, greater than 100 m in width; therefore, the mapping scale/intensity etc. defined in Tables 1, 2 and 3 of the Guidelines are not considered to be directly applicable the Border to Gowrie Project at the reference design (EIS) stage. ASRIS Atlas of Australian Soils (CSIRO, 2014a) Australian Soil Classification mapping is a national dataset published at a scale of 1:2,000,000 but is based on localised surveys and mapping completed at a scale of 1:250,000. Consequently, the mapping scale considered to be appropriate by the Guidelines for the purpose of an EIS can be achieved with reference to publicly available mapping, published by CSIRO. ARTC has committed to undertaking detailed soil investigations at a suitable sampling intensity to inform the development of detailed design. Subject to land access, the soil sampling will be of an intensity to enable mapping at a 1:10,000 scale. The methodology for the detailed soil investigation will be developed in consultation with the Department of Resources and will be in accordance with the Guidelines for surveying soil and land resources (McKenzie et al., 2008), the Australian soil and land survey field handbook (National Committee on Soil and Terrain, 2009) and the Guidelines for Soil Survey along Linear Features. Soil investigations will be conducted under the supervision of a suitably qualified soil practitioner. These additional investigations have commenced.

Legislation, policy or guideline	Relevance to the Project
Central Darling Downs Land Management Manual (Harris et al., 1999)	This publication set describes the soils and land resources of the Central Darling Downs. It is part of a series, which details the recommended land management practices for the major cropping areas of Queensland. The survey area covers 2.6 million hectares in the shires of Millmerran, Pittsworth, Jondaryan, Toowoomba, Rosalie and Wambo. The field manual, resource book and soil chemical data book contain currently available land resource information, combined with local knowledge and experience, primarily concerning soils and their management. Land resource area mapping was produced at a scale of 1:250,000.
Queensland Acid Sulfate Soil Technical Manual: Soil Management Guidelines 2014 (Dear et al., 2014)	The management guidelines for ASS provide risk-based management measures, with a variety of 'preferred' or 'high risk' strategies that can be used to manage documented ASS. If ASS is disturbed directly or indirectly during Project activities, an ASS Management Plan is required to be prepared.
National Guidance for the Management of Acid Sulfate Soils in Inland Aquatic Ecosystems (Environment Protection and Heritage Council and the Natural Resource Management Ministerial Council (EPHC & NRMMC), 2011)	This guidance document for the management of ASS in inland aquatic ecosystems is designed to guide the identification and management of inland ASS to reduce or eliminate the risks they pose to the environment and the economy. The document explains the complexities associated with managing ASS and describes how to manage ASS in a range of aquatic environments in a drying climate.
Guidelines for Sampling and Analysis of Lowland Acid Sulfate Soils (ASS) in Queensland (Ahern C. R. et al., 1998)	These guidelines provide a State-wide standard, sampling and analysis regime, to enable accurate assessment of environmental impact prior to disturbance of acid sulfate soils—the term includes potential acid sulfate soils. The guidelines are intended to enable objective decisions regarding the management of ASS to be made, in a manner consistent with the principles of ecologically sustainable development and best practice environmental management.
Best Practice Erosion & Sediment Control (International Erosion Control Association (IECA), 2008)	This publication set provides guidance on erosion and sediment control best practice within Australia. It contains the necessary strategies and techniques to assist erosion and sediment control practitioners to reduce the degradation of land and water from uncontrolled erosion and sedimentation. This publication set has been, and will continue to be, referenced in the planning, development and implementation of erosion and sediment control measures for the Project.

9.5 Methodology

9.5.1 Land resources study area

The land resources study area adopts the EIS investigation corridor, being a 2 km (approximate) wide study area, 1 km (approximate) either side of the proposed rail alignment. The land resources study area includes the Project disturbance footprint, which encompasses all areas where works are proposed, including both permanent and temporary works.

The Project disturbance footprint includes:

- The permanent disturbance footprint: the rail corridor, which includes the rail tracks and associated infrastructure (e.g. intermediate ventilation shaft and infrastructure, tunnel portal infrastructure and operational and maintenance facilities etc.) as well as other permanent works associated with the Project (e.g. where changes to the road network are required)
- The temporary construction disturbance footprint: the permanent disturbance footprint and any temporary storage and laydown areas to be used on a temporary basis during the construction phase
- The assessment also includes additional areas outside the land resources study area (in close proximity to, or adjoining, lots) where intensive industrial activities or other potentially contaminating activities are identified that may pose a risk to the Project, or where ground disturbance may occur as a result of the Project
- Commercially operated quarries are excluded from this assessment as they operate under their own environmental approvals/permits.

9.5.2 Data sources

This assessment has been prepared in reference to published datasets and literature, including reports recommended by the Department of Resources, in addition to site-specific geotechnical and soils data collected during investigations undertaken to inform the development of the reference design and the EIS for the Project.

Other information sources relevant to the Project used for the assessment of existing conditions for land resources included:

- Detailed solid and surface geology—Queensland DNRME (2017b)
- *Atlas of Australian Soils* (Northcote et al., 1960–68)
- *Queensland Agricultural Land Audit* (Department of Agriculture Fisheries and Forestry (DAFF), 2013b, updated in 2017) (The Audit), along within the https://qldspatial.information.qld.gov.au/AGTrendsSpatial/
- Contour mapping (DNRME, 2017b)
- Australian Soil Resource Information System (Commonwealth Scientific and Industrial Research Organisation (CSIRO), 2014)
- Australian Government, Department of Defence Unexploded Ordnance (UXO) mapping (Australian Government, 2017)
- Department of Resources (formerly DNRME) Soil Conservation Plans (under the *Soil Conservation Act 1986* (Qld))
- Department of Environment and Science (DES) Contaminated Land Register (CLR) and Environmental Management Register (EMR)
- Soil mapping provided by the Department of Transport and Main Roads (DTMR) (as at December 2020) for the Toowoomba Second Range Project.

An assessment of land resources was undertaken to identify and assess the risks arising from the disturbance and excavation of land and the disposal of soil and spoil. The assessment was conducted in accordance with statutory requirements and guidelines identified for Queensland, as shown in Table 9.2, which included the *Guidelines for Soil Survey along Linear Features* (Soil Science Australia, 2015). The guideline recommends a 1:250,000 scale of soil mapping for characterisation of soil for an EIS.

9.5.3 Geotechnical and soil investigations

Geotechnical, soils and hydrogeological investigations were undertaken within the Project disturbance footprint with the objective of obtaining data to inform development of the reference design and the EIS.

The geotechnical and soils components of these investigations included the following:

- 13 seismic refraction surveys
- 14 geotechnical boreholes (which included 5 boreholes for soil investigations)
- 12 groundwater monitoring wells.

Fourteen holes were drilled, using a solid stem auger, prior to being progressed by rotary drilling (water flush) technique. Soils that rose on the auger were described, and the auger was lifted to the surface at intervals to allow nominally undisturbed tube sampling to be undertaken. Soil descriptions were made based on the drill cuttings and recovered samples.

Noting that geotechnical data was also available from geological assessment of a proposed 7.1 km long Toowoomba Range railway tunnel located to the north of the current G2H tunnel alignment by the former Queensland Department of Mines in 1984 and 1986 (Denaro, 1985 and 1986). The tunnel alignment commenced around 200 m south of the current western tunnel portal and intersects the Toowoomba Range Tunnel at Ch 4,700 km (approximate) and ends approximately 400m north of the current eastern tunnel portal location. The borehole stratigraphy presented in Denaro (1986) is generally comparable to the stratigraphy encountered by the geotechnical investigations. Geotechnical data was also sourced from the Toowoomba Second Range Project including the exploratory tunnel at Mount Kynoch, which overlies the Toowoomba Range Tunnel.

Borehole logs, core photography and certificates of analysis for geotechnical testing are included in Appendix W: Geotechnical.

Restrictions, such as limited access to sections of operational rail corridor, meant that not all of the targeted locations could be investigated. The subsequent detailed geotechnical investigations have recently been completed, including within the rail corridor and along the tunnel alignment. In total, 158 geotechnical boreholes (BH), with depths ranging between 10 m to 256.6 m below ground level (bgl), including 41 core holes along the tunnel alignment. The findings of this assessment are not currently available and have not been incorporated into the design, and, as such, are not considered in the EIS for this Project.

The development of a reference design is an interactive process and the Project disturbance footprint remains subject to confirmation through the detailed design process. Consequently, it was considered to be of limited value to undertake soil sampling and analysis at a more intensive scale during the reference design stage for a Project of this nature. ARTC is currently undertaking soils investigations along the Queensland section of the Inland Rail alignment, including within the Project disturbance footprint. Soil investigations are being undertaken in accordance with the Guidelines for surveying soil and land resources (CSIRO/McKenzie et al., 2008), the *Australian Soil and Land Survey Field Handbook* (National Committee on Soil and Terrain, 2009) and the *Guidelines for Soil Survey along Linear Features* (Soil Science Australia, 2015) as recommended by the Department of Resources.

ARTC has committed to undertaking detailed soil investigations at a suitable sampling intensity to inform the development of detail design. Subject to land access, the soil sampling will be of an intensity to enable mapping at a 1:10,000 scale (refer Section 9.8).

The methodology for the detailed soil investigation will be developed in consultation with the Department of Resources and will be in accordance with the Guidelines for surveying soil and land resources (McKenzie et al., 2008), the Australian soil and land survey field handbook (National Committee on Soil and Terrain, 2009) and the Guidelines for Soil Survey along Linear Features. Soil investigations will be conducted under the supervision of a suitably qualified soil practitioner. These additional investigations commenced in the first quarter of 2021.

Additional soil data, from the current soil sampling assessment along the Inland Rail alignment from Gowrie to Kagaru, will be incorporated into the Final EIS and will enable identification of potential/actual problematic soils including: acid sulfate, reactive, erosive, dispersive, saline, acidic, alkaline and liberation of contaminants.

9.5.4 Laboratory testing

The geotechnical and soil investigation undertaken as input to the concept design included drilling of 14 boreholes. Five boreholes were targeted for soil investigations with depths between 0 m and 1.10 m bgl at varying intervals, dependent on subsurface conditions (refer Figure 9.1). A total of 27 soil samples were analysed from the 5 soil sampling locations by a National Association of Testing Authorities (NATA) accredited laboratory, with a summary of results provided in Section 9.6.4.1 and Table 9.4.

Soil samples were analysed for the following analytes:

- Sodium adsorption ratio—a measure of the amount of sodium (Na) relative to calcium (Ca) and magnesium (Mg) in the water extract from saturated soil paste
- Cation exchange capacity—the total capacity of a soil to hold exchangeable cations. It influences the soil's ability to hold onto essential nutrients and provides a buffer against soil acidification
- Exchangeable sodium percentage—measure of sodium ions relative to other cations.

The geotechnical analysis included a suite of analytes, including the following, which are relevant to the land resources chapter:

- Moisture content (21 tests performed)
- Particle size distribution (grading) (21 tests performed)
- Atterberg limits and linear shrinkage (20 tests performed)
- Shrink/swell properties (1 test performed)
- Emerson class number (16 tests performed)
- Aggressivity testing suites (9 tests performed).

Laboratory results from soil analysis are included in Appendix X: EMR Search Certificates and Laboratory Certificates.

The soil physical and chemical analysis has been used to complement published soil data from previous soil assessments of relevance to the land resources study area, and to verify soil mapping at a 1:100,000 scale. The geotechnical and soil investigation will also inform the assessment of existing conditions for problematic soils (saline, dispersive and reactive) and erosion risks. The scope for sampling and analysis included soil properties and not potential contaminants.

Additional soil data, from the current soil sampling assessment along the Inland Rail alignment from Gowrie to Kagaru, will be incorporated into the Final EIS and will enable identification of potential/actual problematic soils including: acid sulfate, reactive, erosive, dispersive, saline, acidic, alkaline and liberation of contaminants.

9.5.5 Contamination assessment

The land resources assessment included a Tier 1 Preliminary Site Investigation (contaminated land assessment), in accordance with ASC NEPM. The Tier 1 Preliminary Site Investigation was undertaken to identify the potential for contamination within the land resources study area. This type of assessment is used to assess the potential for the land to pose a risk to ecological and human health receptors due to potentially contaminating activities. The assessment of contaminated lands was conducted by a suitably qualified person in accordance with the relevant DES requirements.

In addition to the Tier 1 Preliminary Site Investigation, additional studies were undertaken, which included limited soil sampling at EMR-listed properties within the Project disturbance footprint, road–rail interface locations, key public roads that require realignment for the Project, and along the existing rail corridor. Limited sediment sampling was also undertaken at key watercourse crossings.

9.5.6 Impact assessment methodology

Impact assessment was undertaken using both quantitative compliance assessment and qualitative risk assessment methodologies, assessing potential risks within the land resources study area throughout the life of the Project. Detailed descriptions of these methods are presented in Chapter 4: Assessment Methodology.

A quantitative compliance assessment was undertaken for:

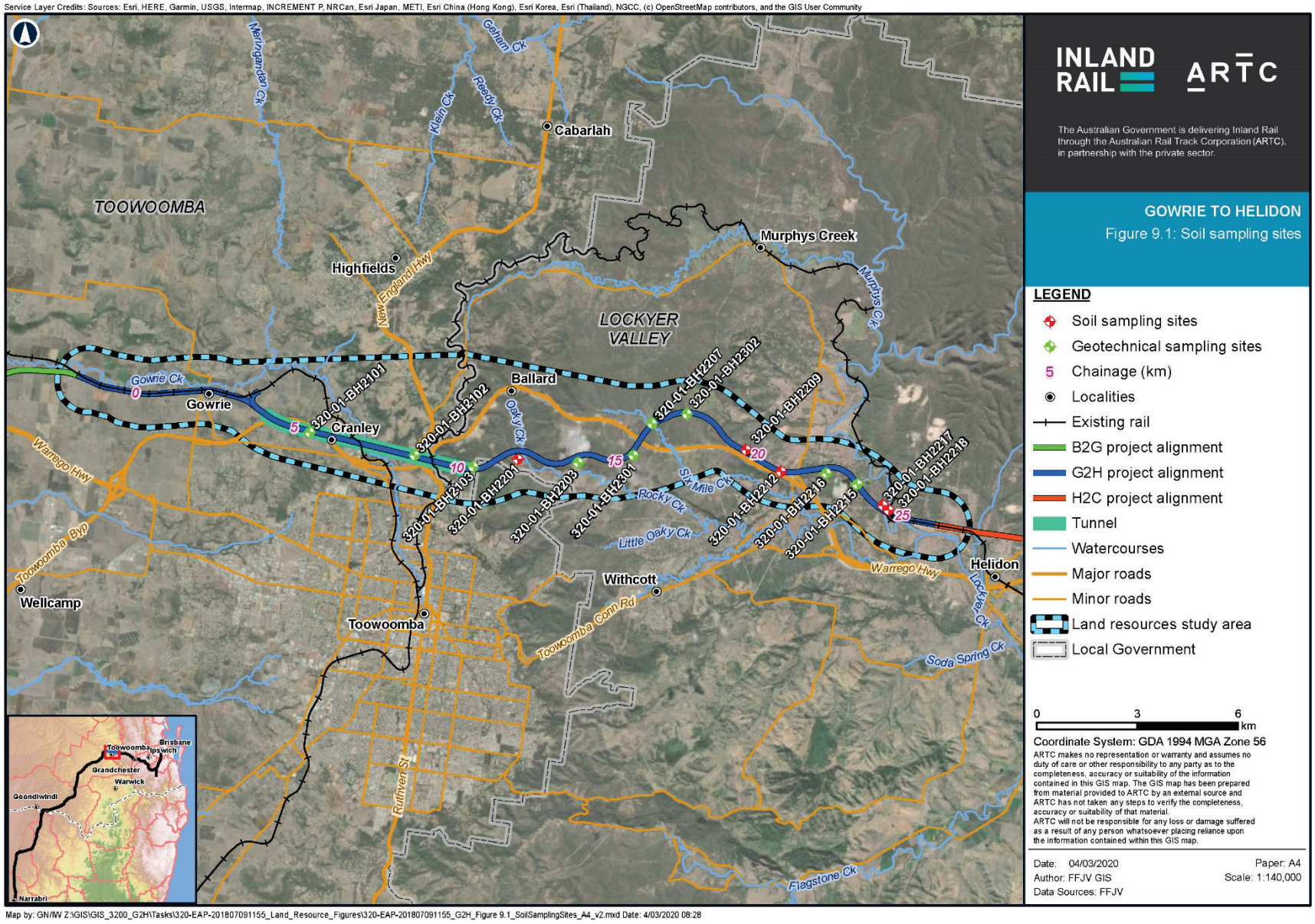
- Soil properties, including:
  - Erosion and sedimentation
  - Problematic soils (i.e. saline, dispersive and reactive soils).

A qualitative risk assessment was undertaken for:

- Contaminated land, including:
  - Existing contaminated land
  - Construction risks (e.g. hydrocarbon spills)
  - Operational risks (e.g. hydrocarbon spills, use of pesticides/herbicides)
- Agricultural land, which also included approved soil conservation plans
- Geology, topography and geomorphology
- ASS/acid rock
- NOA
- UXO.

Following an assessment of potential risks for the Project, appropriate mitigation measures were developed.

FIGURE 9.1: SOIL SAMPLING SITES



9.6 Description of existing land resources

9.6.1 Geological and topographical setting

9.6.1.1 Topographical setting

The land resources study area traverses through the rugged topography of the Toowoomba Range (Dudgeon, 1982). The shape of the terrain, hills and valleys, are a result of Mount Kynoch and Mount Lofty, as well as the alignment straddling escarpments of the Great Dividing Range (GDR). The landscape, from Gowrie, approaching the GDR, consists of a gentle incline before reaching peak elevation of approximately 644.5 m Australian Height Datum (AHD), as the alignment traverses under (depth of ~200 m) the New England Highway and Toowoomba Bypass at Mount Kynoch.

A steep drop in elevation occurs after the alignment passes the GDR to the east with periodic and isolated peaks featuring with reducing elevation as the alignment reaches Helidon. The lowest elevation for the rail alignment occurs at Lockyer Creek, 1 km to the west of Helidon, with an approximate elevation of 148.5 m AHD (refer Figure 9.4).

The topography intersected by the tunnel ranges from approximately 450 m AHD, at the eastern tunnel portal, to approximately 643 m AHD, where the tunnel intersects the New England and Warrego Highways (refer Figure 9.2).

The landforms east of the Great Dividing Range (GDR) to Helidon have been developed as a result of landslides associated with escarpment regression and hillside instability. Several types of slides can be recognised on the hillsides and foothills of the Toowoomba Range eastern slopes (Great Escarpment) and near the proposed eastern portal of the Toowoomba Range Tunnel. These landslides can be classified in the following types:

- Soil creep—comprises small, gradual movements in the upper soil layers, which commonly give rise to a series of small steps or terraces down a slope. It is more likely to occur on thicker sections of soil and can be recognised from a distance by the uneven surface of the slope.
- Debris Slides and flows—occur predominantly on the sleep to very steep slopes and scarps of the basalt and sedimentary terrain. Within the sedimentary rocks, they are generally shallow, with narrow movements of soil, colluvial debris and some weathered rock, which move rapidly down slope, often as a viscous fluid, leaving behind an arcuate head scarp. Along the basaltic terrain, debris slides also occur on the very steep slopes and scarps, but there they are generally smaller, narrower and more isolated.
- Rotational slides or slumps—mainly on the steep slopes on the sedimentary terrain. The slides move relatively quickly and exhibit a sizeable semi-circular head scarp, with some indication of a back-tilted upper section, and a disrupted toe section which in some could be classed as an earth flow. Their occurrence is found in a variety of topographical situations on the steep slopes and are the most difficult to predict. Smaller rotational slides also occur on moderate to sleep slopes adjacent to gullies on the basalt terrain.
- Complex multiple rotational slides—broad, relatively deep, slow-moving slides that occur on the outer edges of benches on both the sedimentary and basalt terrain. They may also occur above any drop-off on tongues or aprons of colluvium.
- Localised rockfalls—small rockfalls may occur on the cliffs of sandstone that outcrop on many of the scarp lines of the sedimentary terrain. They mainly occur following debris sliding on the slopes immediately below, which removes support and de-stabilises the blocks on the cliff. These movements are caused, in many cases, by localised root jacking and/or toppling.

Slope stability mapping by Willmott classifies a range of stability zones between the GDR and Wards Hill, with the Project overlying or in close proximity to the majority of these zones. A cross section of the Toowoomba Range showing the different stability zones and slides is provided in Figure 9.3.

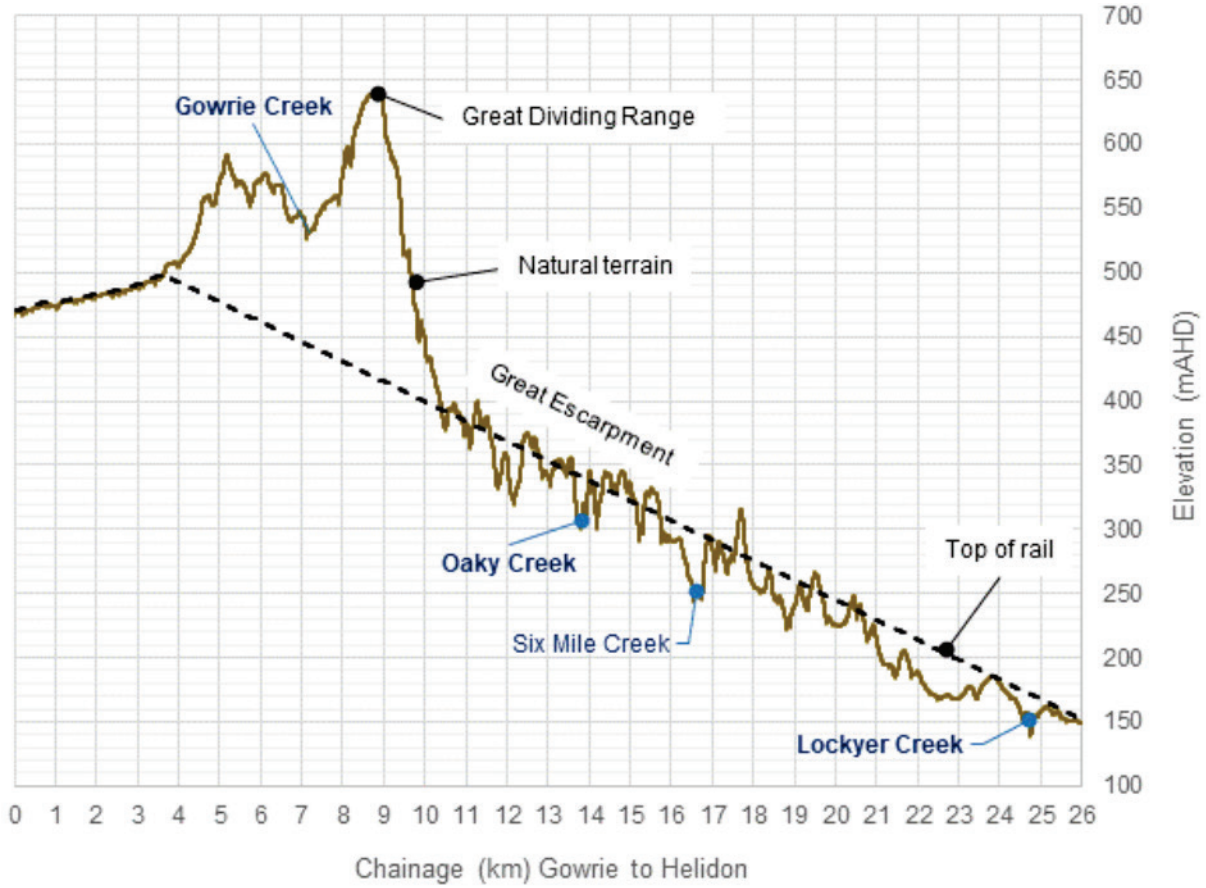


FIGURE 9.2: TOPOGRAPHICAL CROSS-SECTION OF THE PROJECT

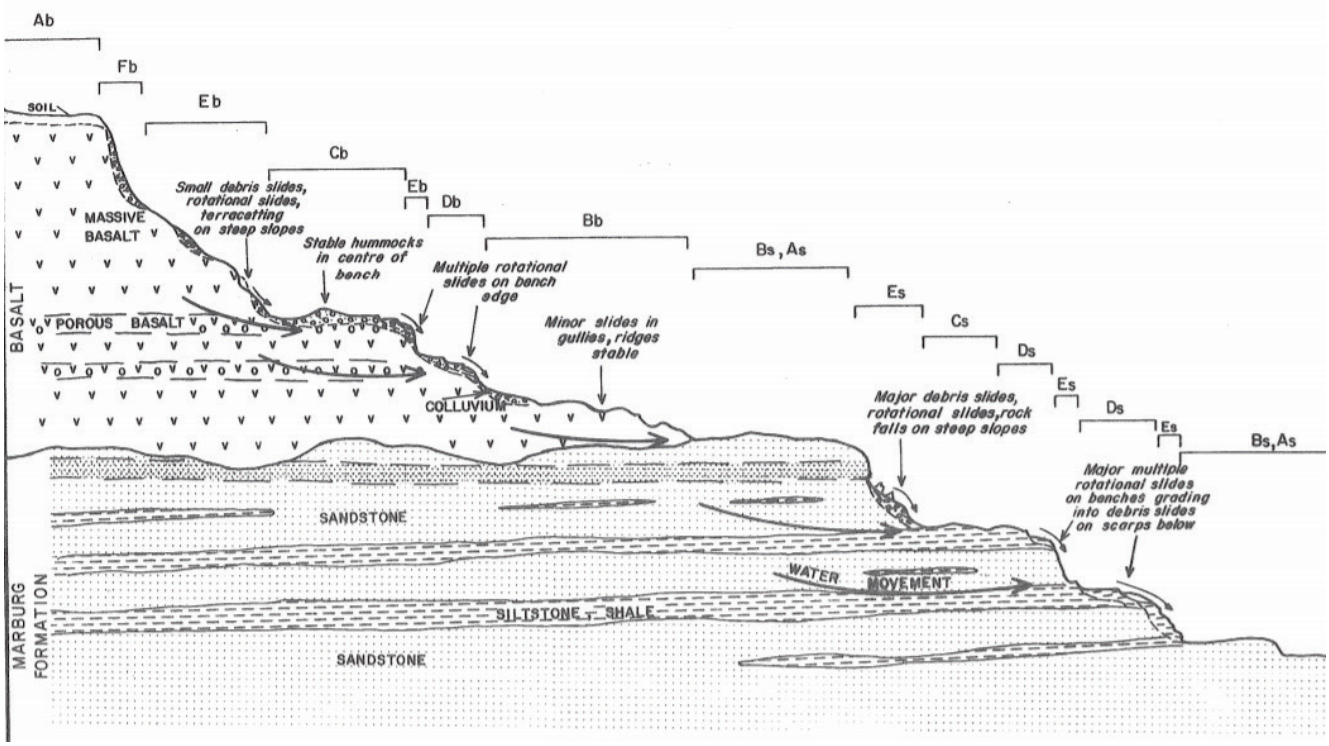
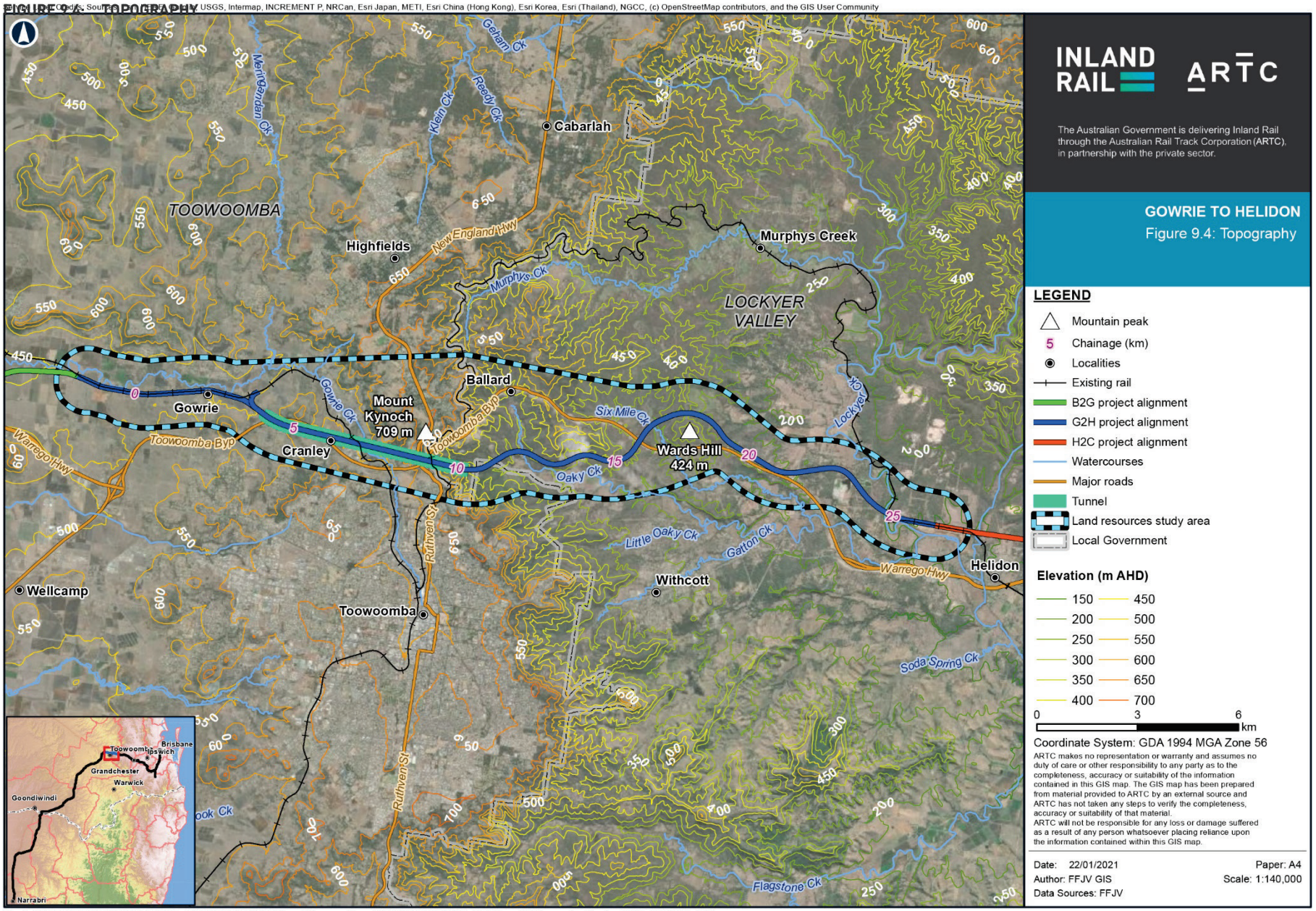


FIGURE 9.3: DIAGRAMMATIC CROSS SECTION OF TYPICAL RIDGE ON THE EASTERN SIDE OF THE TOOWOOMBA RANGE, SHOWING THE LOCATIONS OF SLIDES AND STABILITY ZONES (WILLMOTT, 1983)

FIGURE 9.4: TOPOGRAPHY



Map by: GN/IW/TM Z:\GIS\GIS_3200_G2H\Tasks\320-EAP-201807091155_Land_Resource_Figures\320-EAP-201807091155_G2H_Figure 9.3_Topography_A4_v4.mxd Date: 22/01/2021 11:28

9.6.1.2 Geological setting

Eight geological layers were found to underlie the land resources study area between Gowrie and Helidon in accordance with the 1:100,000 scale detailed surface geology map of Queensland (DNRME, 2017b), which is illustrated in Figure 9.5, with further detail in Table 9.3.

Surface geology indicates Main Range Volcanics at the western tunnel portal and Main Range Volcanics and TQCB-SEQ at the eastern tunnel portal. A cross section schematic distribution of the main geological units between Toowoomba and Helidon is presented in Figure 9.6.

TABLE 9.3: GEOLOGICAL UNITS

Geological unit	Location	Age	Description
Main Range Volcanics	▸ Gowrie to Mount Kynoch ▸ Two small patches west of Withcott Quarry and at the intersection of Morleys and Hanleys Roads	Eocene to Miocene	A layer of olivine basalt dominated by basalt rock
TD/R-QLD>Main Range Volcanics	▸ Small patch at Blue Mountain Heights	Tertiary	A layer of developing red soil with minor ferricrete-forming soil profile dominated by ferricrete rock
TD-QLD	▸ Small patch south of Mount Kynoch	Tertiary	A layer of duricrusted paleosols at the top of deep weathering profiles, consisting of ferricrete and silcrete on old land surfaces. The dominant rock type in this layer is ferricrete
TQCB-SEQ	▸ Minor areas north of Harlaxton Quarry and south of Ballard	Late Tertiary to Quaternary	A layer of soil, clay, cobbles and boulders of colluvium derived from basalt. The dominant rock type in the layer is colluvium
Koukandowie formation	▸ Majority of the approximate 7 km landscape between Ballard and west of Lockyer	Early Jurassic to Middle Jurassic	A layer of lithofeldspathic labile and sub-labile to quartzose sandstone, siltstone, shale, minor coal and ferruginous oolite marker dominated by Arenite-Mudrock
QA-QLD	▸ Minority of the approximate 7 km stretch between Ballard and west Lockyer ▸ Small patch at Helidon	Quaternary	A layer of clay, silt, sand and gravel on a flood-plain dominated by alluvium
Gatton Sandstone	▸ Majority of Lockyer to Helidon	Early Jurassic	A layer of lithic labile and feldspathic labile sandstone dominated by Arenite rock
QR-QLD	▸ Minority of Lockyer to Helidon	Quaternary	A layer of clay, silt, sand, gravel and soil of colluvial and residual deposits dominated by colluvium rock

Source: DNRME, 2017b

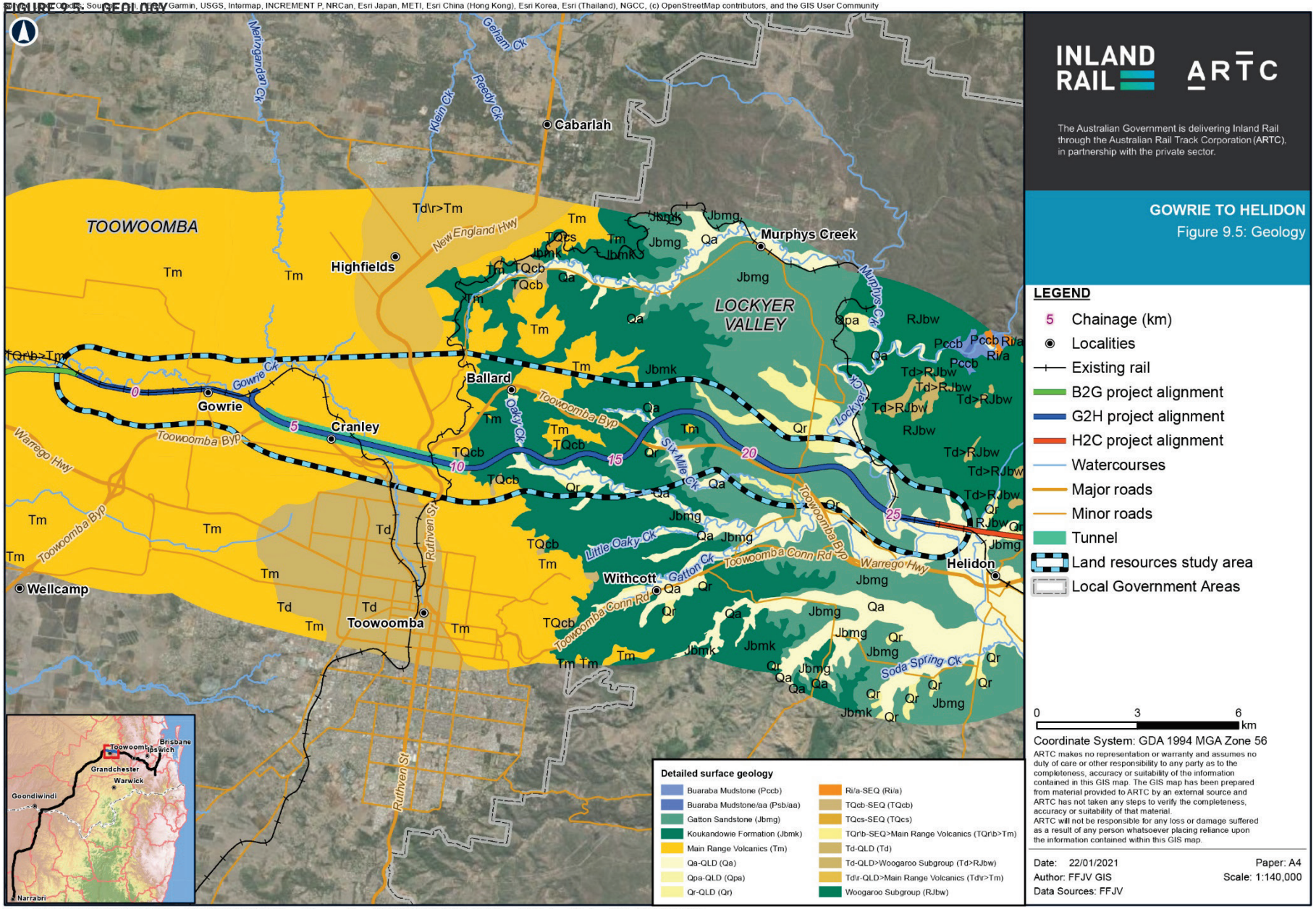
The Toowoomba Range Tunnel will intersect a variety of materials that will be determined through further detailed geotechnical investigation and detailed design. Preliminary assessment has identified the tunnel will encounter one or more of the following geological units:

- Tertiary age Main Range Volcanics consisting mainly of basalt
- Undifferentiated Tertiary Sediments
- In-filled Paleo Valley sediments consisting of basalts, tuffs, sandstones to mudstones
- Jurassic sandstones and siltstones of the Koukandowie Formation
- Basaltic colluvium mainly on the eastern side of the range
- Quaternary alluvium.

The suitability and extent of the material intercepted by the Toowoomba Range Tunnel cannot be estimated with accuracy due to the variable nature of basalt flows deposited on the undulating Jurassic sedimentary paleo topography. Typically, the spoil characteristics are monitored as the excavation progresses with samples taken directly from a temporary stockpile. All rock that is won through excavation has been assumed to be reused for the Project and is not defined as a waste.

It has also been assumed that this material will be stockpiled at the western tunnel portal, with the tunnel being constructed from west to east.

FIGURE 9.5: GEOLOGY



INLAND RAIL

ARTC

The Australian Government is delivering Inland Rail through the Australian Rail Track Corporation (ARTC), in partnership with the private sector.

GOWRIE TO HELIDON

Figure 9.5: Geology

LEGEND

- 5 Chainage (km)
- Localities
- Existing rail
- B2G project alignment
- G2H project alignment
- H2C project alignment
- Watercourses
- Major roads
- Minor roads
- Tunnel
- Land resources study area
- Local Government Areas

0 3 6 km

Coordinate System: GDA 1994 MGA Zone 56

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Author: FFJV GIS Scale: 1:140,000

Data Sources: FFJV

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The topographical and surface geology investigation indicated the escarpments of the GDR are a result of residual erosion from denudation of the Main Range Volcanics and underlying Mesozoic strata (Willey, 2003).

The geological units within the land resources study area reflect the history and topography of the area, which was a centre for volcanic activity during the Tertiary era with large quantities of basaltic lava covering a landscape of flat-lying Mesozoic sedimentary rock (Thompson & Beckmann, 1959).

Alluvial and colluvial deposits were the dominant soil type present within the geological layers and can be attributed to recent Tertiary and Quaternary denudation (Willey, 2003). The main form of alluvium deposit in the region was likely caused by prairie soils, black earths and grey clays, which have developed on finer-grained sediment. Alluvium deposits in the region will potentially result in deposits of sand, silt or silty clay at the base of hillslopes and along floodplains (Department of Science, Information Technology, Innovation and the Arts (DSITIA), 2012).

Arenites are another rock present within the geological layers of the region. Arenites are identified as texturally clean matrix free or matrix poor sandstone that allow cement precipitates to form in what were originally empty intergranular pores (University of Puerto Rico-Mayaguez (UPRM) Geology Department, 2012). A study of the soil distribution and physical properties indicated that parent material strongly influences soil development in the area.

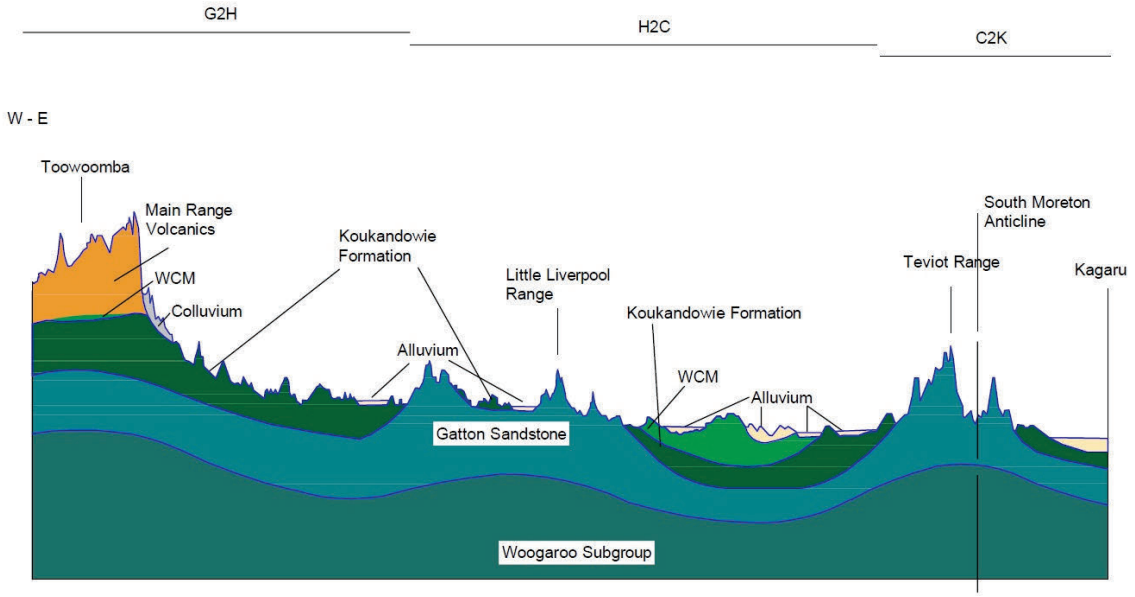


Figure notes: G2H Gowrie to Helidon H2C Helidon to Calvert C2K Calvert to Kagaru WCM = Walloon Coal Measures

FIGURE 9.6: SCHEMATIC DISTRIBUTION OF THE MAIN GEOLOGICAL UNITS BETWEEN TOOWOOMBA AND KAGARU

The tunnel is anticipated to intersect the Main Range Volcanics, specifically an informal sub-unit, referred to as Toowoomba Volcanics, approximately up to 330 m thick along the escarpment at Toowoomba (Willey, 2012). Below the Main Range Volcanics, in the western portion of the land resources study area, is the undifferentiated Tertiary sediments which, while not a recognised stratigraphic unit, is the highly to extremely weathered older sedimentary rocks of the Walloon Coal Measures or Koukandowie Formation commonly represented by claystone, where the plasticity of the resultant clays is significantly higher and includes the presence of tuff or tuffaceous layers.

Faults and fold axes are mapped to affect the Clarence Moreton Basin rock both to the east and west of the tunnel. Historically, earthquakes in the region have had magnitudes less than 5 (modified Richter scale), but potential for ongoing reactivation of tectonic movements along the pre-existing structures exists. The reactivation of movement along the pre-existing structures are supported by small-scale strike slip faulting within the Tertiary age basalts, north-east of Toowoomba. It is not known whether similar faults are present in the Toowoomba Volcanics, which the tunnel will traverse, or if the faulting has been restricted to the main regional fault systems, located to the east of the alignment.

As part of the geotechnical investigations, 11 geotechnical boreholes were drilled along the Project alignment within, and in close proximity to, the Harlaxton key resource area (KRA) south of Ballard, between approximate Project Chainage (Ch) 10.0 km to Ch 10.3 km, with the proposed eastern tunnel portal located at approximate Ch 10.3 km. The boreholes ranged in depth from 15 m to 120 m bgl.

Basalt was intercepted at three borehole locations above the proposed tunnel at Ch 9.6 km, Ch 9.8 km, Ch 10.0 km, at depths between 2.26 m and 33.88 m bgl. Basalt was also present as colluvial material at three boreholes in the eastern tunnel portal area, generally in a gully or on a southwest trending spur outside the resource processing area.

Further details on the geology of the land resources study area, including the geology encountered by the tunnel as well as tectonic movement, is provided in Appendix W: Geotechnical.

9.6.1.3 Naturally occurring asbestos

A review of available geological mapping (DNRME, 2017b) indicated no NOA within the land resources study area. The geological history of the rock types that were encountered during the geotechnical investigations, together with the available petrographic analysis results, also indicated the rock anticipated along the Project alignment is unlikely to contain NOA, which only occurs in metamorphosed basic and ultrabasic igneous rock.

9.6.2 Surface water

The land resources study area travels through two catchment areas—the Lockyer Creek Catchment and the Condamine River Basin.

The Condamine River Basin is located on the western side of the GDR, with the main rivers of the catchment the Condamine–Balonne, and the Maranoa (DES, 2019d). The Project alignment lies within the Condamine River Basin from Ch -1.76 km to approximately Ch 8.8 km, with the alignment entering the proposed tunnel at Ch 4.1 km and exiting into the Lockyer Creek catchment. The catchment covers an area of approximately 25,440 square kilometres (km^2), with the main watercourse, the Condamine River, surrounded by several sub-catchments, including Oakey Creek, which the Project alignment intersects (DES, 2019d). The Condamine River Basin typically has a consistent rainfall across the region with the exception of the edges of the catchment associated with the GDR.

The Lockyer Creek catchment is located west of Brisbane and east of Toowoomba, within the local government areas of Lockyer Valley, Somerset, Ipswich and Toowoomba. The Project alignment lies within the Lockyer Creek catchment from approximately Ch 8.8 km to Ch 26.3 km. The catchment covers an area of approximately 3,000 km^2 with the main Lockyer Creek surrounded by several sub-catchments, including Gatton Creek and Upper Lockyer Creek, which intersect the Project alignment. The Lockyer Creek catchment experiences high rainfall in the south and parts of the north. The rest of the catchment has moderate to low rainfall; however, due to the steep slopes in the upper reaches of the catchment, many streams can experience high flows despite the relatively low rainfall (DES, 2015).

An assessment of surface water quality identified increased debris; altered water quality and hydrology; increased salinity; erosion and sedimentation; as well as introduction of contaminants as potential impacts, as a result of Project activities. An assessment of the flooding regime identified potential impacts such as changes to peak water levels, flow velocities and duration of inundation times within the land resources study area.

Further information regarding surface water is included in Chapter 13: Surface Water and Hydrology as well as Appendix L: Surface Water. Hydrology and flooding information is provided in Appendix M: Hydrology and Flooding.

9.6.3 Groundwater

The water table is typically a subdued version of topography, with the depth to groundwater increasing beneath topographic highs (for example the GDR), and shallower groundwater in lower lying reaches (such as close to surface water drainage lines such as Lockyer Creek and Gowrie Creek). This is particularly evident in the Main Range Volcanics and Gatton Sandstone.

The water table occurs in the alluvial/colluvial sediments, or outcropping Main Range Volcanics, across much of the land resources study area, which is west of and within the GDR. The Koukandowie Formation, east of the GDR, and the Gatton Sandstone, in the eastern portion of the land resources study area, form the upper (water table) aquifer in these areas.

A summary of groundwater level relevant to the Project, which consists of the Department of Resources groundwater database bores, with results and 2018 data available for eight monitoring bores installed along the alignment as part of the ongoing geotechnical investigation, found groundwater elevation to be between 140.32 and 660.25 m AHD. The majority of the bores are for domestic use and water supply, with authorisations under the relevant water plans generally not required for these purposes. Irrigation is the primary groundwater entitlement licence for the key aquifers near the Project (refer Appendix N: Groundwater Technical Report).

The potentiometric surface indicates that lower groundwater elevations correspond to alluvial sediments, suggesting these act as regional discharge areas for the underlying and flanking Clarence-Moreton Basin sedimentary sequence (e.g. Gatton Sandstone in the land resources study area). Groundwater levels will also reduce in areas where groundwater discharges to surface water. Recharge areas along the alignment include the GDR, the highest point along the alignment, as well as drought-reduced surface water levels, which act as recharge to alluvial aquifers.

Groundwater within the land resources study area was assessed for salinity and found to be between 1,001 and 10,000 milligrams per litre (mg/L), which is considered typically brackish, from sedimentary bedrock formations.

The main potential long-term impacts identified beyond the construction phase for groundwater include:

- Changes to groundwater levels and flow associated with loading from embankments and ongoing dewatering/draining of the Toowoomba Range Tunnel and deep cuts
- Management of discharge from dewatering/drainage of the tunnel and deep cuts.

Further information regarding existing groundwater conditions is included in Chapter 14: Groundwater and Appendix N: Groundwater Technical Report.

9.6.4 Soil

9.6.4.1 Soil descriptions

Australian soil classification

Australian Soil Classification 1:100,000 (or better) mapping (CSIRO, 2014) indicated a high variability in soil type along the land resources study area, including vertosols, dermosols, ferrosols, hydrosols, chromosols, rudosols and sodosols (refer Figure 9.7).

The area between the tablelands of Gowrie and the gently sloping hills of Mt Kynoch, approaching the GDR, are dominated by three soil types. Vertosols are the major soil within this landscape, while regular patches of scattered dermosols exist throughout the land resources study area. Ferrosols intercept a large proportion of the land resources study area between Cranley and the GDR (Thompson & Beckmann, 1959).

A soil survey of the Easting Darling Downs Westbrook-Highfields-Oakey area (1:100,000 or better) also found the area between Gowrie and Mount Kynoch to be dominated by black vertosols, along hillslopes of flat to gently undulating plains, which are alkaline, and very shallow brown or black dermosols along scarps as well as hillslopes (Department of Natural Resources and Mines, 2001a).

Vertosols are a cracking clay soil with a clay field texture and a crusty surface horizon at a depth of 0.03 m or less in thickness (Isbell & National Committee on Soil and Terrain (NCST), 2016). Vertosols are often found in imperfectly drained sites with annual rainfall up to 1,150 mm and in well-drained sites with annual rainfall up to 900 mm. As the soil has a strong water-holding capacity and high chemical fertility, the soil is considered to have a high agricultural potential. A majority of vertosols have neutral or alkaline soil pH and generally have high cation exchange capacity, between 30 and 80 milliequivalents per 100 grams of soil (meq/100 g) (Gray & Murphy, 2002).

Dermosols exist within the land resources study area between Gowrie and Mount Kynoch; underlying areas of natural, dense and clustered vegetation. They are a red, brown, yellow, grey or black soil and have loam to clay textures with a well-structured B2 horizon containing low levels of free iron. The soils are normally found in areas of imperfectly drained sites with annual rainfall between 550 mm and 1,350 mm and in well-drained sites with annual rainfall between 450 mm and 1,200 mm. Dermosols generally have a high agricultural potential given their good structure, moderate-to-high chemical fertility and high water-holding capacity (Gray & Murphy, 2002).

Areas of ferrosol within the land resources study area are concentrated in the hills around Mount Kynoch and Blue Mountain Heights. Ferrosols are a soil with a B2 horizon high in free iron oxide (>5%) and lack strong contrast between the A and B horizon. The well-structured soil is intermediate or mafic in composition and found in well-drained sites with rainfall between 700 mm and 1,450 mm. Ferrosols have a high agricultural potential due to good soil structure, moderate-to-high chemical fertility as well as water holding capacity; however, if ferrosols are exposed to excessive amounts of rainfall structural decline, acidification and nutrient leaching is likely to occur (Gray & Murphy, 2002; Isbell & NCST, 2016).

The land resources study area beyond the GDR escarpment features two main soil types, chromosols and sodosols, with rare patches of hydrosols, vertosols and rudosols scattered throughout. Chromosols exist along the plateauing peaks between the GDR and Wards Hill, underlying relatively dense vegetation.

Chromosols are defined as strong textural contrast soils that are neither strongly acidic nor sodic in the upper B horizon. In imperfectly drained sites, chromosols can be found in areas of annual rainfall between 250 mm and 900 mm, while in well-drained sites, annual rainfall between 350 mm and 1,400 mm is necessary for chromosols to be present. Chromosols have a moderate agricultural potential, chemical fertility and water-holding capacity, although chromosols can be susceptible to soil acidification and structure decline (Gray & Murphy, 2002).

Reducing in elevation from Wards Hill towards Helidon, sodosols become the dominant soil type. Sodosols are predominately found in poorly drained sites with annual rainfall between 50 mm and 1,100 mm and are defined by a clear or abrupt textural B horizon, with a major part of the upper 0.2 m of the B horizon being sodic and not strongly acidic (pH > 5.5) (Isbell & NCST, 2016). The high sodicity of the soil makes it highly erodible, with poor structure and low permeability, and is often associated with saline soils. As such, sodosols have very low agricultural potential (Gray & Murphy, 2002).

An area, approximately 0.11 km^2, of hydrosols exists 1 km south of Lockyer, in close proximity to the banks of Lockyer Creek. Hydrosols are identified as a range of seasonally or permanently wet or waterlogged soils (typically gley soils) with a perched water table caused predominantly by slow permeability through horizons or layers within a soil profile (Isbell & NCST, 2016). Hydrosols tend to occur in areas of low-lying depressions and on valley floors (Agriculture Victoria, 2017).

Small patches of vertosols, west of Postmans Ridge and west of Helidon Spa, and rudosols, south of Lockyer and north-west of Helidon, feature along the low hilled landscape of the land resources study area. Rudosols are defined by their negligible pedologic organisation and can potentially be highly saline. They are usually young soils, as formation has had little time to pedologically modify parent rocks or sediments. Rudosols have good infiltration capacity and low water-holding capacity (Isbell & NCST, 2016).

Laboratory results from soil samples collected during investigations for the Project have been compared to the Australian Soil Classification mapping to provide localised validation of the 1:100,000 mapping. The comparison against Australian Soil Classification mapping revealed all samples were taken from areas mapped as sodosols. Soil sample results indicated the soil to have a slightly acidic to strongly alkaline soil pH and a high exchangeable sodium percentage, which are generally characteristic of sodosols.

A summary of the available soil chemistry for the land resources study area is provided in Table 9.4.

TABLE 9.4: SOIL CHEMISTRY INVESTIGATION RESULTS

Soil parameter	Range
pH	5.8 to 9
Sodium adsorption ratio	2.58 to 39.8
Electrical conductivity (µS/cm)	14 to 615
Exchangeable calcium (meq/100g)	<0.2 to 6.9
Exchangeable magnesium (meq/100g)	0.7 to 6.9
Exchangeable sodium (meq/100g)	0.6 to 3.6
Exchangeable sodium per cent (%)	17.1 to 45.2
Cation exchange capacity (meq/100g)	1.3 to 16.5

Table notes:
µS/cm = microsiemens per centimetre
meq/100g = milliequivalents per 100 grams of soil

Table 9.5 summarises laboratory analysis results from 27 samples, analysed as part of the geotechnical suite relevant to the Project—between 0.5 m and 3.95 m bgl. The location of the soil sampling sites are illustrated in Figure 9.1.

The results indicate samples were dispersive soils, such as sodosols, in accordance with Australian Soil Classification mapping, and had Emerson class ranges between 1 (very high dispersion potential) to 3 (variable/moderately). Soil samples collected from areas mapped as chromosols and vertosols were categorised generally as high-plasticity clays (CH) in accordance with the Unified Soil Classification System, while sodosols were generally categorised as low-plasticity clays (CL).

Shrink-swell properties were evident in a soil sample collected from an area mapped as vertosols, with 320-01-BH2201 between 2.0 m and 2.18 m bgl producing an index percentage of 4.2 per cent. The laboratory analysis indicated the soil is moderate–highly reactive. Soil pH was also analysed as part of the geotechnical suite, and ranged from 5.2 (acidic) to 9.8 (very strongly alkaline), with all soil samples collected from areas mapped as sodosols. Appendix W: Geotechnical provides further details of the geotechnical analysis.

It should be noted, variations between investigation results and mapping are potentially attributed to scale of mapping; the natural heterogeneity of soil; soil chemistry changing across a landscape due to various factors (e.g. climate, land use) and sampling only capturing a specific point along the land resources study area.

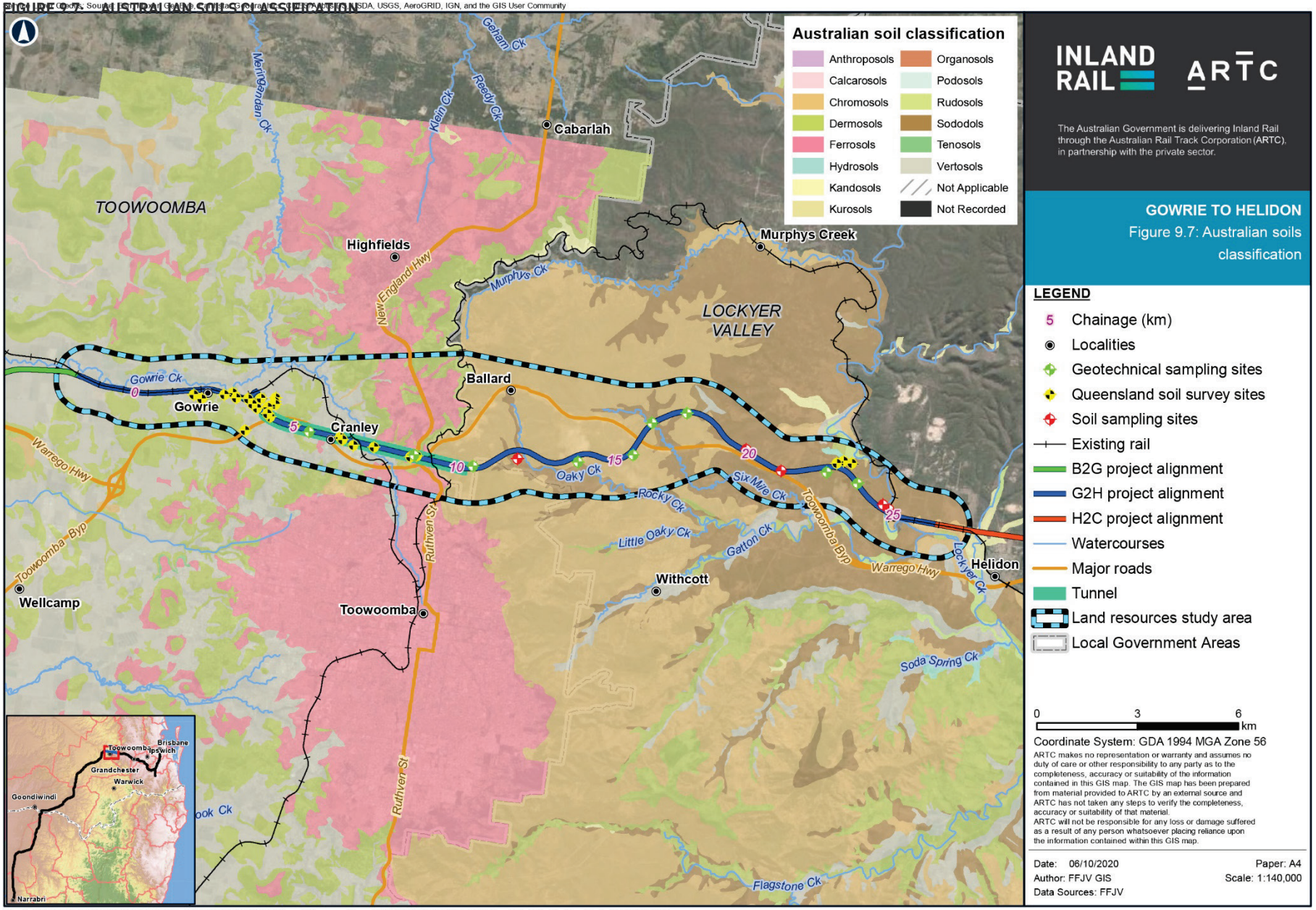
TABLE 9.5: SUMMARY OF GEOTECHNICAL ANALYSIS RELEVANT TO LAND RESOURCES

Sample ID	Depth (m bgl)	Australian Soil Classification (1:100,000)	Unified Soil Classification System	Soil description	Moisture content (%)	Shrink-Swell index (%)	Soluble sulfate (mg/kg)	Chloride (mg/kg)	pH	Emerson class number
320-01-BH2103	0.50–0.95	Chromosols	CHa	Clay with sand	21	-	-	-	-	-
	3.50–3.95	-	CH	Clay trace sand, trace gravel	26.6	-	-	-	-	-
320-01-BH2201	2.00–2.18	Sodosols	CH	Clay	22.9	4.2	-	-	-	2
	3.50–3.95	-	CH	Sandy Clay	13.3	-	-	-	-	3
320-01-BH2203	2.00–2.45	Sodosols	CL		11.6	-	-	-	-	-
	2.00–2.45	-	-	Sandy Clay	-	-	-	220	8	-
	3.50–3.95	-	-	-	-	-	20	-	-	3
320-01-BH2207	2.00–2.45	Sodosols	CL	Sandy Clay	12.3	-	-	-	-	-
	3.50–3.95		CL	Sandy Clay	12	-	-	310	9	2
320-01-BH2209	2.00–2.45	Sodosols	CL	Sandy Clay	16.3	-	20	-	-	3
320-01-BH2212	2.00–2.45	Sodosols	CL	Sandy Clay	8	-	-	<10	6.4	5
	3.50–3.95		CH	Sandy Clay	17.3	-	10	-	-	-
320-01-BH2215	0.50–0.95	Sodosols		Clayey sand with	4.2	-	-	-	-	1
	2.00–2.45	-	CL	Clayey sand	11.6	-	-	160	5.2	-
	3.50–3.77	-	-	-	-	-	70	-	-	-
320-01-BH2216	0.50–0.95	Sodosols	CL-CL	Clay with sand	10.6	-	-	-	-	1
	2.00–2.35	-	CL	Sandy clay	6.2	-	-	120	9.8	-
	2.80–2.92	-	-	-	-	-	40	-	-	-
320-01-BH2217	2.90–3.00	Sodosols	-	-	-	-	-	-	-	2
320-01-BH2218	2.00–2.45	Rudosols	CL	Sandy Clay	13.2	-	-	-	-	2
	3.50–3.95	-	CL	Sandy clay	11.9	-	-	-	-	1

Sample ID	Depth (m bgl)	Australian Soil Classification (1:100,000)	Unified Soil Classification System	Soil description	Moisture content (%)	Shrink-Swell index (%)	Soluble sulfate (mg/kg)	Chloride (mg/kg)	pH	Emerson class number
320-01-BH2301	2.00–2.45	Chromosols	CH	Clay trace sand	21.2	-	-	-	-	1
	3.50–3.95	-	CH	Clay with sand	18.6	-	-	-	-	1
320-01-BH2302	0.50–0.95	Chromosol	-	Sandy clay	-	-	-	-	-	-
	1.10–1.20	-	-	-	-	-	-	-	-	-
	3.01–3.12	-	-	-	-	-	-	-	-	-
	3.12–3.27	-	-	-	-	-	-	-	-	-

Table note:
mg/kg = milligrams per kilogram
Not all of the samples were tested for the same components

FIGURE 9.7: AUSTRALIAN SOIL CLASSIFICATION



Map by: GN/IW/MF Z:\GIS\GIS_3200_G2H\Tasks\320-EAP-201807091155_Land_Resource_Figures\320-EAP-201807091155_G2H_Figure 9.6_ASC_A4_v5.mxd Date: 6/10/2020 10:17

DTMR soil group mapping

Soil mapping provided by the Department of Transport and Main Roads (DTMR) (as at December 2020) for the Toowoomba Second Range Project was also reviewed as part of the soil classification for the proposed rail alignment. DTMR soil mapping identified uniform cracking clays/non-cracking clays and uniform loams/clay loams dominate the landscape west of the GDR. East of the GDR, beyond the escarpment, sandy and loamy gradational soils, as well as texture contrast dispersive soils, were identified.

DTMR soil types correlate with Australian Soil Classification mapping, which identified vertosols, dermosols and ferrosols west of the GDR, while chromosols and sodosols dominate the landscape east of the GDR.

Queensland soil survey sites

A further validation of the Australia Soil Classification mapping for the Project disturbance footprint, as shown on Figure 9.6, was undertaken in reference to previous soil survey data that is held in the Queensland Government's Soil and Land Information (SALI) database (QLD Government, 2020). In total, historical data obtained from 27 soil survey sites, established for soil mapping and research activity, were used to validate the Australia Soil Classification mapping for the Project disturbance footprint. Some soil survey sites adjacent to the Project disturbance footprint were also included but within the land resources study area. Locations of the historical survey sites are shown on Figure 9.7.

This assessment was also undertaken to verify the applicability of potential soil limitations, as outlined in relevant land management manuals (refer Table 9.7), to soils that can be encountered within the land resources study area.

A summary of the soil classifications and key findings and observations for the historical soil survey data is presented in Table 9.6.

TABLE 9.6: SUMMARY OF HISTORICAL SOIL SURVEY DATA OBTAINED FROM THE SALI DATABASE

Area	Historical survey sites within Project disturbance footprint	Australian soil classifications	Soil findings and observations
Gowrie	17		▸ Periodic cracking ▸ Self-mulching ▸ Surface crusting ▸ Hardsetting
Cranley	7	Vertosols Ferrosol	▸ Periodic cracking ▸ Self-mulching ▸ Both firm and soft surface conditions
Lockyer	3*	Unidentified	▸ Hardsetting ▸ Unconsolidated material ▸ Alluvial soil ▸ Loose surface conditions

Table notes:
* Locations outside the Project disturbance footprint but considered due to proximity to alignment.

Source: SALI database (Queensland Government, 2020b)

The soil types identified within the Project disturbance footprint from the referenced historical soil survey data have a good correlation with the Australian Soil Classification mapping; however, the historical soil survey data could not provide an Australian soil classification to the three soil samples from the Lockyer region, adjacent to Lockyer Creek.

The historical soil survey data obtained from the SALI database identified that soils within the Project disturbance footprint, particularly between Gowrie and west of the GDR, are dominated by self-mulching, hardsetting, cracking soils. Areas of firm and soft surface ferrosols were also identified near the Toowoomba Waste Facility, at Mount Kynoch.

Self-mulching clays have a uniform heavy clay texture from the surface to deep into the soil profile. The surface soil, when dry, is self-mulching, being composed of easily disturbed small aggregates resulting from extensive swelling and shrinking from wetting and drying (Agriculture Victoria, 2017).

Land Management Manuals

In addition to ASRIS Australian Soil Classification mapping (CSIRO, 2014), soil mapping from the following land management manuals, at a scale of 1:250,000 or better, have been assessed to understand the potential limitations of the soil types identified within the Project disturbance footprint:

- *Central Darling Downs Land Management Manual* 1:250,000 (Harris et al.,1999)
- *Moreton Region Land Management Manual* 1:250,000 (Harms & Noble, 1996).

Descriptions of soils that occur within the Project disturbance footprint have been obtained from each of the above-mentioned publications and are amalgamated and summarised in Table 9.7.

The general descriptions of soils within the Project disturbance footprint correlate closely with the soil types identified from Australian Soil Classification mapping (refer Figure 9.7), DTMR soil group mapping, data from the geotechnical and soil investigation, as well as with observations from historical soil surveys (refer Table 9.6). It should be noted that Australian Soil Classification mapping (1:100,000) for the Project disturbance footprint was mapped at a better scale in comparison to the land management manual data.

TABLE 9.7: SUMMARY OF SOIL DESCRIPTIONS AND LIMITATIONS FROM LAND MANAGEMENT MANUALS FOR SOILS WITHIN THE PROJECT DISTURBANCE FOOTPRINT

Land resources area[1]	Approximate Project chainage	Broad landform description	General soil description	Potential soil limitations
Older alluvial plains (2a)	Ch 0.0 km to Ch 4.5 km	Broad level plains of basaltic alluvium	Black self-mulching cracking clays	▸ Periodic cracking ▸ Calcareous nodules ▸ Very slow to slow permeability ▸ Crabhole gilgai ▸ Crusting to hardsetting surface soil
Basaltic Uplands (7a)	Ch 0.0 km to Ch 8.0 km	Undulating rises and rolling low hills	Black to dark brown clays or brown clay loams	▸ Linear gilgai ▸ Potentially nodular and/or soft carbonate throughout soil profile ▸ Susceptible to sheet, rill and gully erosion
Basaltic Uplands (7d)	Ch 9.0 km	Gently undulating plains to undulating rises on the Toowoomba Plateau	Friable red clays	▸ Firm and soft surface soils ▸ Moderate to high permeability
Basaltic Uplands (7c)	Ch 11.0 km	Steep hills and mountains	Black to dark brown clays or brown clay loams	▸ Linear gilgai ▸ Potentially nodular and/or soft carbonate throughout soil profile ▸ Susceptible to sheet, rill and gully erosion
Basaltic Uplands	Ch 10.0 km	Steep mountains, hills and rises	Dark, yellowish, red brown shallow soils overlying weathering rock, typically sandy clay loam	▸ Hardsetting surface ▸ Very high erosion risk ▸ Mildly alkaline subsoils
Marburg Forest (7a)	Ch 11.0 km to Ch 26.0 km	Undulating hills and rises, steep hills and mountains	Dark, yellowish, red brown shallow soils overlying weathering rock, typically sandy clay loam	▸ Hardsetting surface ▸ Very high erosion risk (sheet and wind) ▸ Mildly alkaline subsoils ▸ Saline seepages may occur in lower slopes

Land resources area[1]	Approximate Project chainage	Broad landform description	General soil description	Potential soil limitations
Mixed Alluvial Plains (1c)	Ch 20.0 km	Alluvial plains	Brown sandy loams overlying red, well-structured clay subsoils	▸ Loose to hardsetting surface ▸ Strongly acidic surface soils (5.2 to 6.5 pH) ▸ Highly erodible on slopes (sheet and wind)
Fine Textured Alluvial Plains (1b)	Ch 26.0 km	Broad alluvial plains	Self-mulching cracking black earths and grey brown clays, deep prairie soils, alluvial soils	▸ Prone to seasonal flooding ▸ Moderate risk of erosion (rill, sheet and streambank) ▸ May cause waterlogging

Table note:
1. Land resources area and number relate to those used in the corresponding land resource area mapping for each Land Management Manual

Source: Harris et. al. (1999), Harms & Noble (1996)

9.6.4.2 Soil erosion

Soil erodibility is the susceptibility of a soil to erosion by wind and rain, and is interdependent on topography, land use, rainfall intensity and vegetation cover (Zund and Finn, 2015). Erodibility is a function of the mechanical, chemical and physical characteristics of a soil, and describes the susceptibility of the soil particles to become detached and transported. A soil's overall inherent soil erodibility is a combination of the stability of the surface soil and the dispersibility of the subsoil. Land degradation in Queensland, which is largely attributed to soil erosion, contributes to lost agricultural income, infrastructure damage and reduced environmental services. On the Darling Downs, unprotected cultivated land in upland areas may lose up to 60 tonnes of soil per hectare in one year depending on the slope (Queensland Government, 2016d).

Shaw (1979) mapped soil units of the Lockyer Catchment based on geology and landforms as the basic determinant. Shaw (1979) identified soil units within the Lockyer Catchment to generally be erosion prone. Soils on Gatton Sandstone in the region were identified as prone to accelerated erosion, evident in the form of extremely badly gullied patches, which occur particularly where clay subsoils are exposed. Soil units on Ma Ma Creek and Heifer Creek Sandstone displayed evidence of landslips, as well as sheet, rill and extreme gully erosion also prevalent in the landscape.

The *Lockyer Catchment Action Plan 2015–2018* (Lockyer Valley Regional Council, 2016) notes that the banks of the of upper Lockyer Creek are relatively stable and are unlikely to experience major erosion and bank retreat.

The soil variability in the region is typically a reflection of the dominant presence of erosional and transportation surfaces on the slopes as opposed to the depositional environments of valleys and floodplains. The transitional zones of these soil environments can increase the complexity and variability of the soil types (Lobb, 2011).

The types of erosion that have potential to occur within the land resources study area, due to the existing landforms and underlying geology, include:

- Sheet: occurs on hill slopes when thin layer of topsoil is removed over a hillside
- Gully: occurs when a strong concentrated runoff of water detaches and moves soil particles, creating gullies
- Rill: occurs on hill slopes when surface runoff forms small channels as it concentrates down a slope
- Aeolian: occurs predominantly in arid grazing lands of inland Queensland when winds blow over light textured soils
- Tunnel: removal of subsoil when water travels through a soil crack or hole where a root decay has caused the soil to disperse.

The most highly erodible soils are those that are most easily detached and transported by erosive forces, such as fine particle soils with sodic and dispersive properties (Houghton and Charman, 1986). Additionally, surface soils with high sand and/or low organic matter content have low cohesion between soils particles, making them susceptible to erosion. Sodosols, as encountered throughout the land resources study area (refer Figure 9.6) and have a particularly dispersive sodic clay subsoil. This is as a result of sodium ions that are attached to the clay particles. When exposed to water, the size of the sodium ions increases, forcing the individual clay platelets to separate and causing the soil to disperse (Zund, 2017).

The dispersive nature and presence of sodosols within the land resources study area is supported by the exchangeable sodium percentage (ESP) of soil samples analysed as part of the geotechnical and soil investigation. All soil samples analysed detected ESP above 6 per cent, which is generally regarded as high (Queensland Government, 2016c).

Soils that are not dispersive, such as vertosols, can still be susceptible to erosion. Unlike soils that disperse, the aggregates of vertosols retain some of their natural structure after they have been removed by runoff (Zund, 2017). These relatively large particles are readily deposited when runoff velocity is reduced, such as in a contour bank or waterway, and they generally only travel a limited distance.

As indicated in Table 9.6 and Table 9.7, some soils within the land resources study area have hardsetting surfaces that reduce the rate of infiltration during rainfall but which also resist erosion. These soils can have low rates of erosion themselves; however, they can contribute to high rates of runoff with erosive power further down the slope where the soils may be less protected (Zund, 2017).

Geotechnical investigations identified potential for erosion and weathering for all geological units encountered across the land resources study area, with more potential for risks in differential erosion/weathering of mudstone/claystone layers, sheet erosion of weaker sandstone, gullying or incisions from preferential drainage into unconsolidated materials, such as colluvium and alluvium, as well as small slumps in mudstone/claystone slopes (refer Appendix W: Geotechnical).

Dispersive soils were identified as present in the residual and alluvial soils that are derived from the underlying sedimentary rocks within the land resources study area. Available data also indicated the basalts locally contain elevated levels of secondary minerals, which are prone to rapid deterioration on exposure to atmospheric conditions and moisture.

As part of the geotechnical analysis (refer Appendix W: Geotechnical) Emerson Aggregate Tests were undertaken, which measure the dispersive characteristics of a soil when exposed to water (AS 1289.3.8.1-2006 (Standards Australia, 2006b)). The investigations identified an Emerson class range between 1 (very high dispersion potential) and 5 (typically not dispersive), with more than 93 per cent of results categorised as highly to moderately/variably dispersive (1–3). Generally, the more dispersive soils were identified north of Withcott and west of Helidon, adjacent to the Toowoomba Bypass.

Erosion risks within the land resources study area, based on landform type and geology, are summarised in Table 9.8.

TABLE 9.8: EROSION RISK

Landform type	Geology	Erosion type	Erosion risk
Erosional surfaces with weak pedality: refers to the distinctness, size, shape and condition of natural, or artificially produced soil aggregates (peds). The degree of structural distinctness is referred to as grade of pedality. The soil contains peds that are barely observable and has less than one third of their soil material in the form of peds.	Quaternary alluvium (coarser materials) and colluvium	Sheet Rill	Moderate
Floodplains and river terraces subject to fairly regular overbank flooding, sandy banks and poorly defined levees and cobble plains. Supports grassy eucalypt woodlands, tussock grasslands and soft spinifex grasslands.	Quaternary alluvium	Sheet Aeolian	Moderate
Erosional surfaces: ridges and plateaux remnants on basalt with steep stony slopes, restricted lower slopes, stony interfluves.	Toowoomba Range, Mount Kynoch, Mount Lofty, GDR	Sheet Rill Tunnel Aeolian	Moderate

Source: Damara Pty Ltd, 2013 and Biggs et al., 2010

Erosion is a potential risk for the Project, as the rail infrastructure, as well as other associated infrastructure, will require a stable base to operate safely. Adequate material assessment in the pre-construction phase should ensure that only durable materials are used in areas where breakdown could affect the final earthworks.

An estimate of the long-term soil loss from both sheet and rill erosion can be calculated using the Revised Universal Soil Loss Equation (RUSLE) (IECA, 2008). ARTC has committed to undertaking detailed soil investigations at a suitable sampling intensity, to inform the development of the detail design. Additional soil data will be used to refine the assessment of soil erosion potential within the Project footprint using the RUSLE with the objective of ensuring that the design of erosion control measures (temporary and permanent) are reflective of site-specific soil conditions.

Soil conservation plans

Soil conservation plans are regulated under the *Soil Conservation Act 1986* (Qld), which intends to facilitate the implementation of soil erosion control measures by landholders in Queensland through the use of property plans and project area plans. Soil conservation plans may cover the whole of a property or just part of it (DSITI, 2015). Soil conservation plans aim to ensure soil capability is not exceeded and no adverse impacts occur onsite as well as offsite, such as polluting water resources and degrading aquatic habitats.

Approved property and project area plans are binding on all present and future owners and the Crown. Both approved property plans and project area plans can be modified to accommodate circumstances that differ from those applying at the time of approval. Plans may be amended, or their approval may be revoked by the Department of Resources, which involves a similar process to that used in the initial approval process.

The Project has assessed existing Soil Conservation Plans (property and project) through a review of approved plans within the land resources study area (provided by the Department of Resources), and no approved soil conservation plans (property or project) exist in the land resources study area.

9.6.4.3 Soil acidity

Queensland has more than 500,000 hectares (ha) of agricultural and pastoral land that has acidified or is at risk of acidification. Soils most at risk are lighter-textured sands and loams with low organic matter levels, and the naturally acidic red clay loam soils. Soils least at risk are the neutral to alkaline clay soils (e.g. brigalow soils and the black clay soils of the Darling Downs and Central Queensland) (Soil Quality, 2020).

Many soils are naturally acidic, but agricultural practices have contributed to the increasing acidification of many neutral to slightly acid soils (Agriculture Victoria, 2017). These practices include:

- Use of some ammonium fertilisers, particularly ammonium sulfate
- The production of legumes that fix nitrogen, if that nitrogen is leached, rather than being taken up by plants
- The removal of nutrients in the form of produce.

An assessment of surface soil pH, using the Australian Soil Resource Information System (ASRIS) pH mapping (CSIRO, 2014), revealed soil pH ranging between 4.8 and 8.0 underlaying the land resources study area. West of the GDR, basic to neutral soils underlay the land resources study area, with soil of 6.5 to 8.0 pH following the surface beneath the existing rail track from Gowrie to Cranley. Beyond Cranley, approaching the GDR, more acidic soils with pH of 5.5 to 6.0 dominate the landscape, with scattered patches of 4.8 to 5.5 pH soils within the area.

Descending from the GDR peak towards Wards Hill, the landscape consists of more neutral 6.5 to 7.0 pH soils, with streams of acidic 4.8 to 6.0 pH soils evident. The Wards Hill to Helidon section is dominated by 4.8 to 5.5 pH acidic soils with a small outline of 5.5 to 6.0 pH soil bordering the land resources study area from the north and south.

The laboratory analysis of the surface soil samples (<1.10 m bgl) in Table 9.4 indicated soil pH ranged between 5.8 (moderately acidic) to 9 (strongly alkaline), with all samples collected from areas mapped as sodosols. The geotechnical analysis of deeper soils (0.5 m to 3.95 m bgl) indicated soil pH ranged from 5.2 (acidic) to 9.8 (very strongly alkaline). The soil pH from the investigation generally correlates with the identified soil types from Australian Soil Classification mapping and ASRIS soil pH mapping.

9.6.4.4 Acid sulfate soils and acid rock

ASS are predominantly a coastal and near-coastal soil, sediment or other materials containing iron sulfides, which generate acidic conditions when exposed to oxygen. ASS, in general, have a field pH of 4 or less and can be visually identified through the presence of jarosite or iron oxide in the soil horizon. They are often associated with low-lying areas below 5 m AHD, such as alluvial plains where groundwater is generally close to the surface and materials are in reducing condition along coastal regions. ASS in non-coastal areas are commonly known as inland ASS (DSITIA, 2014).

Inland ASS can also be found in parts of central Queensland at elevations above 5 m AHD if an anoxic, aqueous environment, which consists of sulfate-reducing bacteria and available sulfate ions, exist (DSITIA, 2014, EPHC and NRMMC, 2011). Inland ASS are generally associated with poorly drained inland basins with stagnant water bodies in distinctly seasonal, arid climates but are not widely distributed in Queensland; however, inland ASS are known to occur in landscapes with high levels of salt, where significant concentrations of sulfate reside.

An assessment of ASS using the National Acid Sulfate Soils Atlas (CSIRO, 2014) indicated 'No Known Occurrence' along the land resources study area from Gowrie to Wards Hill and 'Low Probability' of ASS occurrence throughout the remainder of the land resources study area (refer Figure 9.8).

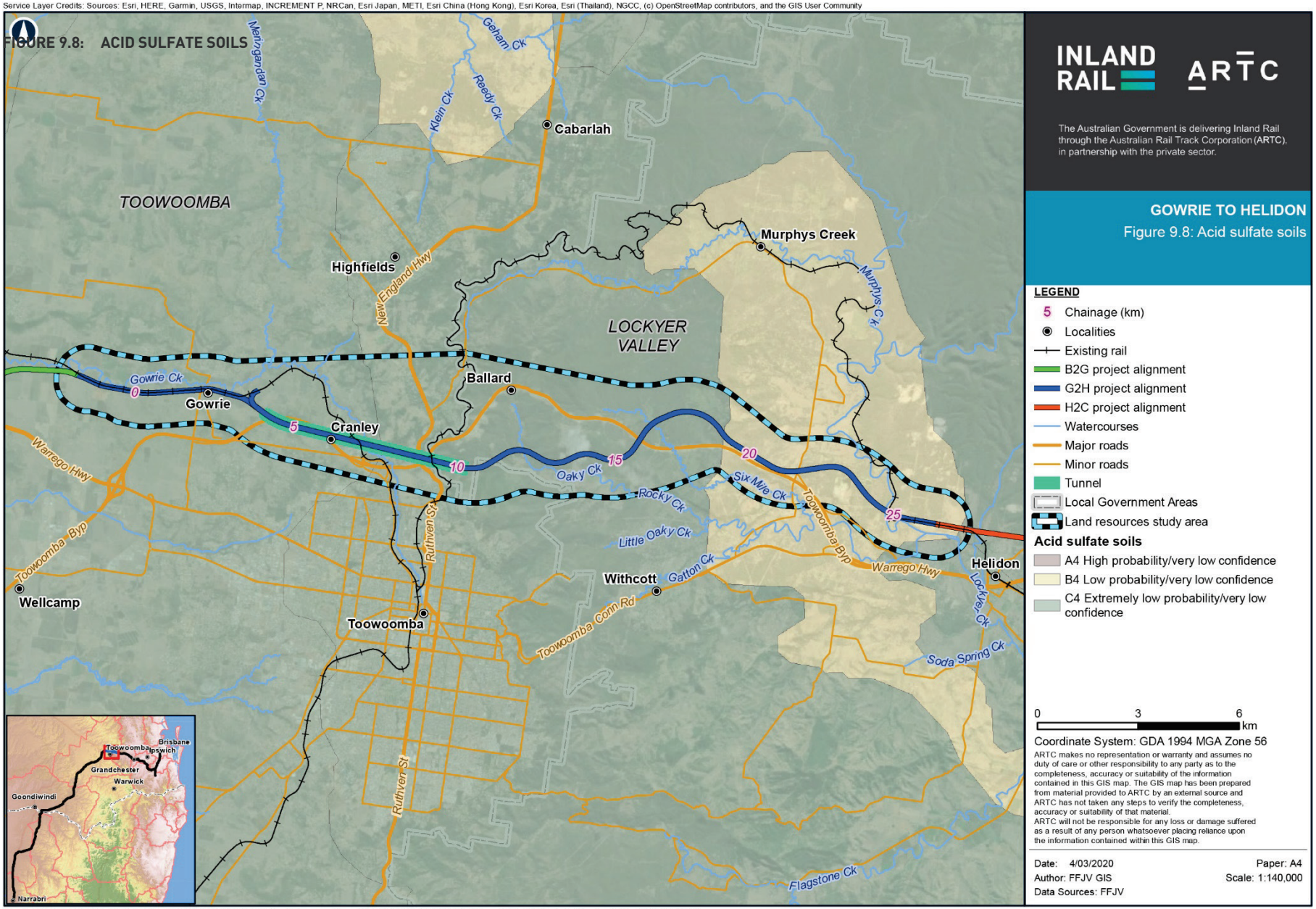
The geotechnical and soil investigation, which included site walkovers and geotechnical sampling, did not identify the presence/visual evidence of ASS or acid rock within the land resources study area.

Given the topographical position of the Project, the underlying geology and landscape features (e.g. limited presence of water bodies), it is considered that there is a low-to-no risk of inland ASS or potential inland ASS presence within the land resources study area. This is further supported by the ASS mapping for the area and field investigations along the Project alignment.

An unexpected finds protocol/procedure will still be implemented (refer Section 9.8) to manage potential risks in the unlikely event ASS is encountered during the construction phase of the Project.

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FIGURE 9.8: ACID SULFATE SOILS



INLAND RAIL ARTC

The Australian Government is delivering Inland Rail through the Australian Rail Track Corporation (ARTC), in partnership with the private sector.

GOWRIE TO HELIDON

Figure 9.8: Acid sulfate soils

LEGEND

- 5 Chainage (km)
- Localities
- Existing rail
- B2G project alignment
- G2H project alignment
- H2C project alignment
- Watercourses
- Major roads
- Minor roads
- Tunnel
- Local Government Areas
- Land resources study area

Acid sulfate soils

- A4 High probability/very low confidence
- B4 Low probability/very low confidence
- C4 Extremely low probability/very low confidence

0 3 6 km

Coordinate System: GDA 1994 MGA Zone 56

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Date: 4/03/2020 Paper: A4

Author: FFJV GIS Scale: 1:140,000

Data Sources: FFJV

Map by: GN/IW Z:\GIS\GIS_3200_G2H\Tasks\320-EAP-201807091155_Land_Resource_Figures\320-EAP-201807091155_G2H_Figure 9.7_AcidSulfateSoils_A4_v4.mxd Date: 31/03/2020 17:47

9.6.4.5 Soil texture

Soil texture provides a guide to the proportions of gravel, coarse sand, fine sand, silt and clay in the soil. Texture is important, because it affects the movement and availability of water and nutrients in the soil (Agriculture Victoria, 2017). Soil particles are grouped into five main size ranges: gravel, coarse sand, fine sand, silt and clay. A soil with a relatively even mix of particle sizes is called a loam.

A range of soil textures existed within the A horizon of the land resources study area from heavy clays (>45%) to sand (<10%), as indicated by the ASRIS textural and clay content map (CSIRO, 2014), as well as general findings from the geotechnical investigations.

Soil texture between Gowrie and the GDR featured an even mixture of heavy clay to clay loam, while beyond the GDR towards Helidon the land resources study area featured predominantly heavy clays, becoming loams of silt or sandy clay. Heavy clays within the land resources study area showed a tendency to occur in areas of dense vegetation, whereas soil of lower clay content was prominent along the low hills nearing Helidon.

Data obtained from the DTMR soil group mapping, land management manuals and historical soil surveys (SALI database) identified that the majority of the soils within the Project disturbance footprint demonstrate one, or more, characteristics of hardsetting surfaces, self-mulching, periodic cracking, alkaline subsoils and potential areas of gilgai development (refer Table 9.6 and Table 9.7).

Areas of hardsetting surfaces, cracking, self-mulching clays with gilgai development are typically associated with areas of vertosol, west of the GDR, while areas of alkaline and erosion prone soils are typically associated with areas of sodosols, east of the GDR.

Despite land management manuals identifying potential gilgai development for the soils in the region, Queensland soil survey sites as well as the geotechnical and soil investigation, did not identify gilgai development within the Project disturbance footprint. Gilgai are repeated mounds and depressions that form on shrink-swell and cracking clay soils (or vertosols) (State of Queensland, 2011). There is also no evidence of gilgai in the high-resolution aerial imagery for the Project disturbance footprint.

9.6.4.6 Soil salinity

Salinity is the amount of salt in the soil or water. The dominant salt in most saline soil is sodium chloride (NaCl), although varying amounts of calcium, magnesium and potassium chlorides and sodium sulfates can also occur. There are two main types of salinity:

- Primary—naturally occurring salinity
- Secondary—resulting from human activities.

Saline soils occur naturally in parts of coastal, south-west and northern Queensland. Salinity is generally induced by unsuitable land management practices (Queensland Government, 2018).

Salinity presents a major land degradation issue, which can impact on land salinisation, in-stream salt loads and concentrations. Salinity expresses itself in the landscape in a variety of ways (e.g. scalds). Some landscapes are more hydrologically sensitive and susceptible to salting than others. Identification of these landscapes helps to determine which management strategies will be effective in combating salinity (DERM, 2011).

A land degradation study undertaken by Shaw (1979) in the Lockyer Catchment found saline soil patches in the region can be directly related to clearing of vegetation from slopes of affected valleys, underlying geology of the region (sandstone) and excessive irrigation. The *Lockyer Catchment Action Plan 2015–2018* (Lockyer Valley Regional Council, 2016) identifies salinity as a concern in sub-catchments where groundwater is in contact with sandstone and is further exacerbated by naturally sodic soils in these areas as a result of erosion and vegetation clearing. Two salinity risk assessments have previously been undertaken in the land resources study area: the *Strategic Salinity Risk Assessment for the Condamine Catchment* (Searle et al., 2007) and the *Bio-physical options to prevent, minimise or manage salinity issued in the Lockyer Catchment* (Shaw, 2008). The Condamine catchment salinity risk assessment provides coverage of the land resources study area from Gowrie to the eastern side of the GDR escarpment near Mount Kynoch, while the Lockyer catchment salinity risk assessment provides coverage of the land resources study area from the western side of the GDR escarpment to Helidon.

The Condamine catchment salinity risk assessment identified more than 170 salinity expression sites, with most influenced by climatic conditions. The salinity risk assessment identified that a return to typical long-term weather patterns will likely increase the size and number of dryland salinity expressions in the region, resulting in an increased salt load exported from the catchment.

The Condamine catchment salinity risk assessment identified the Toowoomba area as having a moderate overall salinity risk, with a high confidence rating. The salinisation process was found to have commenced in the Toowoomba catchment; however, no impact to assets (including built infrastructure), through secondary salinity, is expected to arise within the next 100 years.

The Lockyer catchment salinity risk assessment (Shaw, 2008) built on the land degradation study undertaken by Shaw (1979), characterising and ranking 29 sites with current or predicted risk of salinity in the Lockyer Catchment. Predicted areas of salinity risk were based on emerging pressures in the region, which included rainfall increase, residential development, development on the Winwill geology, degradation of riparian vegetation and vegetation management. The study also found built infrastructure is generally unaffected by salinity in the region at present; however, 15 of the 29 sites identified with salinity risk, under emerging pressures, may cause impacts to built infrastructure without management measures. The land resources study area did not intersect any areas of current or predicted salinity risk in the Lockyer Catchment.

The *Lockyer Catchment Action Plan 2015–2018* (Lockyer Valley Regional Council, 2016) notes that there are no specific salinity issues in the Upper Lockyer Creek and Gatton Creek catchments, though salt-affected areas in the Upper Lockyer Catchment are known to occur; this includes an area 250 m downstream of the Project where the Project alignment intersects Murphys Creek Road. This area, identified as a moderate risk by the South East Queensland salinity project, extends north, to the west of Murphys Creek and then to the east-north of Rossiter Road, Lockyer to Lockyer Creek. A portion of the Withcott Seedling facility, south of the Roma Brisbane Gas Pipeline, at Postmans Ridge, has also been mapped as a low-risk area (refer Section 9.6.4.6).

Desktop salinity hazard assessment

A salinity hazard assessment was undertaken in the land resources study area to meet the requirements of Part B of the *Salinity Management Handbook* and understand the existing primary salinity within the landscape, as well as assessing the potential for secondary salinity formation as a result of Project activities (DERM, 2011).

Primary salinity is the presence of salts within a landscape where salts are stored within the geology or soils and moved by the water that flows through a catchment area. Each catchment has a different level of stored salts and how each landscape is managed will depend on the severity of salinity. Predicting areas at risk from salinity is a complex exercise, which requires both determining the inherent salinity hazard in a landscape, and the effects of past, present and future land management practices.

The desktop salinity hazard assessment was conducted adopting the assessment methodology described in *Strategic Salinity Risk Assessment for the Condamine Catchment* (Searle et al., 2007).

The assessment included a review of aerial imagery to identify potential locations of salinity expression (e.g. scalding) within the land resources study area. No scalding or salinity expression was observed.

The approach adopted for the Project to find overall salinity hazard included collecting and analysing data that relates salinity risk to biophysical hazard. Biophysical hazard is the inherent capacity of the landscape to develop salinity and is often determined through factors such as geology, soil, topography, and groundwater availability or flow. Five factors were used to relate salinity risk to biophysical hazard, which included soil salt store, basalt contact potential expression areas (PEA), catena PEA, artificial restriction PEA and confluence of streams PEA. PEAs are locations where salinity has potential to be expressed, either through natural or anthropogenic processes.

The land resources study area was broken down by the Australian Hydrologic Geospatial Fabric Catchment GIS layer (Australian Government, 2015), into smaller sub-catchments to enable a more precise analysis of the Project. Consideration was given to how Project construction activities may alter the hydrology of the land resources study area.

The *Salinity Management Handbook* (DERM, 2011) describes several models that provide an excellent conceptual basis for describing different landscapes and different forms of salinity. These models provide and aid both the prediction of where salinity may occur and the description of possible contributing factors; however, they do not provide a definitive answer to the cause of all salt outbreaks and, for conclusive proof, detailed site investigations are required.

Inherent soil salt store

Each sub-catchment through which the Project disturbance footprint traverses was overlain with Australian Soil Classification mapping (CSIRO, 2014) (verified by Land Management Manuals, data from Project geotechnical and soil investigation and with observations from historical soil surveys (refer 9.6.4.1)) to derive the dominant soil type in each sub-catchment.

Inherent salt store ratings for each soil type were adopted from the Strategic Salinity Risk Assessment for the Condamine Catchment (Searle et al., 2007) and applied to assign a low, moderate, or high soil salt store hazard rating to each soil type. This salt store categorisation is summarised in Table 9.9 and illustrated in Figure 9.9.

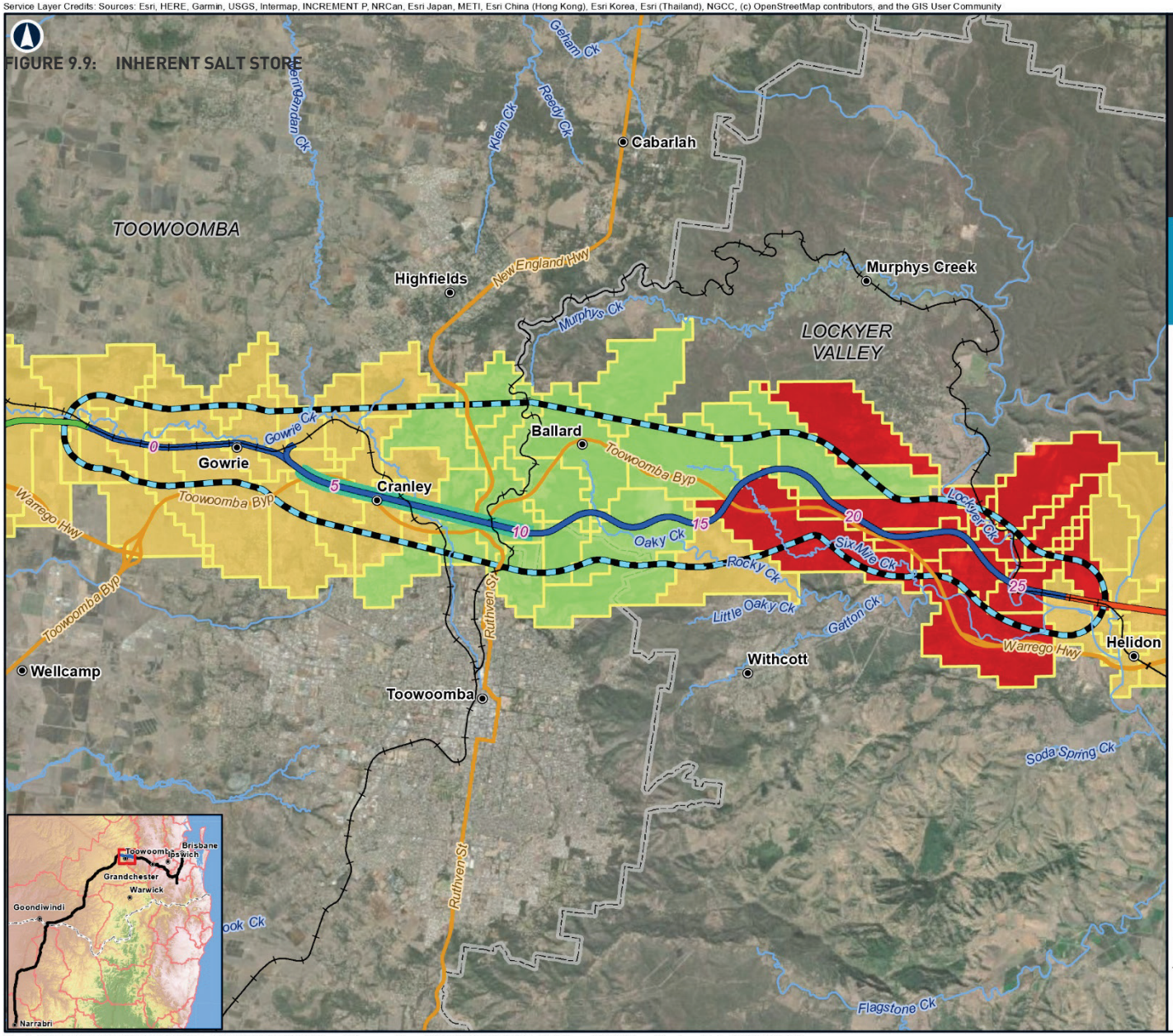
TABLE 9.9: SOIL TYPE AND SOIL SALT STORE

Soil type	Soil salt store risk category	Approximate Project chainage (Ch) of soil salt store risk along alignment
Black dermosols	Low	Ch 8.0 km–Ch 15.0 km
Black vertosol	Moderate	Ch 0.0 km–Ch 7.0 km, Ch 15.0 km, Ch 26.0 km
Grey vertosol	High	Ch 15.0 km–Ch 25.0 km
Chromosol	High	Ch 15.0 km–Ch 25.0 km

Source: Searle et al., 2007

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FIGURE 9.9: INHERENT SALT STORE



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Figure 9.9: Inherent salt store

LEGEND

- 5 Chainage (km)
- Localities
- Existing rail
- B2G project alignment
- G2H project alignment
- H2C project alignment
- Watercourses
- Major roads
- Tunnel
- Land resources study area
- Local Government Areas

Soil Salt Store by Catchment

- High (Sodosol, Rudosol)
- Moderate (Vertosol, Kurosol)
- Low (Tenosol, Ferrosol, Chromosol, Dermosol)
- Sub-catchments

0 3 6 km

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Potential expression areas: Basalt and sandstone contact

The underlying geology of the land resources study area features PEAs of basalt and sandstone contact. These PEAs result in salts being transported through underlying basalt layers towards surface soils in an area of basalt and sandstone contact (DERM, 2011). Salinity in a basalt layer forms when both recent and highly weathered layers overlay a less permeable sandstone and mudstone layer at fairly shallow depths. Seepage and the visible expression of salt occurs at the contact point between the two rock types.

The percentage of basalt and sandstone contact PEAs for each sub-catchment within the land resources study area was calculated and is illustrated in Figure 9.10, with further detail provided in Table 9.10. When analysing the risk of basalt and sandstone contact PEAs within the sub-catchments, a hazard category rating of none-to-high can be applied based on the percentage of occurrence.

Calculation of basalt and sandstone contact was based on an analysis of the 25 m digital elevation model developed for the Project. Three derivatives were used; tangential curvature, relative elevation (kernel size 90) and slope percentage. These derivatives were calculated using ArcGIS Spatial Analyst functions.

The analysis was only applied to the Main Range Volcanics, Walloon Coal Measures, Koukandowie Formation and the Gatton Sandstone landscapes, which were identified as the main geological types where salinity may be a potential issue.

The basalt and sandstone contact PEAs are predicted to occur where the following occurs (Searle et al., 2007):

- Tangential curvature is less than 0 (i.e. the downhill slope shape is concave—flow tends to slow and converge)
- Relative elevation is greater than two (i.e. there is typically a distinct break of slope)
- Slope is greater than 1 per cent and less than 10 per cent (i.e. typically mid slope positions).

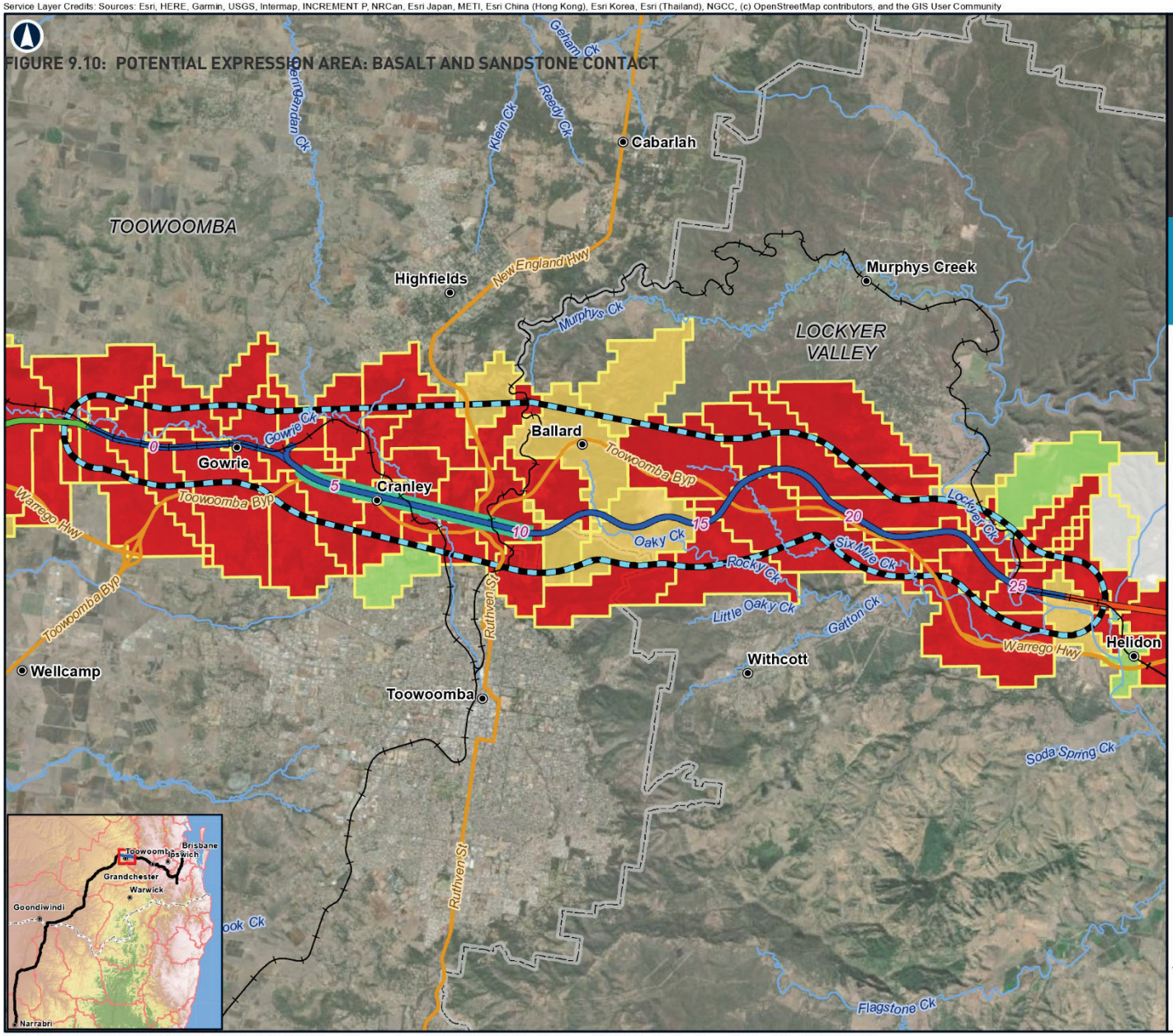
TABLE 9.10: POTENTIAL EXPRESSION AREA: BASALT AND SANDSTONE CONTACT

Percentage of each sub-catchment containing basalt and sandstone contact PEAs (%)	Hazard category	Approximate chainage of PEA along alignment
0	None	N/A
0 to 2	Low	N/A
2 to 5	Moderate	Ch 10.0 km–Ch 15.0 km, Ch 26.0 km
Greater than 5	High	Ch 0.0 km–Ch 10.0 km, Ch 15.0 km–Ch 25.0 km

Source: Searle et al., 2007

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FIGURE 9.10: POTENTIAL EXPRESSION AREA: BASALT AND SANDSTONE CONTACT



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Figure 9.10: Potential expression area: basalt and sandstone contact

LEGEND

- 5 Chainage (km)
- Localities
- Existing rail
- B2G project alignment
- G2H project alignment
- H2C project alignment
- Watercourses
- Major roads
- Tunnel
- Land resources study area
- Local Government Areas

PEA of basalt and standstone contact

- None
- High: >5
- Moderate: 2-5
- Low: 0-2
- Sub-catchments

0 3 6 km

Coordinate System: GDA 1994 MGA Zone 56

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Potential expression area of catena form of salinity

The land resources study area also features PEA areas of catena form. Catena form occurs when shallow soils located upslope overlie weathered parent material, which then extend out into flat, heavy clay alluvial areas. These alluvial areas are characterised by high sodicity due to restricted permeability, and result in the formation of salt as well as changing soil properties and water movement (DERM, 2011).

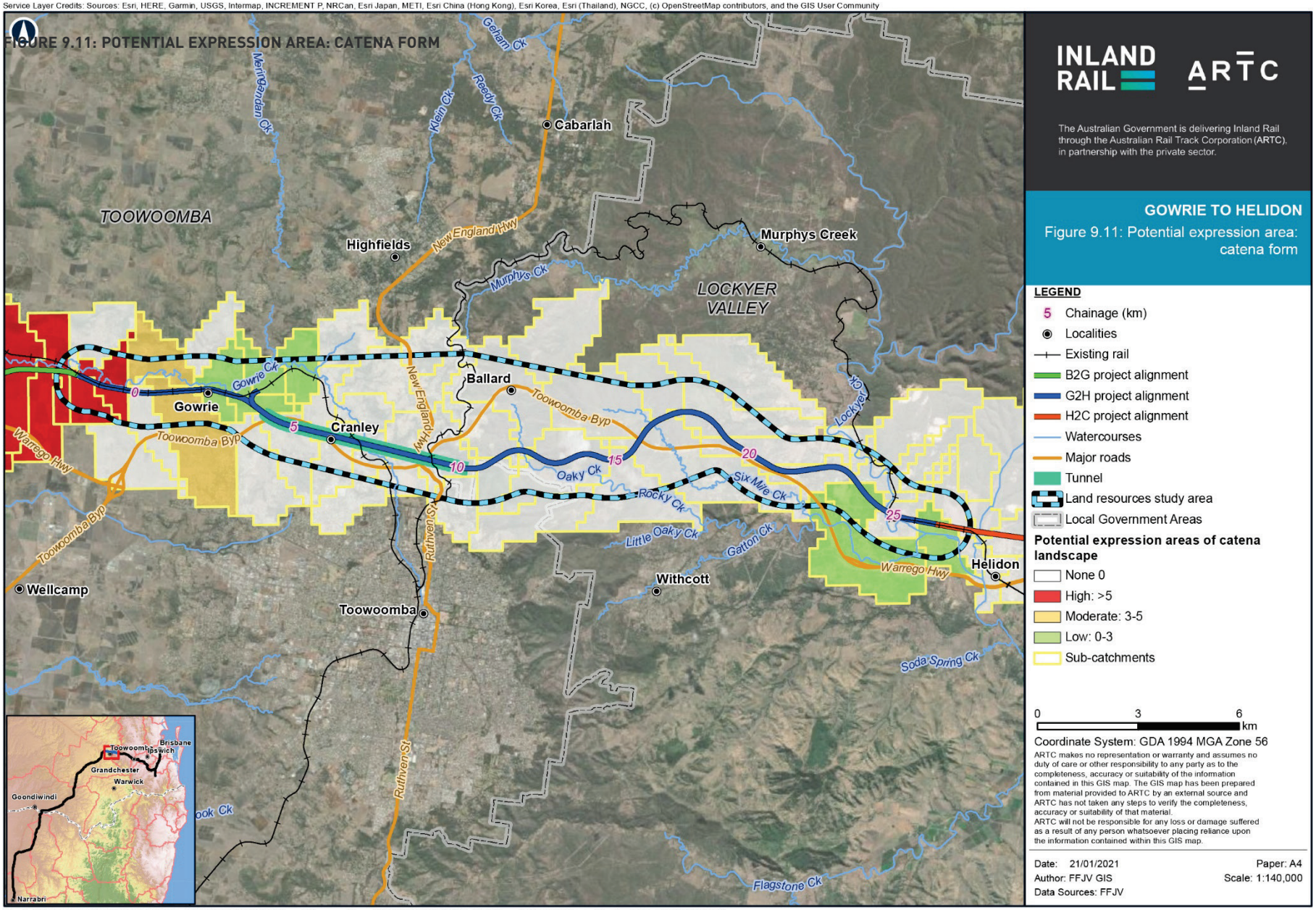
The percentage of catena form PEA for each sub-catchment within the land resources study area was calculated and is shown on Figure 9.11. Calculation of catena form was based on an analysis of the 20-m digital elevation model developed for the Project. Two digital elevation model derivatives were used in this analysis, being slope per cent and a Multi Resolution Valley Bottom Floor index, which was described by Gallant and Dowling (2003). The Multi Resolution Valley Bottom Floor index identifies areas that are both relatively flat and low in the landscape at different scales, which is interpreted as a map of valley bottom areas. This index is used to separate upland terrain dominated by erosional processes from lowland depositional terrain (Searle et al., 2007). Also refer Appendix N: Groundwater Technical Report for further details.

The analysis was only applied to the Main Range Volcanics, Walloon Coal Measures, Koukandowie Formation and the Gatton Sandstone as these are the geological layers most susceptible to catena form salinity. When analysing the risk of the catena form within the sub-catchments, a hazard category rating of none to high was applied, as shown in Table 9.11.

TABLE 9.11: POTENTIAL EXPRESSION AREA OF CATENA FORM

Percentage area of sub-catchments containing catena PEAs (%)	Hazard category	Approximate chainage of PEA along alignment
0	None	Ch 0.0 km, Ch 4.0 km–Ch 24.0 km, Ch 25.0 km
1–3	Low	Ch 2.0 km–Ch 4.0 km, Ch 24.0 km, Ch 26.0 km
4–5	Moderate	Ch 1.0 km–Ch 2.0 km
Greater than 5	High	Ch 0.0 km

Source: Searle et al., 2007


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FIGURE 9.11: POTENTIAL EXPRESSION AREA: CATENA FORM
TOOWOOMBA
LOCKYER VALLEY
Cabarlah
Highfields
Murphys Creek
Ballard
Gowrie
Cranley
Wellcamp
Toowoomba
Withcott
Helidon
New England Hwy
Warrego Hwy
Toowoomba Byp
Gowrie Ck
Oaky Ck
Rocky Ck
Six Mile Ck
Little Oaky Ck
Gatton Ck
Soda Spring Ck
Flagstone Ck
Murphys Ck
Lockyer Ck
Ruthven St
Merrigendan Ck
Klein Ck
Reedy Ck
Geham Ck
Brisbane
Ipswich
Grandchester
Warwick
Goondiwindi
Narrabri
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GOWRIE TO HELIDON
Figure 9.11: Potential expression area: catena form
LEGEND
Chainage (km)
Localities
Existing rail
B2G project alignment
G2H project alignment
H2C project alignment
Watercourses
Major roads
Tunnel
Land resources study area
Local Government Areas
Potential expression areas of catena landscape
None 0
High: >5
Moderate: 3-5
Low: 0-3
Sub-catchments
0
3
6
km
Coordinate System: GDA 1994 MGA Zone 56
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Potential expression area: Roads

The placement of roads within a landscape can restrict water flow as well as impede the soil's ability to transmit water, leading to the uprising of groundwater with dissolved salts and waterlogging. This form of salinity is often associated with hillslopes consisting of textural contrast soils or shallow, sandy soils within drainage lines (Searle et al., 2007).

A 25-m digital elevation model was used with two derivatives to derive where the construction of roads in the landscape could potentially present a risk of existing salinity development. The two derivatives are (Searle et al., 2007):

- Compound Topographic Index. The Compound Topographic Index delineates those areas in a landscape that have high contributing area and relatively low slopes. In a general sense, these would tend to be the wetter areas within a landscape.
- Slope (per cent).

The digital elevation model was generalised to 200 m for the slope calculations and 1,000 m for the Compound Topographic Index calculations. The analysis selected the areas that are generally low slope and where there is a general convergence of flow, low in the landscape. These areas are predicted to occur where:

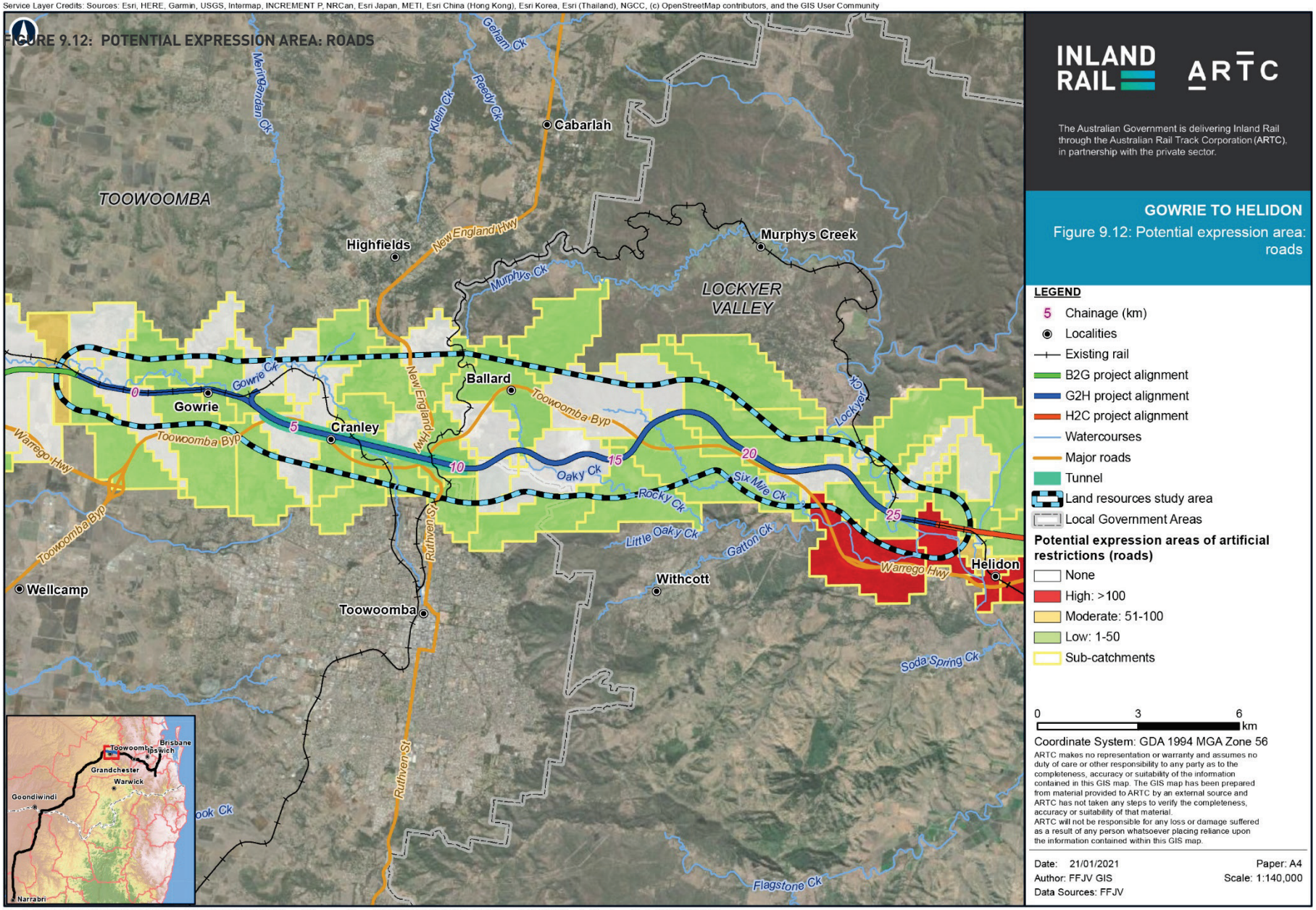
- Slope is greater than 1 per cent
- Compound Topographic Index is greater than 2.

Figure 9.12 presents the potential risk of salinity development with existing road placement. A hazard category rating of none to high was applied for artificial restrictions (roads), and these ratings are presented in Table 9.12.

TABLE 9.12: NUMBER OF ROAD POTENTIAL EXPRESSION AREAS ALONG LAND RESOURCES STUDY AREA CATEGORIES

Number of road PEAs within sub-catchments	Hazard category	Approximate chainage of PEA along alignment
0	None	Ch 0.0 km, Ch 5.0 km, Ch 11.0 km–Ch 15.0 km, Ch 21.0 km–Ch 23.0 km
1 to 50	Low	Ch 0.0 km, Ch 1.0 km–Ch 4.0 km, Ch 6.0 km–Ch 11.0 km, Ch 12.0 km, Ch 15.0 km–Ch 21.0 km, Ch 24.0 km–Ch 25.0 km
51 to 100	Moderate	N/A
>100	High	Ch 26.0 km

Source: Searle et al., 2007



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Potential Expression Area: Confluence of Streams

The confluence of streams form of salinity relates to where a major stream intersects with a minor stream. This intersection can create a reduction in flow velocity and a resultant deposition of the suspended particles at the junction, including a precipitation of salts (Searle et al., 2007).

Confluence of streams were identified through manual interpretation of the Australian Hydrological Geospatial Fabric mapped streams layer (Australian Government, 2015), where watercourses intersected. The number of watercourse intersections were identified within a sub-catchment. When analysing the risk of PEAs due to the confluence of streams within the sub-catchment, a none-to-high hazard category rating can be applied, as shown in Table 9.13. Areas associated with Lockyer Creek were mapped as low, as shown in Figure 9.13.

TABLE 9.13: POTENTIAL EXPRESSION AREA: CONFLUENCE OF STREAMS

Percentage of each sub-catchment containing confluence of streams (%)	Hazard category	Approximate chainage of PEA along alignment
0	None	Ch 0.0 km – Ch 25.0 km
1 to 3	Low	Ch 23.0 km, Ch 25.0 km – Ch 26.0 km
4 to 5	Moderate	N/A
Greater than 5	High	N/A

Source: Searle et al., 2007

Electrical conductivity

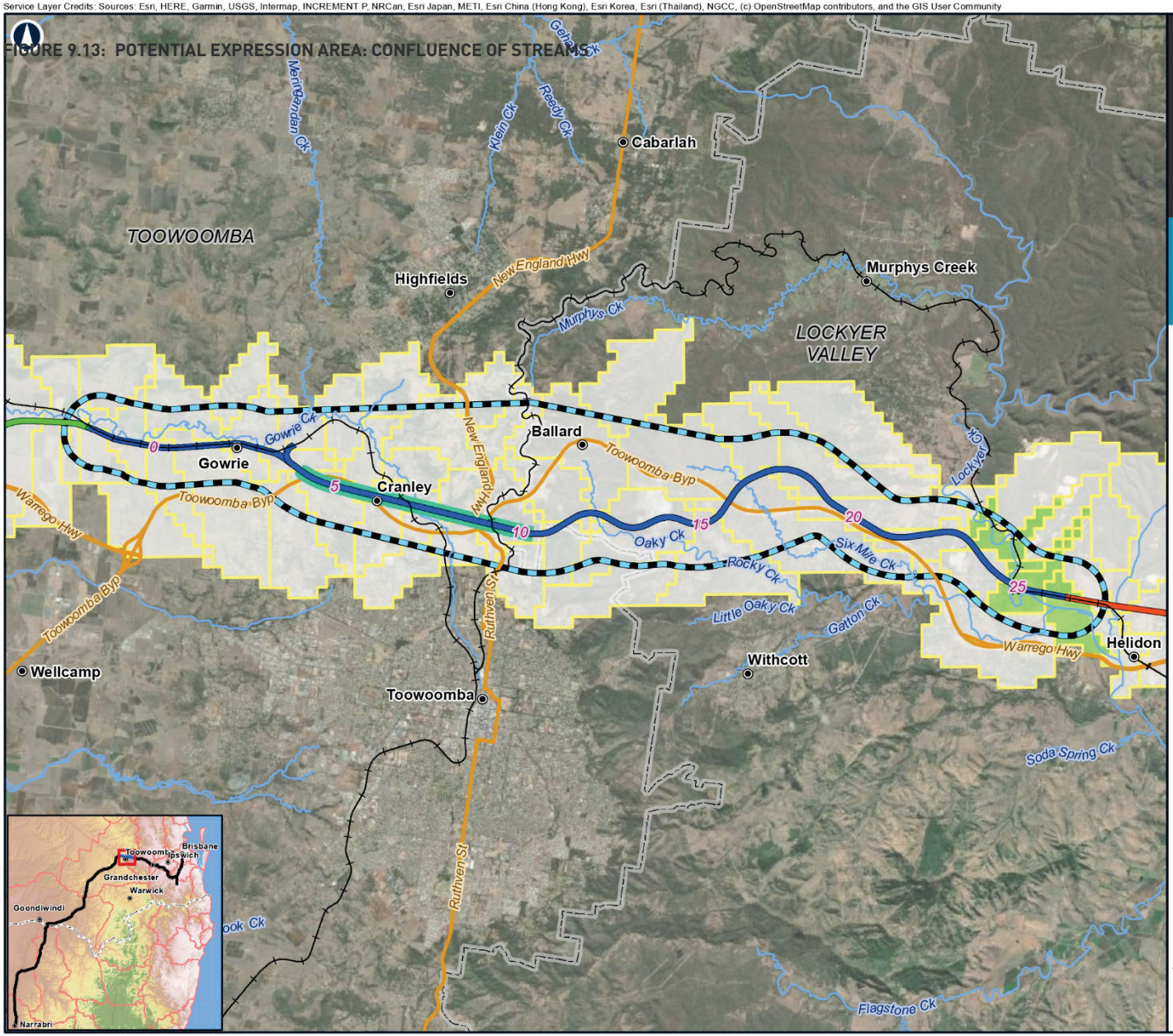
Salinity hazard in the land resources study area was also assessed using the CSIRO (2014) electrical conductivity mapping layer. Electrical conductivity of the soil surrounding Gowrie, and west of the GDR, ranged between 0.09 to 0.15 decisiemens per metre (dS/m), which is considered low. East of the GDR, electrical conductivity of the soil increased to 0.22 dS/m, which is considered moderate conductivity.

An area of high electrical conductivity (0.9 dS/m) meanders through the land resources study area north of Postmans Ridge towards Helidon Spa, while lower electrical conductivity areas dominate the remainder of the landscape (0.09 to 0.15 dS/m).

Geotechnical and soil investigation results revealed the electrical conductivity of the 15 samples collected for soil analysis ranged between 0.014 dS/m to 0.615 dS/m, indicating low electrical conductivity in the surface soils. The results also indicate that there is horizontal and vertical variance in electrical conductivity of soils in the land resources study area and that this variance cannot be closely correlated with soil classification mapping. Surface water salinity and groundwater salinity are detailed further in Chapter 13: Surface Water and Hydrology and Chapter 14: Groundwater, respectively.

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FIGURE 9.13: POTENTIAL EXPRESSION AREA: CONFLUENCE OF STREAMS



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Figure 9.13: Potential expression area: confluence of streams

LEGEND

- 5 Chainage (km)
- Localities
- Existing rail
- B2G project alignment
- G2H project alignment
- H2C project alignment
- Watercourses
- Major roads
- Tunnel
- Land resources study area
- Local Government Areas

% of Confluence of Streams

- None
- Low: 1-2
- Sub-catchments

0 3 6 km

Coordinate System: GDA 1994 MGA Zone 56

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Overall salinity hazard

Overall salinity hazard of the land resources study area was assessed using a desktop assessment of five factors, potential expression areas, and laboratory results from geotechnical and soil investigation results. The assessment for salinity hazard modelled and mapped surface conditions only.

The desktop assessment of salinity hazard was developed with consideration of inherent soil salt store, basalt and sandstone contact, catena form, artificial restrictions and confluence of streams. The desktop assessment indicated a general moderate-to-high potential hazard of salinity occurring in the land resources study area, when risks from each of the five individual potential expression areas was combined (refer Figure 9.14).

Soil sample results from the geotechnical and soil investigation, analysed exchangeable sodium, calcium and magnesium in soil samples, as these salts are generally responsible for salinity (NSW Office of Environment and Heritage, 2018). Soil sample results identified an availability of all three salinity types causing salts to exist at generally low concentrations (refer Table 9.4). Sodosols, which are known to have sodic properties, were also a dominant soil type in the Project disturbance footprint (refer Section 9.6.4.1).

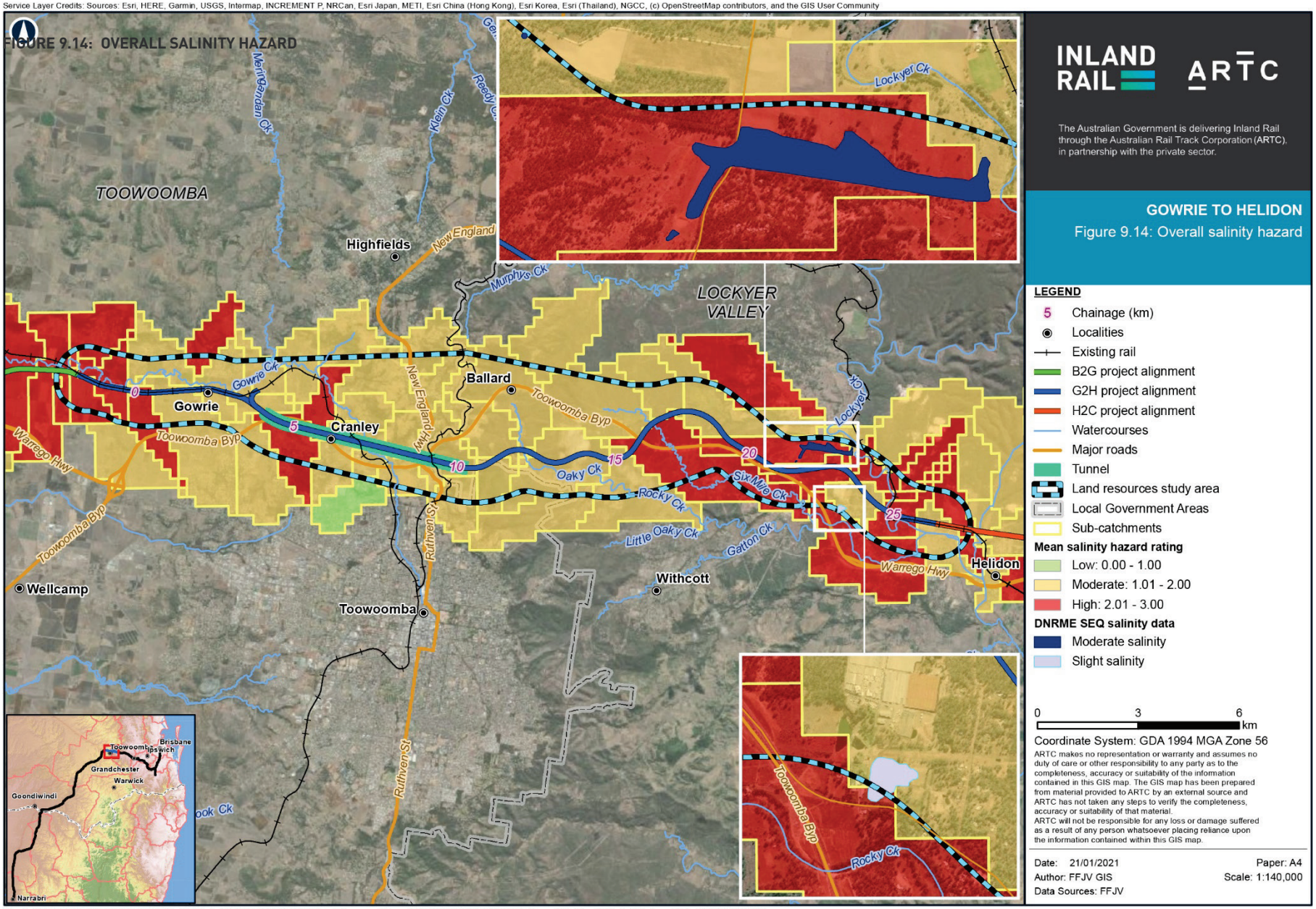
The overall salinity hazard assessment also considered additional data from the Department of Resources (received March 2020) of known salinity sites in south-east Queensland. Three areas of 'Moderate' salinity and one area of 'Slight' salinity were identified in the land resources study area. No sites were identified in the Project disturbance footprint (refer Figure 9.14). Table 9.14 provides a summary of the four known salinity areas.

TABLE 9.14: SUMMARY OF DEPARTMENT OF RESOURCES KNOWN SALINITY AREAS

Location	Salinity risk	Salinity type	Area (ha)
Lockyer—adjacent Howmans Road	Moderate	Stratigraphic form	0.07 (in land resources study area, outside of Project disturbance footprint)
Lockyer—adjacent Murphys Creek Road and Lockyer Creek	Moderate	Alluvial valley—catchment restriction (artificial)	27.30 (in land resources study area outside of Project disturbance footprint)
Lockyer—adjacent Murphys Creek Road	Moderate	Stratigraphic form—dam	0.18 (in land resources study area outside of Project disturbance footprint)
Withcott—adjacent Withcott Seedlings site	Slight	Alluvial valley	3.83 (in land resources study area outside of Project disturbance footprint)

The desktop salinity hazard assessment mapping generally correlated with the risk areas identified by the *Strategic Salinity Risk Assessment for the Condamine Catchment* (Searle et al., 2007), with a majority of the land resources study area, from Gowrie to the eastern side of the GDR escarpment near Mount Kynoch, having moderate-to-high overall salinity risk. The land resources study area east of the GDR escarpment, towards Helidon, also had a moderate-to-high salinity risk, with areas underlying the Gatton Sandstone correlating with areas of high salinity risk in the Lockyer catchment.

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9.6.5 Agricultural land

The *Queensland Agricultural Land Audit* (DAFF, 2013a and DAF, 2017)(the Audit) identifies land important to current and future agricultural production in Queensland. The Audit identifies agricultural potential using a rule-based approach that combines biophysical characteristics of the land, such as soil, climate and landform as well as native vegetation and socio-economic spatial data. The characteristics of land/soil resources are a fundamental determinant of potential for most agricultural land uses. Soils are classified using a four-tier hierarchy ranging from Class A (arable land) through to Class D (land that is unsuitable for agriculture) (DAFF, 2013a and DES, 2020l).

Agricultural land classified as Class A or Class B is considered the most productive land in Queensland, with soil and land characteristics that allow successful crop and pasture production. In July 2020, the Queensland Government released updated Agricultural Land Class (ALC) data for identifying productive Class A and Class B land, which has been used in this assessment.

The Audit also identifies IAAs. IAAs are defined as land that has all the requirements for agriculture to be successful and sustainable, is part of a critical mass of land with similar characteristics and is strategically significant to the region or the State.

The land resources study area between Gowrie and west of Toowoomba Waste Facility at Mount Kynoch is mapped as IAA. East of the GDR, intermittent areas of IAAs meander along the fringes of the land resources study area from Ballard to Helidon. These areas are associated with the floodplain/alluvials of Rocky and Six Mile Creeks and also a section of Lockyer Creek.

Class A and Class B land dominate the land resources study area west of the GDR between Gowrie and Mount Kynoch. East of the GDR, Class A and Class B land is also associated with floodplain/alluvials of Rocky and Six Mile Creeks and also a section of Lockyer Creek (refer Figure 9.15).

Using the Audit (DAFF, 2013a and DAF, 2017) results for the Darling Downs and South-east Queensland (SEQ) region, a strong correlation was found between the strategic cropping land trigger mapping and agricultural land used for the following activities:

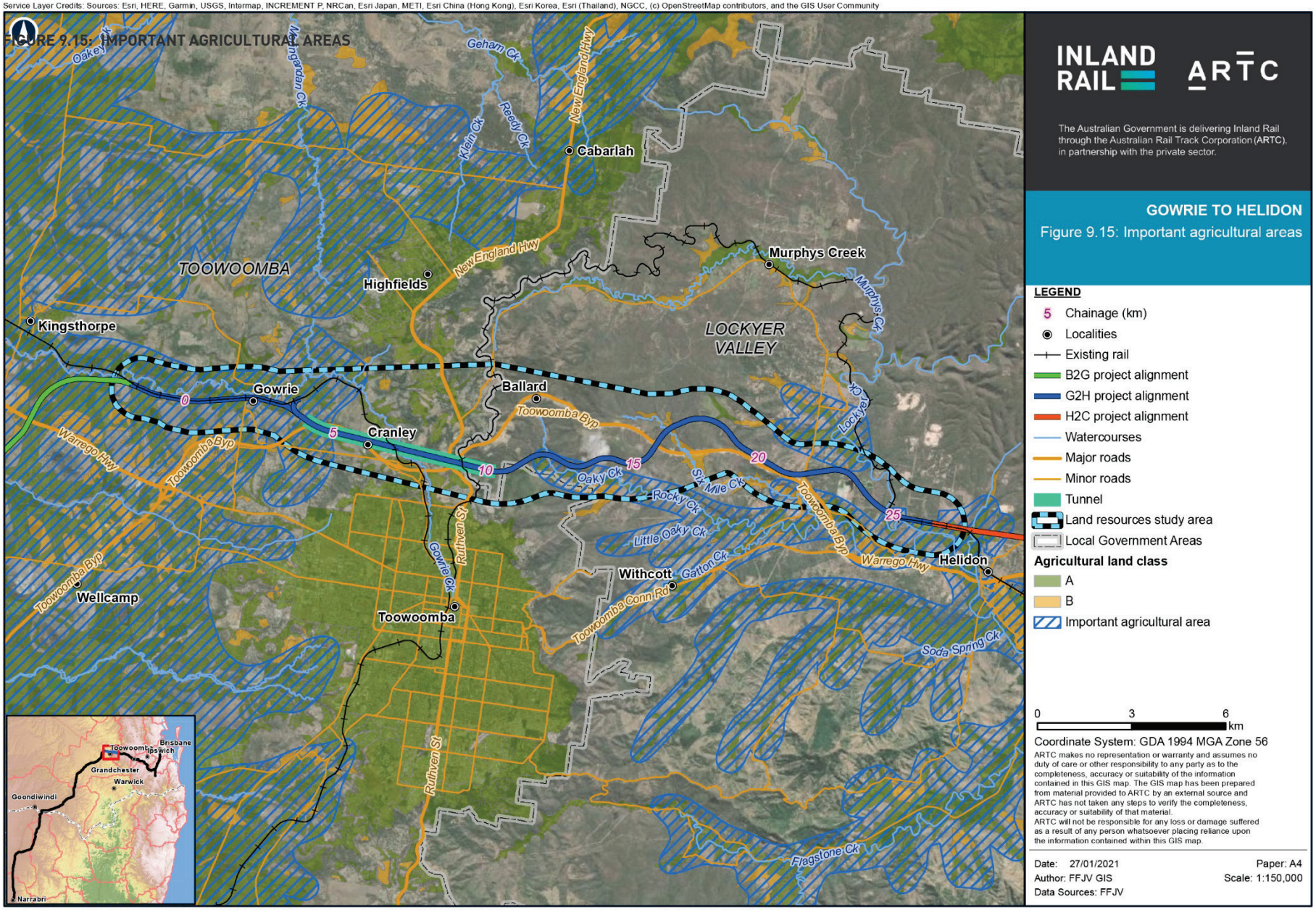
- Pasture production
- Native forestry
- Intensive livestock
- Hardwood plantation forestry
- Broadacre cropping
- Annual horticulture
- Sown pasture.

The Audit (DAFF, 2013a and DAF, 2017) identifies the Darling Downs region as a diverse region with 97 per cent of land use under agricultural production, with grazing and broadacre cropping being the predominant industries. In the SEQ region, the Audit (DAFF, 2013a and DAF, 2017) identifies the region to support a range of agricultural industries with horticulture, poultry, cattle, dairy and cultivated turf the largest industries.

The land resources study area contains a large presence of vertosol soils (refer Section 9.6.4.1) and is a part of the Condamine catchment, which is identified among the most productive areas in Australia for crop production (DAFF, 2013a).

Further details on agricultural land uses and activities are provided in Chapter 8: Land Use and Tenure.

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GOWRIE TO HELIDON

Figure 9.15: Important agricultural areas

LEGEND

- 5 Chainage (km)
- Localities
- Existing rail
- B2G project alignment
- G2H project alignment
- H2C project alignment
- Watercourses
- Major roads
- Minor roads
- Tunnel
- Land resources study area
- Local Government Areas

Agricultural land class

- A
- B
- Important agricultural area

0 3 6 km

Coordinate System: GDA 1994 MGA Zone 56

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Author: FFJV GIS Scale: 1:150,000
Data Sources: FFJV

Map by: GN/IW/MF/TM Z:\GIS\GIS_3200_G2H\Tasks\320-EAP-201807091155_Land_Resource_Figures\320-EAP-201807091155_G2H_Figure 9.14_ImportantAgriculturalAreas_A4_v5.mxd Date: 27/01/2021 14:32

9.6.6 Contaminated land

9.6.6.1 Desktop assessment

Desktop assessment methodology

An assessment of contaminated land in the land resources study area was undertaken using a contaminated land risk assessment based on a contaminant (source)–pathway–receptor methodology, whereby:

- Contaminant (source): a substance present in or on land, water or onsite at above background concentrations that presents, or has the potential to present, a risk to human health, the environment or any environmental value
- Pathway: the route by which the contaminant is brought into contact with the receptor. This can include the transport of contamination via water (surface and groundwater), aeolian deposition, vapour, excavation and deposition.
- Receptor: humans, other living organisms, physical systems and built structures that could be affected by the contaminant. A receptor will only be affected if a pathway from the source to the receptor is present. Groundwater and surface water systems can be considered as receptors in their own right, as well as being pathways for contaminant migration to other receptors.

The source–pathway–receptor relationship allows an assessment of potential environmental risk to be determined, based on the nature of the source, the degree of exposure of a receptor to a source, and the sensitivity of the receptor.

The fundamental concept of contaminated land risk assessment is that an exposure pathway linking the source of contamination and the exposed population (humans or the environment) must be present for a risk to exist (ASC NEPM, 2013).

Identification of potential sources of contamination within the land resources study area was assessed through site inspections (including walkover) of the land resources study area, undertaken as part of the geotechnical investigations, including borehole logs and a desktop assessment.

The desktop assessment identified potential sources of contamination in the land resources study area through:

- Search of ERAs listed on the environmental authorities register (refer Table 9.15)
- Search of Queensland mining and petroleum tenement and tenures
- Search of the EMR and CLR, for those ERAs identified in the land use study area
- Consultation with landholders and stakeholder groups, including Queensland Rail (QR) and Toowoomba Regional Council (TRC)
- Assessment of historical aerial imagery for areas of interest (e.g. potentially contaminated sites, infrastructure, environmentally significant areas, etc.)
- Search of the Department of Defence (Australian Government, 2017) online mapping for UXOs
- Search for KRAs and other resource interests.

Potential sources of contamination identified from the assessment are detailed below as well as results from desktop assessments.

Potential sources of contamination

Based on the land uses in the land resources study area, findings of a desktop assessment and field investigations, the potential sources of contamination in the vicinity of the Project are considered to include:

- Agricultural activities: hydrocarbons (fuel and oil storage and use), pesticides and herbicides, asbestos and lead paint, arsenic (cattle dips), agricultural landfilling
- Quarries: hydrocarbons (fuel and oil storage and use), metals/metalloids, hazardous materials
- Landfilling, waste disposal: hazardous materials, hydrocarbons, metals/metalloids, phenols, polychlorinated biphenyls, phthalates, volatiles and pesticides, and herbicides
- Existing and former rail corridors: metals, asbestos, hydrocarbons, pesticides/herbicides
- Road crossings: metals and hydrocarbons

- Housing/sheds: hydrocarbons (fuel and oil storage and use), pesticides and herbicides, lead paint and asbestos
- Unknown fill material: asbestos, metals/metalloids, hydrocarbons.

During the geotechnical site investigation, no visual contamination was identified and no anthropogenic material was observed (refer Appendix W: Geotechnical). A targeted contaminated land investigation was undertaken by Aurecon (2020) and Golder (2020) where the Project disturbance footprint intersects areas of medium to high risk to determine the likelihood of contaminated soils, the potential for risks to human health and the environment, and required management measures.

There are no mining/petroleum leases or exploration permits within the land resources study area. Two exploration permits do, however, feature within 1 km of the land resources study area for minerals other than coal. Mining tenements are discussed in Chapter 8: Land Use and Tenure, and Chapter 20: Hazard and Risk, provides further discussion on the potential impacts and mitigation measures of recorded and unrecorded abandoned mine workings (including pits, shafts, tunnels and underground workings).

Environmentally relevant activities

An assessment of potential sources of contamination found 17 properties where ERAs are undertaken within the land resources study area. These are discussed further in Chapter 8: Land Use and Tenure.

Of the 17 properties that operate ERAs, 7 were listed on the EMR, though none are listed on the CLR (refer Table 9.15 and Figure 9.16). These properties are recorded on the EMR for the following activities:

- Landfill
- Waste storage, treatment or disposal
- Chemical storage
- Petroleum product or oil storage
- Railway yards
- Explosives production or storage.

The level of risk pertaining to each property was categorised (low, medium or high risk) with consideration of distance to the proposed rail alignment and potential for adverse impact to the Project as a result of contamination source, type, mobility and/or potential transport pathways. The potential for adverse impact considered concentration of likely contamination at the source, type of contamination, contaminant mobility and potential transport pathways.

TABLE 9.15: PROPERTIES LISTED IN THE ENVIRONMENTAL MANAGEMENT REGISTER WITHIN THE LAND RESOURCES STUDY AREA

Lot and Plan	Location	Listing details	Approximate distance of activity to Project disturbance footprint	Risk category potential
172 SP227269 (formerly 172 SP189517)	Toowoomba Waste Management Centre	Landfill disposing of waste	Project passes under this land parcel (i.e. Project is within tunnel, at a depth of 100 m bgl)	High
1 SP270010	Wetalla Sewage Treatment Plant	Waste storage, treatment or disposal	Adjacent rail alignment (above tunnel and intermediate ventilation building)	Medium
196 RP845660	Mount Kynoch Water Treatment Plant	Chemical storage	0.6 km from Project disturbance footprint (tunnel)	Low
2 RP844703	Harlaxton Quarry	Petroleum product or oil storage	0.65 km from Project disturbance footprint	Low
918 RP844703	Adjacent Harlaxton Quarry	Railway yards	0.65 km from Project disturbance footprint	Low
125 CP907566	North-west of Helidon	Explosives production or storage	Adjacent Project disturbance footprint	Medium
67 CP839425	North-west of Helidon	Explosives production or storage	0.8 km from Project disturbance footprint	Medium

Table notes:
Low risk = 1.5 to 2 km from proposed rail alignment and/or with no potential adverse impact to Project, as a result of contamination source, type, mobility and/or potential transport pathways
Medium risk = 1 to 1.5 km from proposed rail alignment and/or with potential for adverse impact to Project, as a result of contamination source, type, mobility and/or potential transport pathways
High risk = < 1 km from proposed rail alignment (i.e. within the land resource study area) and/or with likely adverse impact to Project, as a result of contamination source, type, mobility and/or potential transport pathways)

ARTC has consulted with TRC regarding the potential risk of contamination from the Toowoomba Waste Management Centre and was advised of the following:

- The landfill cells closest to the intermediate ventilation shaft are lined cells constructed post 2000 and are, therefore, properly engineered to contain the waste, and capture and manage leachate
- TRC undertook a comprehensive groundwater assessment in 2019, with the results provided to DES; the assessment identified no contamination of groundwater as a result of landfill leachates
- The sites master plan indicates that the future landfill operations will progress in a generally north-west direction, away from the alignment.
- A request for information was also submitted to QR, who maintain its own register of rail corridor land parcels understood to be listed on the EMR/CLR. QR advised:
- The following land parcels associated with the Western Line are listed on the EMR due to hazardous contaminant: Lot 2 on RP34892; Lot 12 on SP122211; Lot 2 on RP34879; Lot 3 on SP34918; and Lot 4 on RP34921
- The following land parcels associated with the Main Line are listed on the EMR, with Lot 591 on SP117148 due to hazardous contaminant, while Lot 452 on SP117138 is listed due to a railway yard.
- QR also notes that due to the previously agreed approach to listing of rail corridor parcels by the applicable Regulator (for Hazardous Contaminant associated with arsenic herbicide use), some rail corridor parcels may not be listed on the EMR but have the potential for contamination due to similar historic land use.

Appendix X: EMR Search Certificates and Laboratory Certificates, identifies properties that were listed on the register.

Unexploded ordnance

A search of the Department of Defence (Australian Government, 2017) online mapping for UXOs identified two areas of UXO categorised as 'Other' in the land resources study area (refer Figure 9.16). One of the 'Other' UXO areas is located east of Ballard and the GDR, along the Toowoomba Bypass, which is described as an area potentially containing 2-inch (") mortar and grenades. The UXO area will intersect the alignment at Ballard. The second 'Other' UXO area is located north of Helidon at the Queensland Government Explosives Reserve and was used for explosives storage during WWII to present. The second UXO area is located adjacent to the alignment and does not intersect the Project disturbance footprint, with works to occur along the southern boundary of Air Force Road (east of Ch 25 km).

The Department of Defence categorises 'Other' UXO areas as:

> *'Land which has been used for military training but not confirmed as a site where live firing was undertaken. UXO or explosive ordnance fragments or components have not been recovered from these areas. These sites have been included for general information purposes only. Defence makes no recommendations in regards to this category'.*

If the Project disturbance footprint alters, and is required to traverse, identified 'Other' UXOs areas or traverse directly adjacent to these areas, further assessment will need to be undertaken.

The remaining land resources study area had no identified records of UXO-related material or activities, with Department of Defence recommending:

> *'All land usage and development, within these areas, should continue without further UXO investigation or remediation'.*

The Project also traverses a portion (approximately 12 ha) of the former Mount Lofty Rifle Range (Lot 1 on RP 46221, which is 307.59 ha in size), east of the eastern tunnel portal. Defence Housing Australia (DHA), the current owners of the lot, are seeking approval for a residential masterplan in the southern section of the lot. As part of the planning processes, DHA have acknowledged that there may be UXO on some areas of the lot due to its previous use as a rifle range. An independent expert has conducted on-ground inspections for UXO for the proposed masterplan area.

The Project is located away from the former rifle range areas; however, to mitigate potential risks to the Project, consultation with DHA and, where applicable, Commonwealth Department of Defence will be undertaken to determine the level of risk of UXOs to the Project and identify efficiencies with regard to any on-ground inspections and clearance works (DHA, 2015).

Resource areas

One KRA, Harlaxton KRA (No. 8), intersects the Project disturbance footprint, at Ballard. The Harlaxton KRA comprises of a thick basalt sequence and is a major quarry that yields a wide range of crushed rock products (DILGP, 2016c). Further information on the KRA and the existing quarry operations, including the history of the KRA and the relevance to the Project, is provided in Chapter 8: Land Use and Tenure.

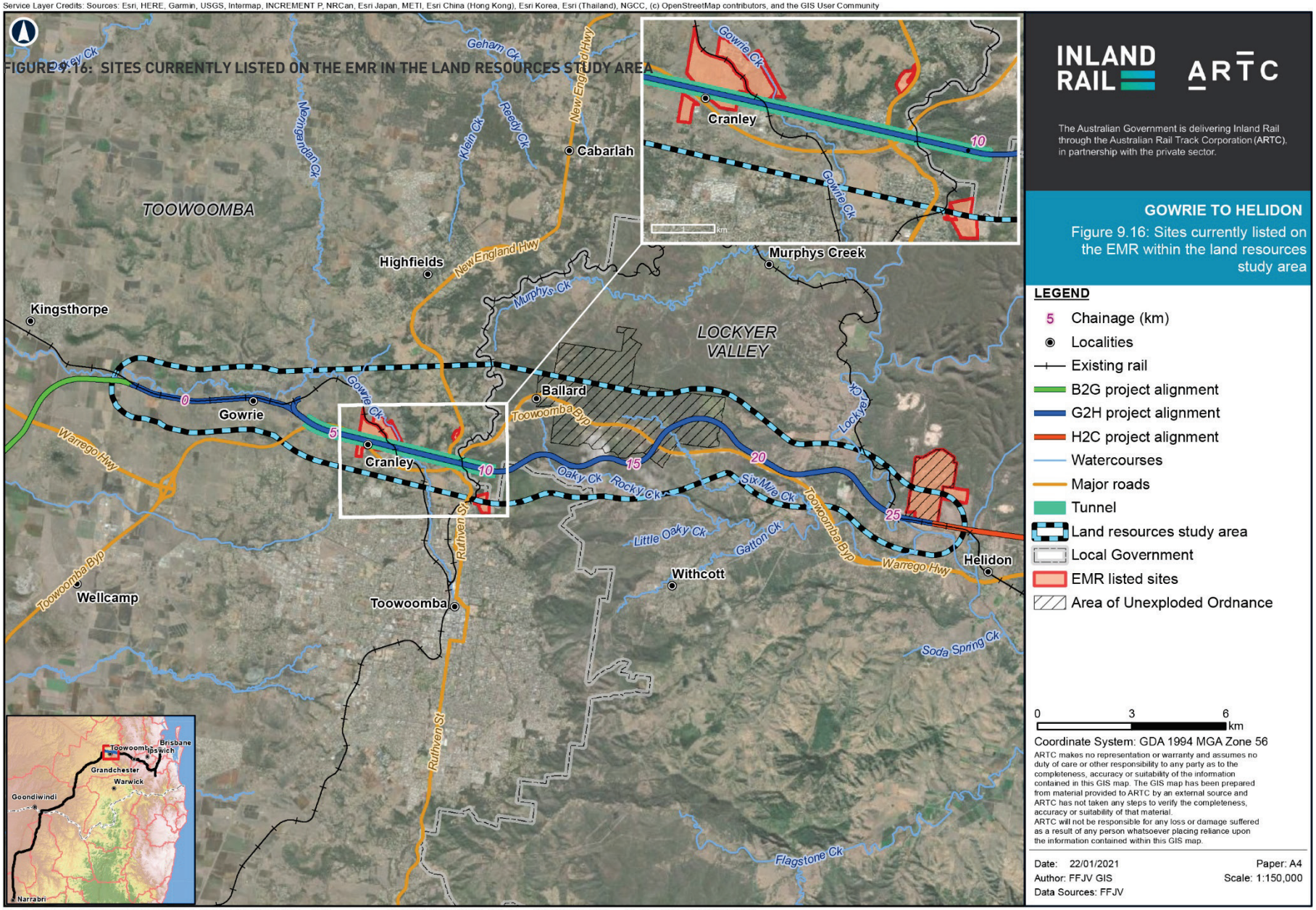
The Project traverses both the separation and processing area associated with KRA 8, with the proposed eastern tunnel portal located in the north-eastern corner of the KRA 8 boundary. This area is currently undeveloped, noting that the current KRA configuration was endorsed under the SPP in 2013, with no KRA present at this location when the Gowrie to Grandchester future state corridor was protected under the *Transport Planning and Coordination Act 1994* (Qld) in 2005.

The active Harlaxton Quarry is located on a spur in the southern part of the KRA, approximately 800 m south of the proposed eastern tunnel portal. As the existing quarry pit is located to the south of the rail alignment, the Project is not anticipated to impact the operation or the available resources of the existing quarry pit. It is anticipated that hard rock resources located in the southern spur will be able to be fully developed during and following the construction of the Project. Further detail regarding the KRA is provided in Chapter 8: Land Use and Tenure.

The quarry is, however, considered a low-risk source of contamination relevant to the Project due to existing environmental licences and management processes implemented onsite.

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FIGURE 9.16: SITES CURRENTLY LISTED ON THE EMR IN THE LAND RESOURCES STUDY AREA



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GOWRIE TO HELIDON

Figure 9.16: Sites currently listed on the EMR within the land resources study area

LEGEND

- 5 Chainage (km)
- Localities
- Existing rail
- B2G project alignment
- G2H project alignment
- H2C project alignment
- Watercourses
- Major roads
- Tunnel
- Land resources study area
- Local Government
- EMR listed sites
- Area of Unexploded Ordnance

0 3 6 km

Coordinate System: GDA 1994 MGA Zone 56

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Author: FFJV GIS Scale: 1:150,000

Data Sources: FFJV

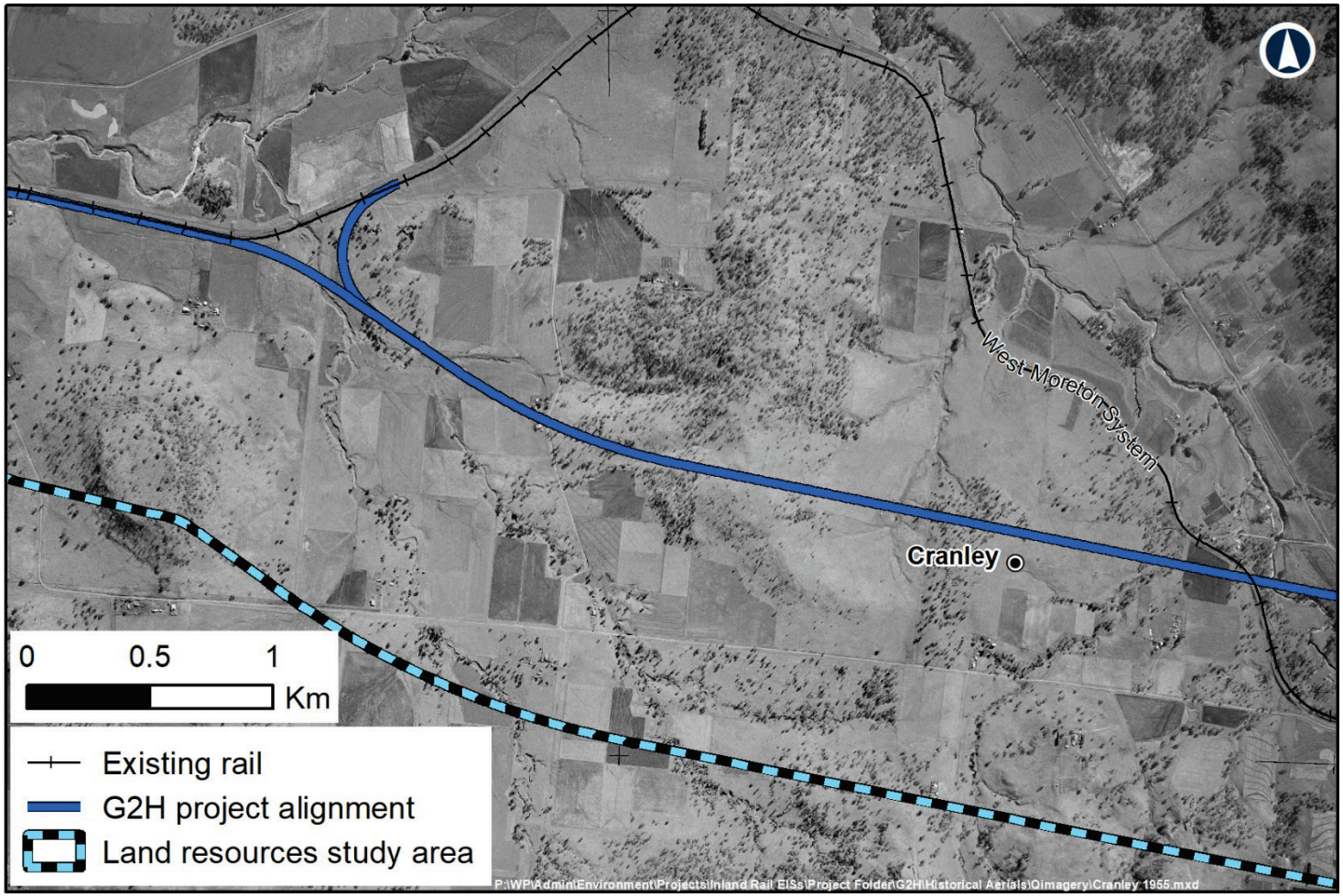
Map by: GN/IW/MF/TM Z:\GIS\GIS_3200_G2H\Tasks\320-EAP-201807091155_Land_Resource_Figures\320-EAP-201807091155_G2H_Figure 9.15_EMR_ListedSites_A4_v5.mxd Date: 22/01/2021 12:03

Historical aerial imagery

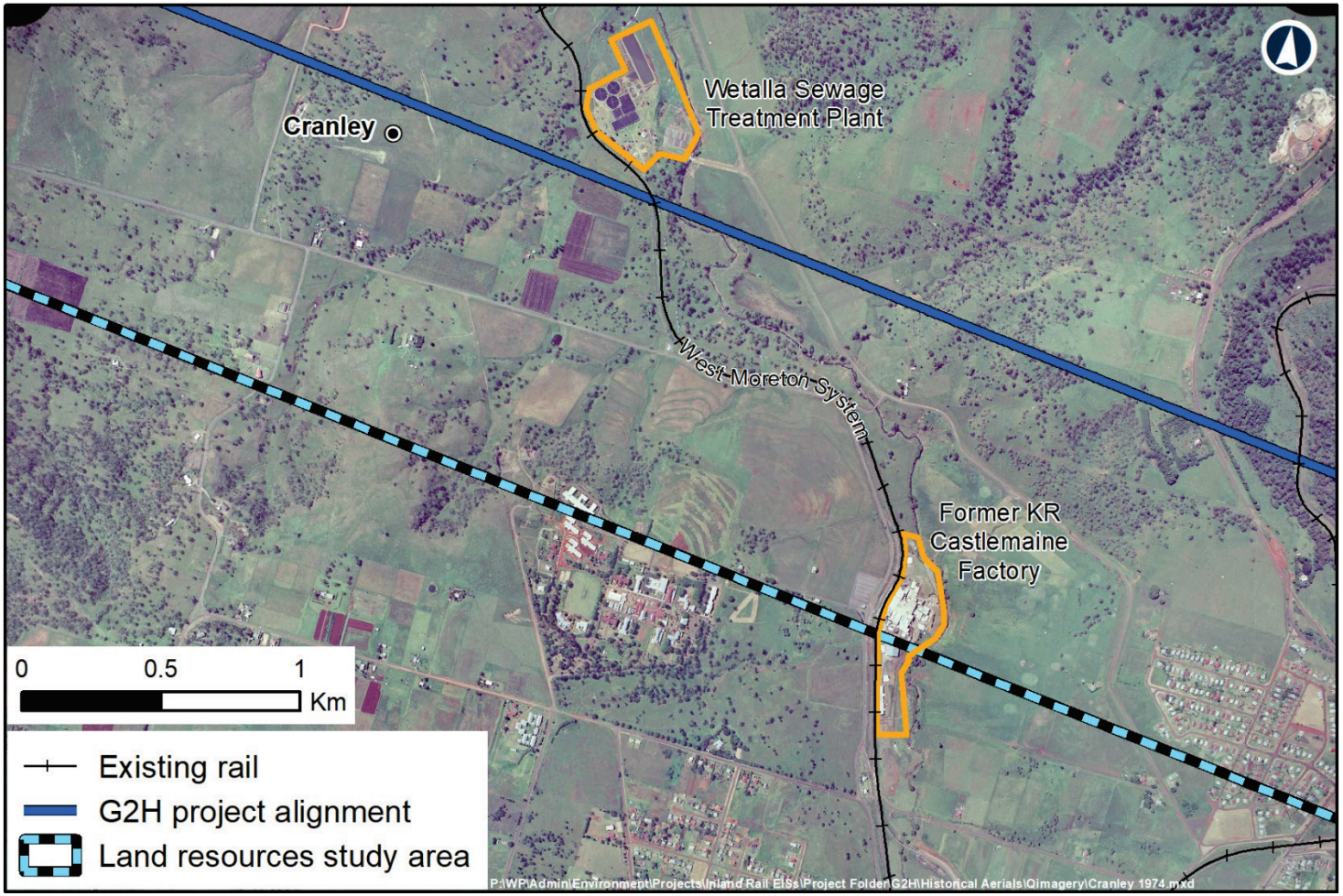
An assessment of historical aerial imagery from areas of interest (e.g. potentially contaminated sites, infrastructure, environmentally significant areas, etc.) was undertaken to identify potential current sources, as well as potential historical sources of contamination in the land resources study area (refer Table 9.16).

The full extent of the land resources study area boundary may not be represented on each image due to the resolution.

TABLE 9.16: HISTORICAL AERIAL PHOTOGRAPHS

Land resources study area	Details
Cranley area	
	**Year:** 1955 **Direction**: Aerial **Details:** The aerial image displays the existing West Moreton System rail corridor running through Cranley towards the GDR. The aerial image shows a mixture of cultivated land and grazing pastures dominating the landscape as well as scattered dense bushland. An established road network already exists in the region, with residential properties spread across the approximate land resources study area. **Source:** DERM (2010).

Land resources study area



Details

Year: 1974

Direction: Aerial

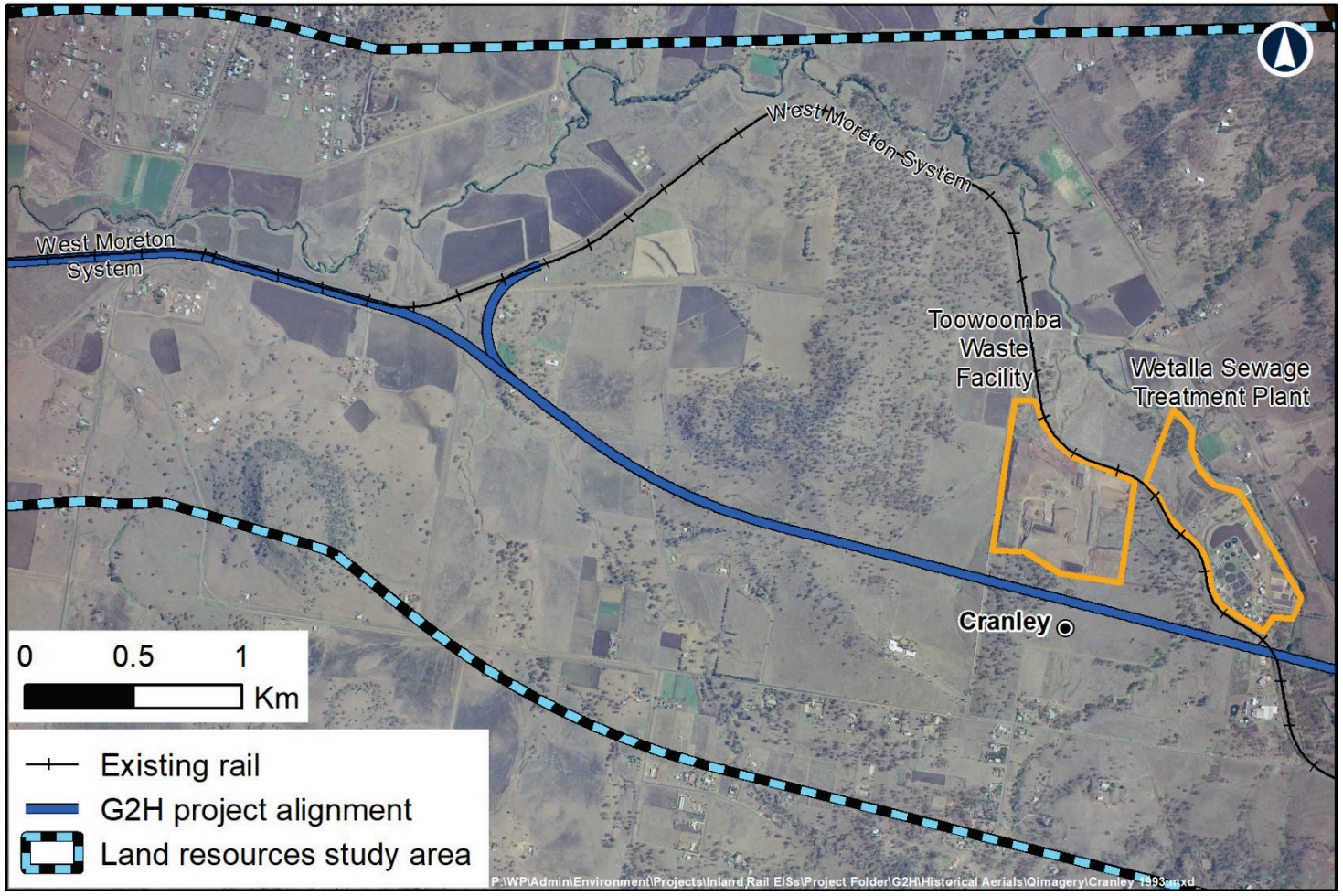
Details: The aerial image displays the existing West Moreton System rail corridor running through Cranley towards the GDR.

A mix of cultivated land, grazing pastures and scattered bushland still feature throughout the landscape.

New infrastructure in the land resources study area include residential properties, the Wetalla Sewage Treatment Plant (operational from approximately 1969) and the former KR Castlemaine Factory.

Source: DNRM (2014).

Land resources study area



Details

Year: 1993

Direction: Aerial

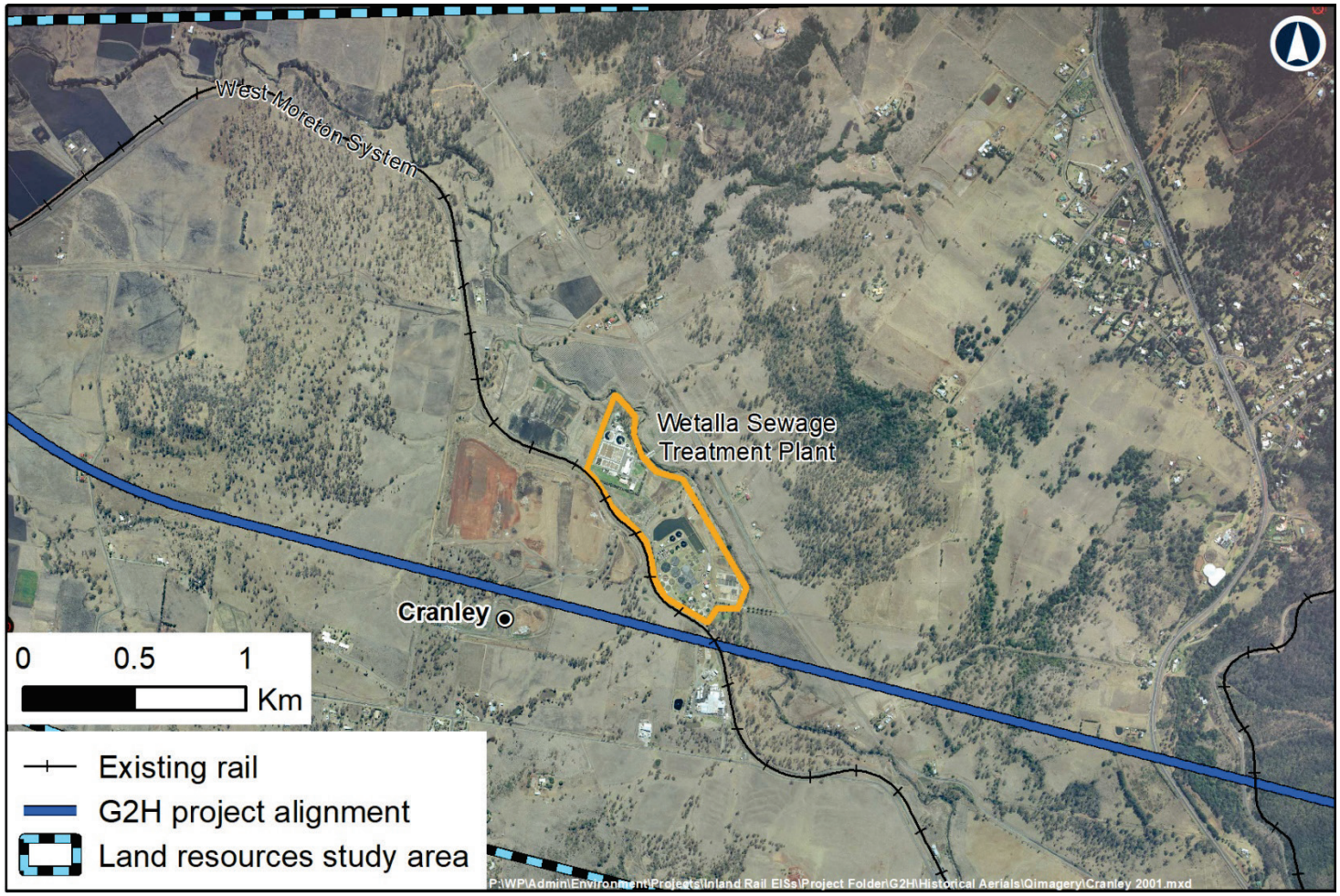
Details: The aerial image displays the existing West Moreton System rail corridor running through Cranley towards the GDR.

Cropping/cultivated land has increased in land use within the approximate land resources study area as well as urban development at town centres such as Wilsonton Heights, Harlaxton and Gowrie.

Earthworks and operation of the Toowoomba Waste Management Centre has also occurred onsite, adjacent to the Wetalla Sewage Treatment Plant.

Source: Department of Lands Queensland (1993).

Land resources study area



Details

Year: 2001

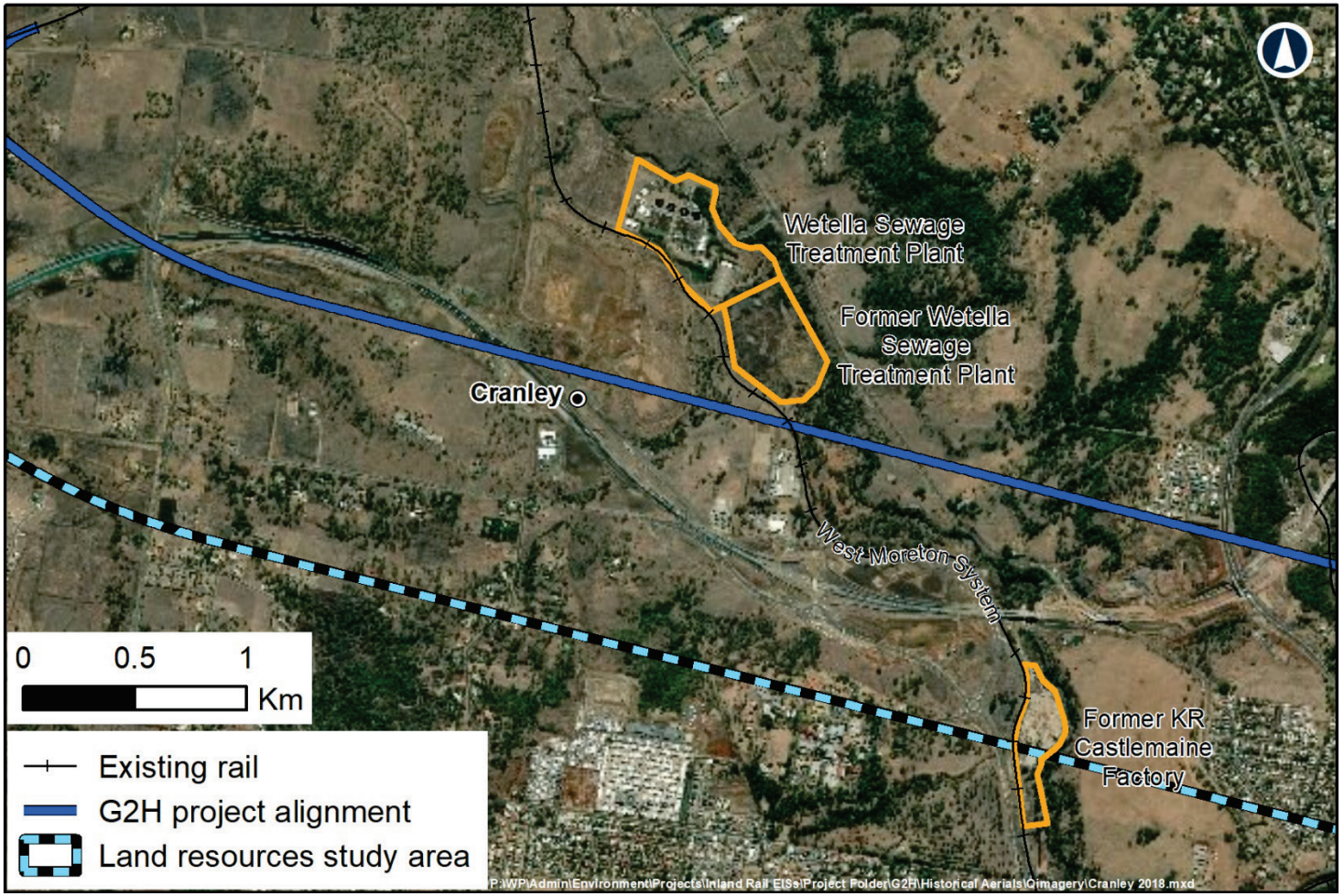
Direction: Aerial

Details: The aerial image displays the existing West Moreton System rail corridor running through Cranley towards the GDR.

Expansion of the Toowoomba Waste Management Centre and Wetalla Sewage Treatment Plant, to a property north of the existing facility, has occurred within the land resources study area. The Mount Kynoch Water Treatment Plant has also been constructed, adjacent to the New England Highway, north of the Project alignment.

Source: DNRM (2001b).

Land resources study area



Details

Year: 2019

Direction: Aerial

Details: The aerial image displays the existing West Moreton System rail corridor running through Cranley towards the GDR.

The Cranley area has seen significant changes occur to the landscape within the land resource study area from the previous historical image.

The former property of the Wetalla Sewage Treatment Plant has now been demolished and rehabilitated to open space.

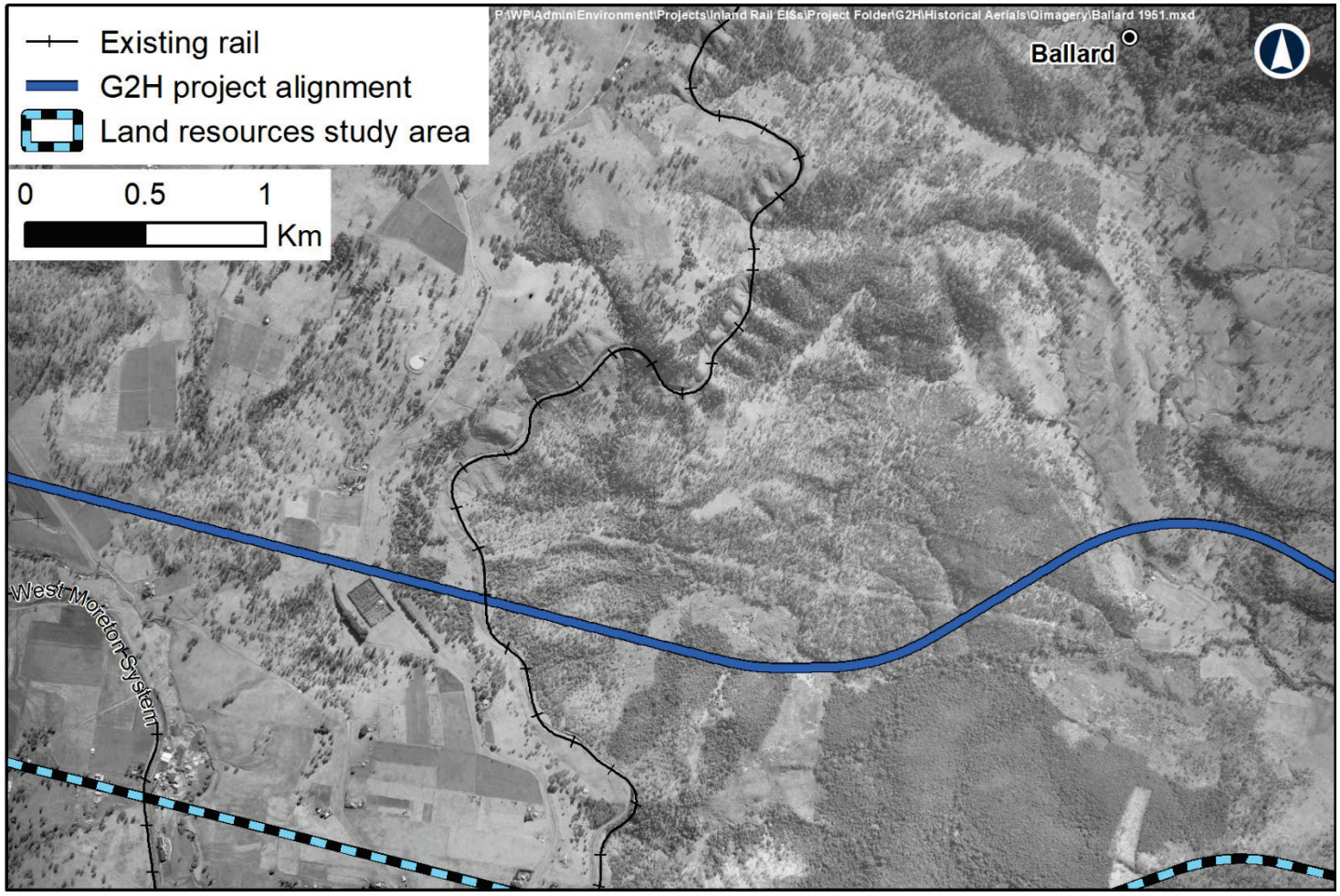
The former KR Castlemaine Factory has also been demolished.

The Toowoomba Bypass construction now crosses through the land resources study area.

The Toowoomba Waste Management Centre has expanded to the east and south.

Source: DNRM (2001b).

Land resources study area	Details
Ballard Area	



Year: 1951

Direction: Aerial

Details: The aerial image displays the land resources study area as it crosses the GDR escarpment from Mount Kynoch into Ballard.

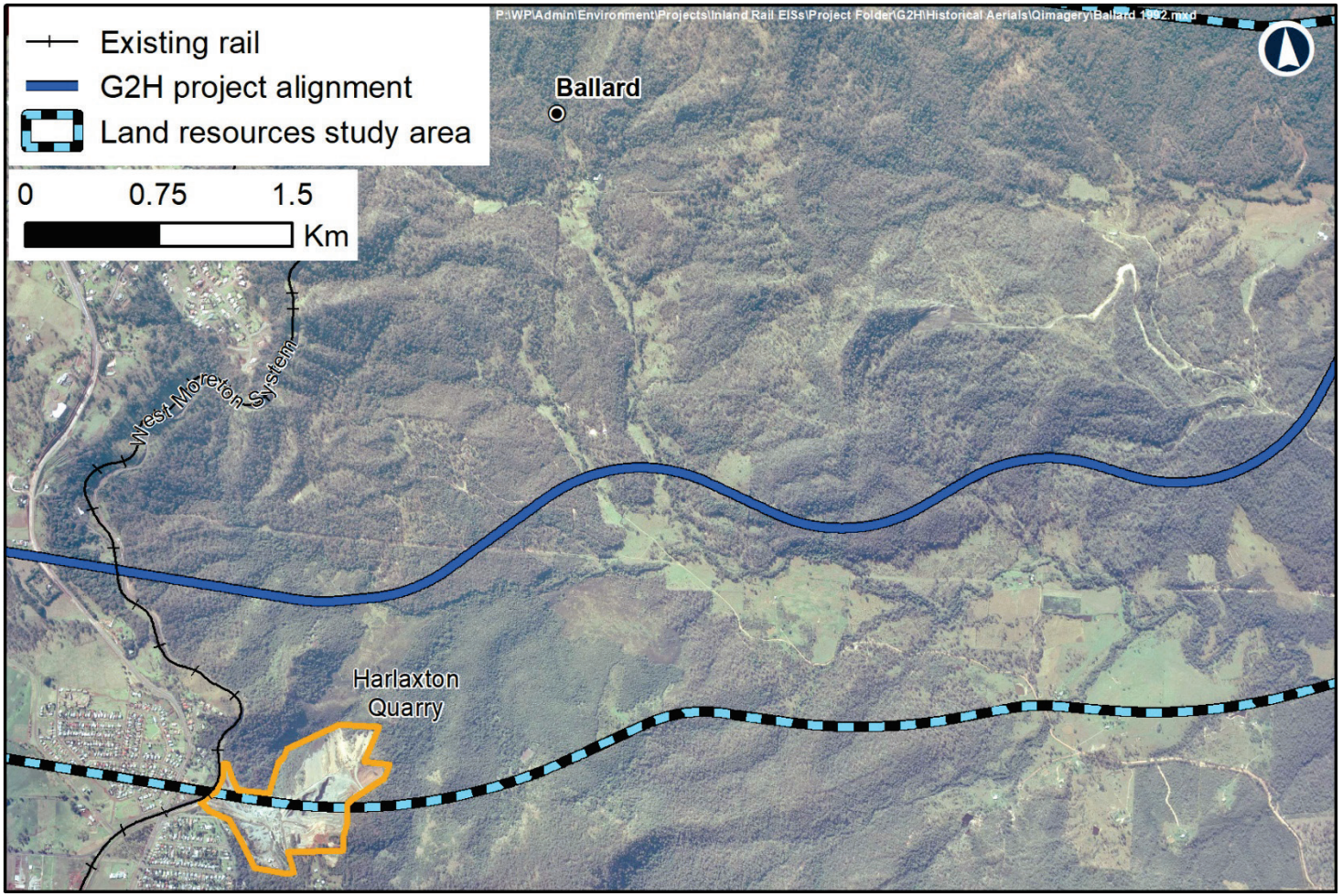
The landscape has several waterways flowing down the ranges and vegetation dominating the region.

The West Moreton System rail corridor can be seen traversing the western edge of the image.

Potential clearing has occurred for the Roma Brisbane Gas Pipeline (constructed 1969) which is evident north and parallel to the Project alignment, north of Harlaxton. Clearing associated with the Mount Lofty Rifle Range is also evident in the image, extending north to the Project alignment.

Source: DNRM (2009).

Land resources study area



Details

Year: 1992

Direction: Aerial

Details: The aerial image displays the land resources study area as it crosses the GDR escarpment from Mount Kynoch into Ballard.

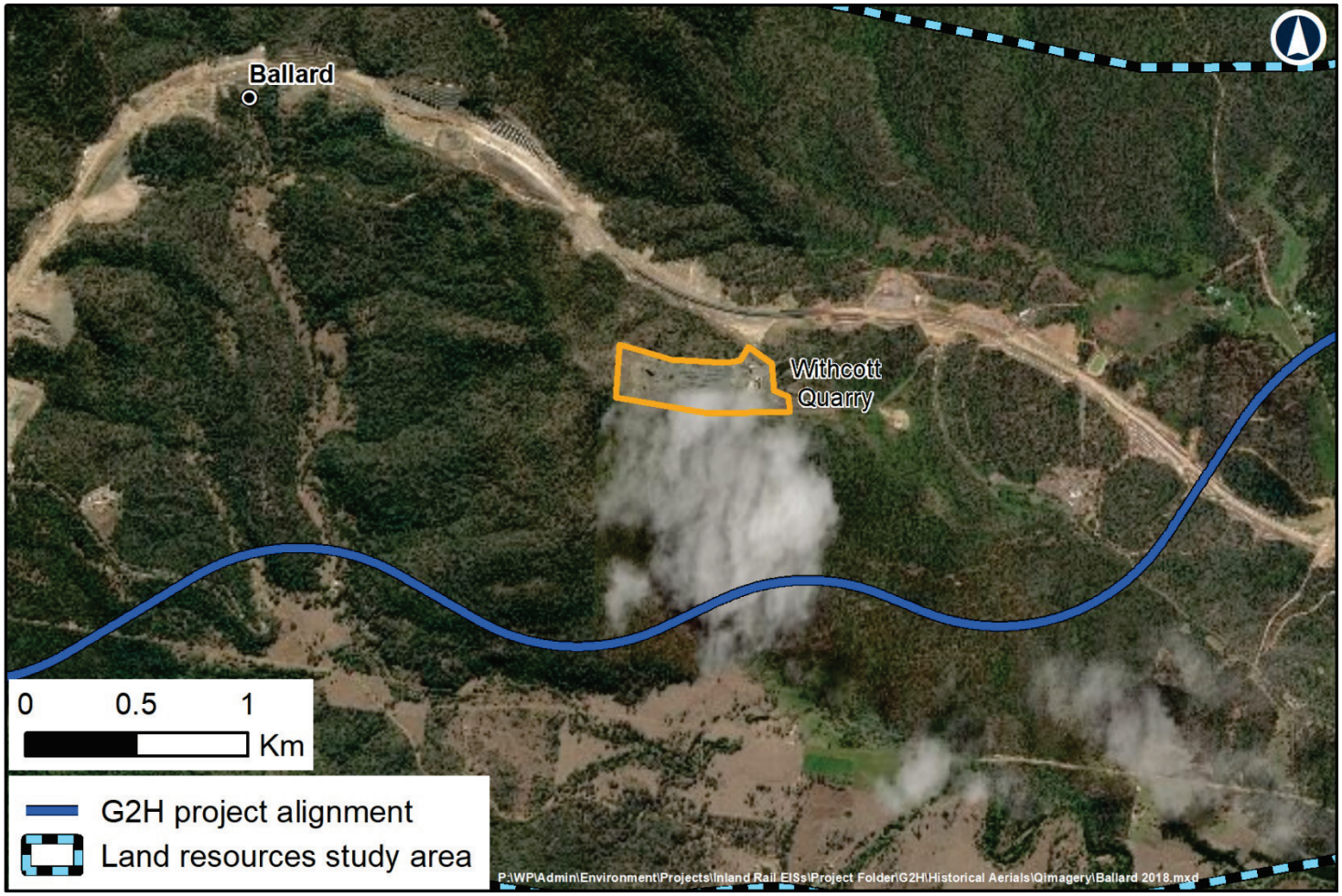
Construction of residential properties adjacent to the West Moreton System rail corridor and expansion of urban areas at Harlaxton has occurred.

Harlaxton Quarry has also begun operations and intersects the land resource study area.

The clearing/alignment for the Roma Brisbane Gas Pipeline (constructed 1969) is evident north and parallel to the Project alignment. The Mount Lofty Rifle Range is no longer evident.

Source: DNRM (1992).

Land resources study area



Details

Year: 2019

Direction: Aerial

Details: The aerial image displays the land resources study area as it crosses the GDR escarpment from Mount Kynoch into Ballard.

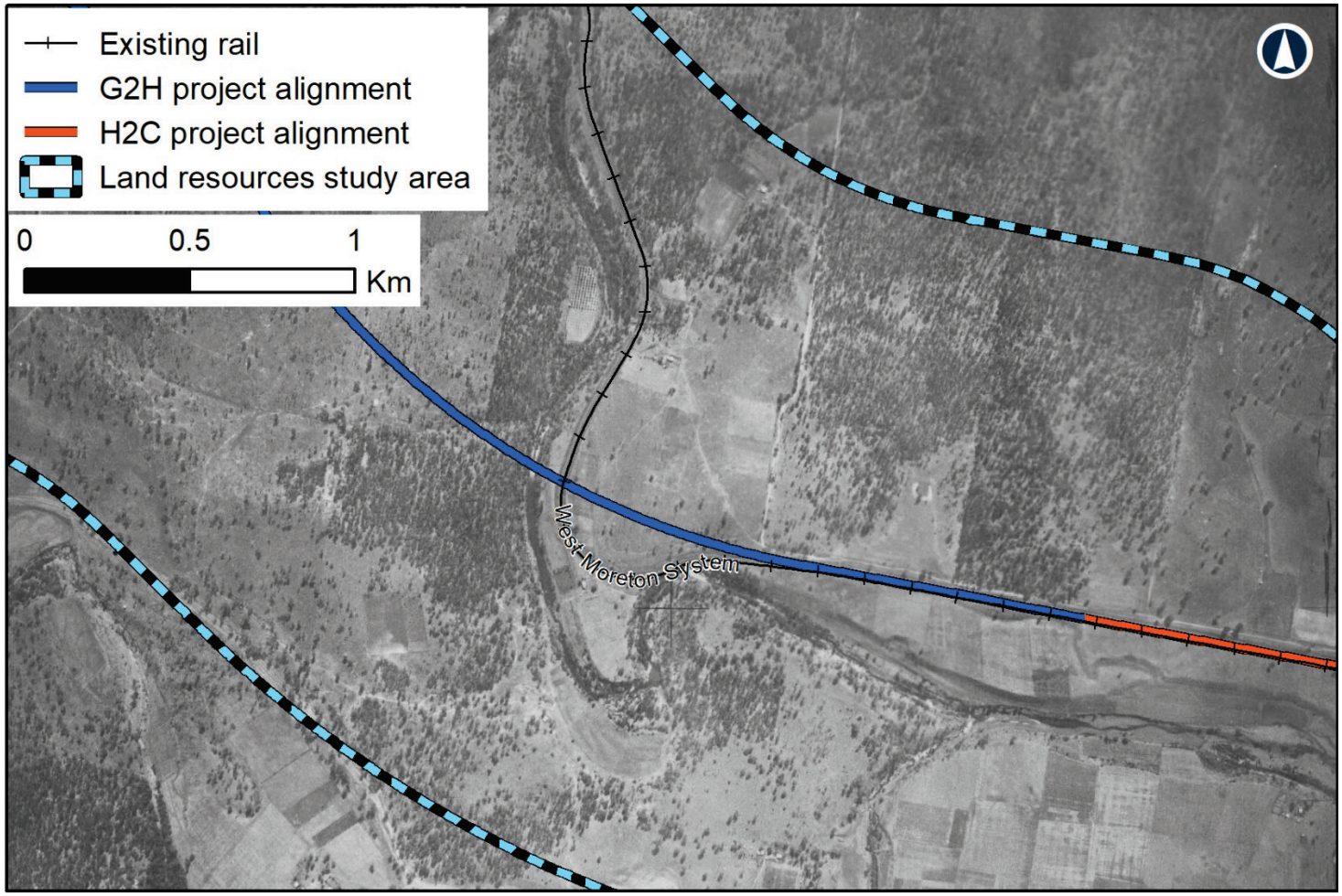
Clearing and construction has begun for the Toowoomba Bypass, which crosses through the land resources study area.

Withcott Quarry has also begun operations and is adjacent the Toowoomba Bypass.

The alignment for the Roma Brisbane Gas Pipeline is also evident predominantly south and parallel to the Project alignment.

Source: Esri (2018).

Land resources study area	Details
Helidon area	



Year: 1933

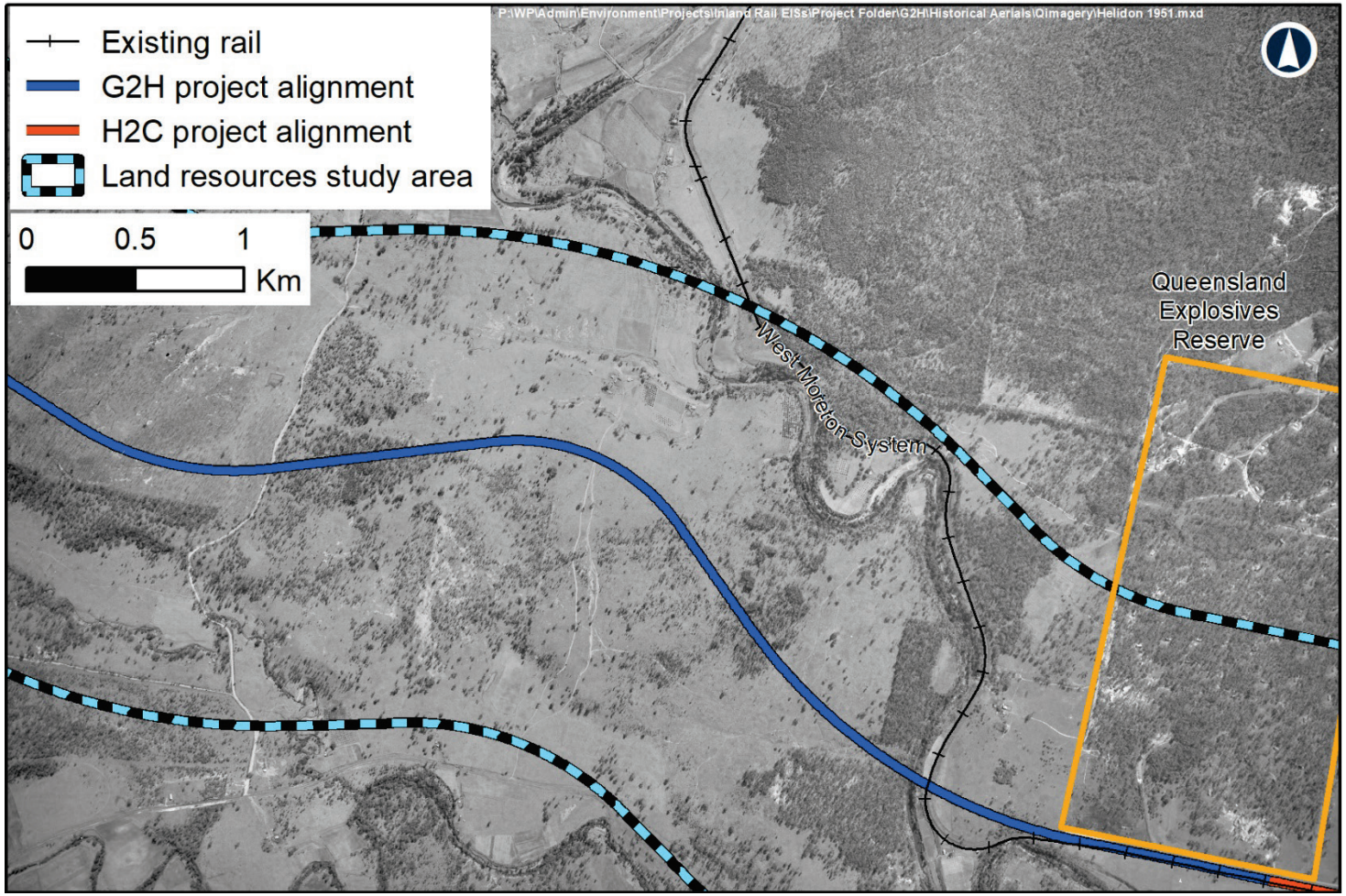
Details:
The aerial image displays the existing West Moreton System rail corridor approaching Helidon from Murphys Creek.

The landscape is dominated by the Lockyer National Park to the north with scattered pastures for grazing and cropping featuring throughout the remaining land resources study area.

A few residential properties feature along the banks of Lockyer and Rocky Creek, which traverse the land resources study area.

Source: DNRME (2019b).

Land resources study area



Details

Year: 1951

Details:

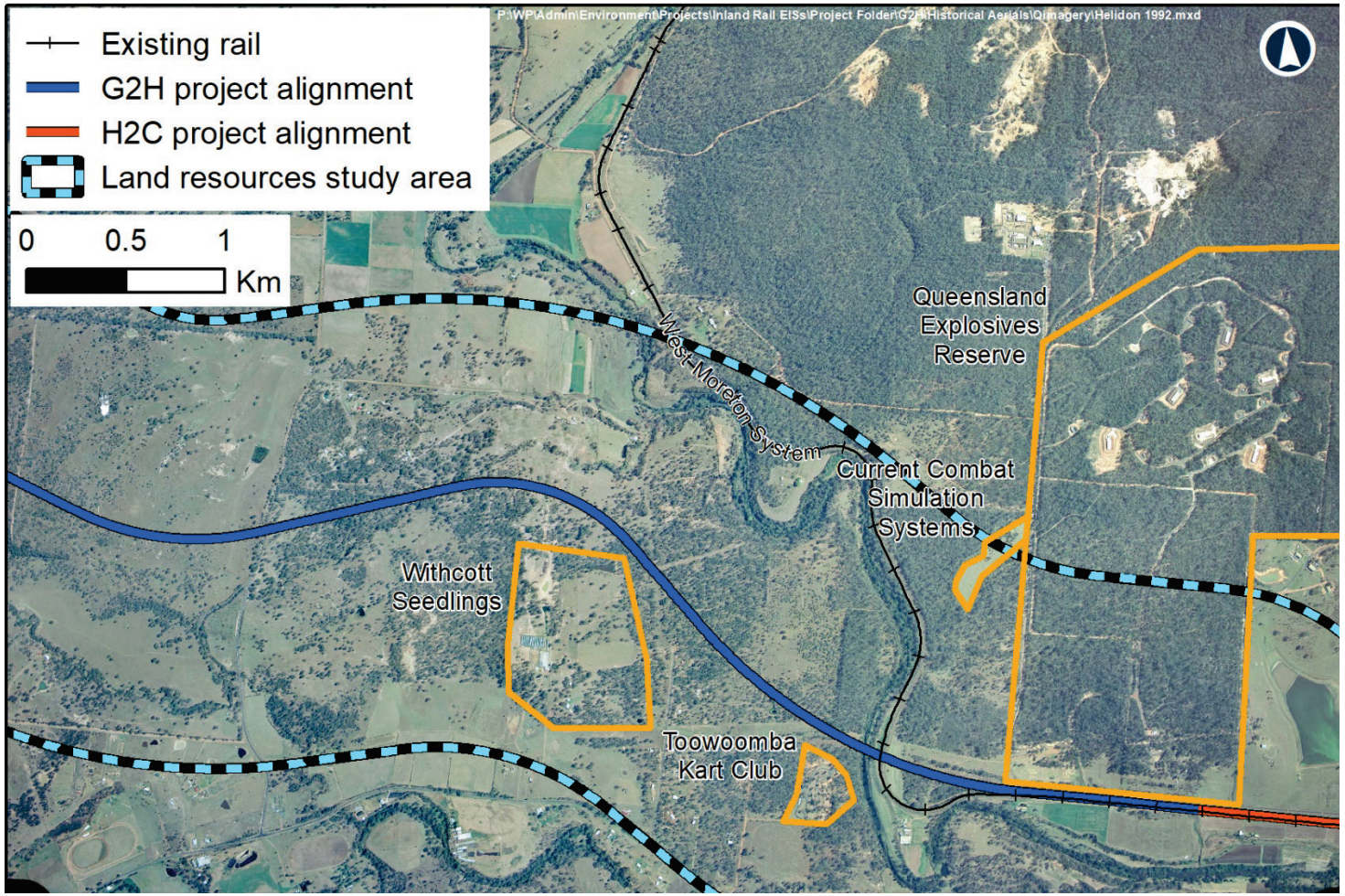
The aerial image displays the existing West Moreton System rail corridor approaching Helidon from Murphys Creek.

Cropping/cultivated land is the dominant land use within the land resources study area.

The Queensland Explosives Reserve is evident and intersects the northern portion of the land resources study area.

Source: DNRM (2009).

Land resources study area



Details

Year: 1992

Details:

The aerial image displays the existing West Moreton System rail corridor approaching Helidon from Murphys Creek.

Several new sites have emerged including the Toowoomba Kart Club, construction of buildings at the Withcott Seedlings site and expansion of the Queensland Explosives Reserve. The current location of the Combat Simulation Systems site has also had clearing along the northern border of the land resources study area.

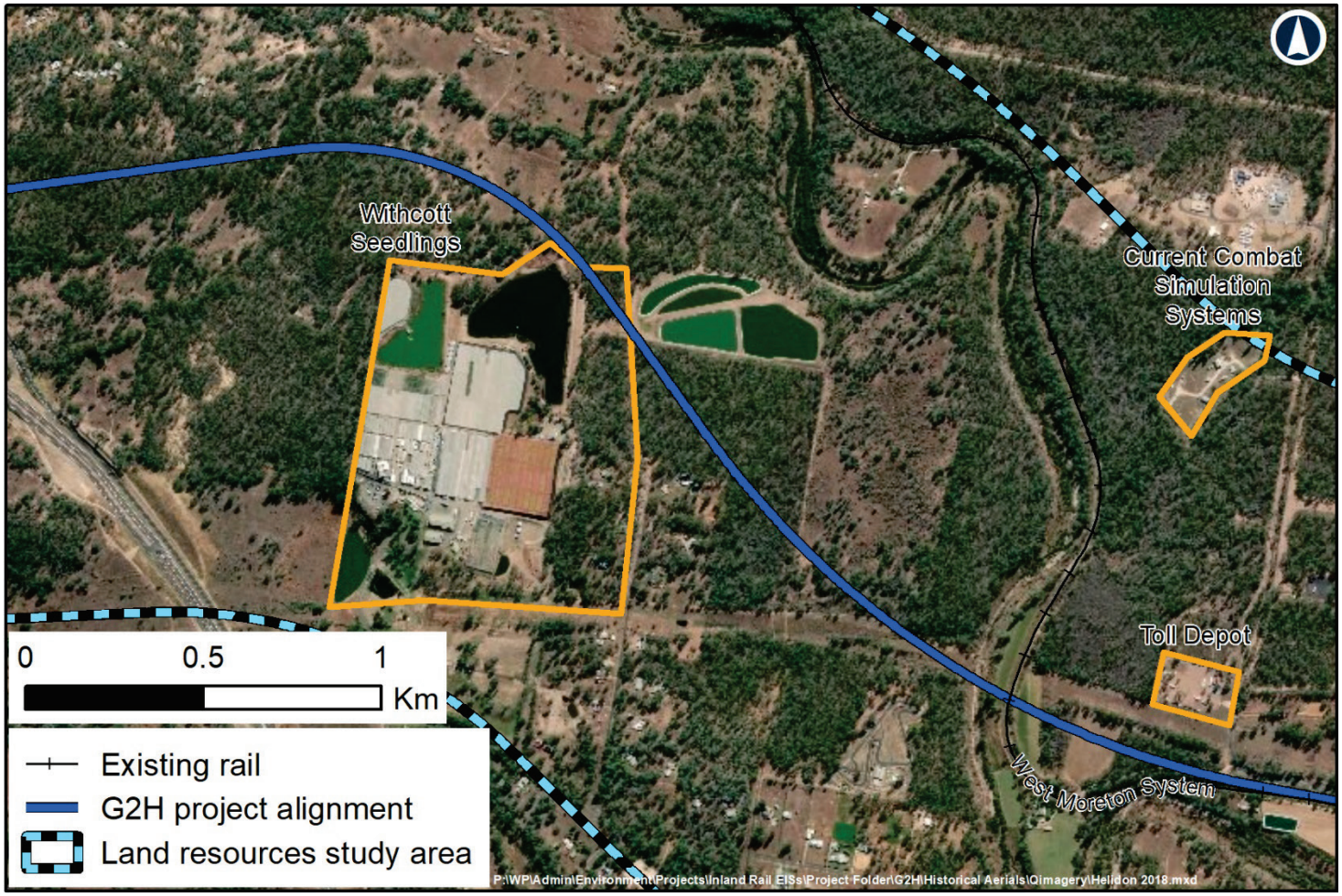
The Roma Brisbane Gas Pipeline alignment is also evident on either side of Lockyer Creek.

The Helidon cattle dip is located in the south-west corner of the Queensland Reserve area but this dip is no longer in use.

Aside from more residential development in the region, no other significant changes have occurred in the land resources study area.

Source: DNRM (2014).

Land resources study area



Details

Year: 2019

Details:

The aerial image displays the existing West Moreton System rail corridor approaching Helidon from Murphys Creek. Withcott Seedlings has expanded operations and features several dams in the land resources study area.

New developments include the Combat Simulation Systems site, Toll Depot along Air Force Road, and Rocky's Own Transport logistic depot adjacent to the northern border of the land resources study area.

No other significant changes have occurred within the land resources study area.

Source: Esri (2019).

Desktop contamination risk summary

Table 9.17 provides a summary of activities or risks identified and considered to be potential sources of contamination in the land resources study area. For the potential impacts to present a risk, there must be a linkage between the three following components:

- Source of contamination
- An exposure pathway
- Environmental values (receptor) that may be affected by this exposure.

Should one or more of these above components be unavailable, or no complete linkage between the three, the risk of exposure to an environmental value is likely to be either minimal or non-existent, due to a break in the linkage between source, pathway and receptor. Where activities pose potential risks to the Project, these activities or risks have been advanced through to the impact assessment. Should further information be obtained during the detailed design phase of the Project, indicating a potential risk is present for any of the activities, further assessment will be required if proposed mitigation measures do not adequately address potential risk.

The potential level of risk for EMR-listed properties has been assessed in Table 9.15.

TABLE 9.17: POTENTIAL EXISTING SOURCES AND IDENTIFIED CONTAMINATION RISKS

Activity	Location	Potential contaminants	Likelihood of occurrence in the land resources study area (based on desktop study)
Within study area			
Agricultural land	Multiple locations throughout the land resources study area	Hydrocarbons (fuel and oil storage and use) (agricultural storage and use)	Potential risk, where Project traverses, adjoins or is adjacent to fuel and oil storage areas, due to distance to agricultural buildings
		Pesticides and herbicides (agricultural storage and use)	Potential risk, where Project traverses, adjoins or is adjacent to storage sheds, due to distance to agricultural land
		Asbestos and lead paint (agricultural buildings/structures)	Potential risk, Project traverses, adjoins or is adjacent to agricultural buildings, due to distance to agricultural buildings
		Livestock dips or spray races arsenic, dichlorodiphenyltrichloroethane (DDT), dichlorodiphenyldichloroethylene (DDE), dichlorodiphenyldichloroethane (DDD) (agricultural storage and use)	Potential risk, where Project traverses, adjoins or is adjacent to livestock dips or spray races, due to distance to agricultural land. This includes the former Helidon cattle dip on Lot 135 on CSH836056.
		Landfilling (agricultural)	Low risk, historical aerials did not identify presence of agricultural landfilling (historic or current)
Housing/ sheds	Multiple locations throughout the land resources study area	Hydrocarbons (fuel and oil storage and use), pesticides and herbicides, lead paint and asbestos (agricultural and residential storage and use)	Potential risk, where Project traverses, adjoins or is adjacent to agricultural and residential storage areas, due to house/shed distance to study area

Activity	Location	Potential contaminants	Likelihood of occurrence in the land resources study area (based on desktop study)
Landfilling/ waste storage/ treatment plants	Multiple locations throughout the land resources study area ▸ Toowoomba Waste Management Centre ▸ Wetalla Sewage Treatment Plant ▸ Mount Kynoch Water Treatment Plant	▸ Hazardous materials, hydrocarbons, metals/metalloids, phenols, polychlorinated biphenyls, phthalates, volatiles and pesticides and herbicides (local council or commercial enterprise)	Potential risk, due to EMR-listed properties: ▸ The Project traverses under the Toowoomba Waste Management Centre (172SP227269, landfill) ▸ The Project is adjacent to Wetalla Sewage Treatment Plant (1SP270010, waste storage) ▸ The Project, is approximatively 600 m south of the Mount Kynoch Water Treatment Plant (196RP845660, chemical storage).
Quarrying operations	Harlaxton Quarry and Withcott Quarry (no longer operating)	Petroleum hydrocarbons (benzene, toluene, xylene, naphthalene), lead and other heavy metals/metalloids (Commercial enterprise)	Potential risk, due to EMR-listed property for petroleum or oil storage: ▸ 2RP844703 ▸ Limited risk is posed, as well displaced from the Project; however, the Project traverses greenfield sections of Harlaxton Quarry and is adjacent to Withcott Quarry.
Rail corridor/ railway yard	▸ West Moreton System rail corridor ▸ Adjacent Harlaxton Quarry	PAHs, metals/metalloids, asbestos, hydrocarbons, pesticides/herbicides (railway land use/ railway yard)	Potential risk, as the Project overlaps existing and former rail corridor lands including six land parcels on the EMR (Hazardous Contaminant. The other land parcels may also be contaminated due to similar historic land use. The Project also intersects EMR listed property for railway yard: ▸ 452SP117138 (Main Line) ▸ Limited risk is posed from 918RP844703, which is listed on the EMR due to the presence of a former railway yard.
Roads	Refer Chapter 19: Traffic, Transport and Access, Section 19.5.2.	Metals, hydrocarbons, pesticides/herbicides (public roads)	▸ Potential risk, due to identified presence of roads
'Other' UXO areas	▸ UXO area east of Ballard ▸ Mount Lofty Rifle Range	UXO	Potential risk, as the Project traverses these two potentials UXO areas. The Project is also in close proximity to the Queensland Explosive Reserve at Helidon.
Industrial (explosive production)	Queensland Government explosives reserve—north of Helidon	Explosives and associated chemicals (e.g. ammonium, metals/metalloids, nitrate/nitrite, sulfates, azides, other organic/inorganic compounds)	Potential risk, with the Project directly adjacent to 125CP907566, which is listed on the EMR (Explosives production or storage).
Unknown fill material	Existing and former rail corridor	Asbestos, metals/metalloids, arsenic, PAHs, hydrocarbons (railway land use)	▸ Low risk, anthropogenic materials not observed during geotechnical and soil investigation

9.6.6.2 Preliminary site investigation

Background

Following a desktop assessment of potential contamination sources in the land resources study area, in Section 9.6.6.1, Aurecon (2020) completed a Tier 1 preliminary site investigation (PSI) of properties along the Inland Rail alignment between Gowrie and Kagaru (G2K) (which included the G2H, Helidon to Calvert (H2C), and Calvert to Kagaru (C2K) projects) with a current environmental authority and/or are registered on the EMR. The PSI also targeted other key areas, such as watercourse crossings and road reserves, where applicable. The former tannery on Lot 2 on RP144734, Cranley was also targeted with the landholder advising that the property was previously registered on the EMR for the operation of a tannery or fellmongery, or hide curing works or commercially finishing leather.

The PSI undertaken by Aurecon (2020) was to identify potential exposure risks to human health and the environment from potentially contaminated soil and sediment within the G2K disturbance footprint. The findings from the PSI were used to inform a Conceptual Site Model (CSM) and identify potential locations that may require further investigation or management during the construction phase of the Project.

Preliminary site investigation methodology

A summary of the soil and sediment sampling methodology adopted for the PSI is provided in Table 9.18, with the sample location illustrated in Figure 9.17.

The number and location of the sampling locations considered professional judgement based on a range of factors, including age of potential contamination, potentially contaminating activity and distance to the Project disturbance footprint, among others.

TABLE 9.18: SUMMARY OF SOIL AND SEDIMENT SAMPLING METHODOLOGY RELEVANT TO THE PROJECT

Activity	Details
Drilling	All soil sampling locations were advanced using a hand auger to a depth of 0.5 m bgl or until refusal. Generally, two samples were collected per location at surface (ground level–0.1 m bgl) and at depth (0.30.5 m bgl). All sediment samples were collected using a trowel from surface (ground level–0.1 m bgl).
Soil logging	Soils encountered were visually examined, logged and photographed in accordance with the Unified Soil Classification System
Soil sampling	The following primary soil samples were collected at three properties that were listed on the EMR: ▸ Property A (172SP227269): Landfill—16 samples ▸ Property B (1SP270010): Waste storage, treatment or disposal—4 samples ▸ Property C (2RP144734): Operating a tannery or fellmongery or hide curing works or commercially finishing leather—10 samples The following primary soil samples were collected from road reserves: ▸ G2K_HA102 (Gowrie Junction Road, Gowrie Junction)—2 samples ▸ G2K_HA103 (Morris Road, Gowrie Junction)—2 samples ▸ G2K_HA104 (Morris Road, Gowrie Junction)—1 sample ▸ G2K_HA105 (Wallens Road, Ballard)—2 samples ▸ G2K_HA106 (Jones Road, Ballard)—2 samples ▸ G2K_HA107 (McNamaras Road, Withcott)—2 samples ▸ G2K_HA108 (Cattos Road/Main Line level crossing, Helidon)—1 sample ▸ G2K_HA109 (Airforce Road, Helidon)—1 sample
Sediment sampling	Three sediment samples were collected from the following key watercourse crossing locations: ▸ G2K_SD07 (Gowrie Creek) ▸ G2K_SD08 (Oaky Creek) ▸ G2K_SD09 (Six Mile Creek)

Activity	Details
Laboratory	Soil and sediment samples were analysed by NATA accredited laboratories, ALS (primary) and Eurofins (secondary). Soil samples were analysed for one or more of the following analytes: ▸ Metals/metalloids ▸ Hydrocarbons (including total recoverable hydrocarbons (TRH) and PAH) ▸ Benzene, toluene, ethylbenzene, xylene and naphthalene (BTEXN) ▸ Asbestos (presence/absence) ▸ Organochlorine pesticides (OCPs) ▸ Organochlorine pesticides (OPP) ▸ Polychlorinated biphenyls (PCBs), phenols, phthalates ▸ Phenoxy acid herbicides ▸ Volatile and semi-volatile organic compounds (VOCs and SVOCs) ▸ Solvents ▸ Nitrogen, phosphate and ammonia

The Aurecon (2020) PSI adopted the screening criteria detailed in Table 9.19 for human health and ecological investigation levels. Residential land use provides the most sensitive land use type for human health investigation levels (HILs), while open space land use considers greater exposure to soil and outdoor environments. An assessment against the HILs for commercial/industrial land uses was also undertaken, as it is reflective of general construction activities and future land use.

TABLE 9.19: AURECON (2020) PSI ADOPTED SCREENING CRITERIA

Media	Screening criteria
Soil	ASC NEPM (2013) HIL—residential (A)
	ASC NEPM (2013) HIL—open space (C)
	ASC NEPM (2013) HIL—commercial/industrial (D)
	ASC NEPM (2013) ecological investigation level (EIL)—residential
Sediment	ANZG (2018) default guideline values (DGV) ANZG (2018) additional upper guideline value (GV-high)

Findings

Aurecon (2020) described the surface conditions of soil from sampling locations in the Project disturbance footprint to generally vary between silty sand, sandy clay, clayey sand and silty clay, to a depth of 0.5 m bgl. Soil colour in the area also varied between brown to dark brown colour throughout the profile. The soil contained fine-to-coarse grained sand and gravel, and regular clay pockets.

Ammonia and methane odours were noted on Property C and particularly evident at G2K_HA12, located above a landfill where potential waste materials from the former tannery operations may be buried and contained. No soil staining, hydrocarbon odours or asbestos-containing materials were evident during the investigation.

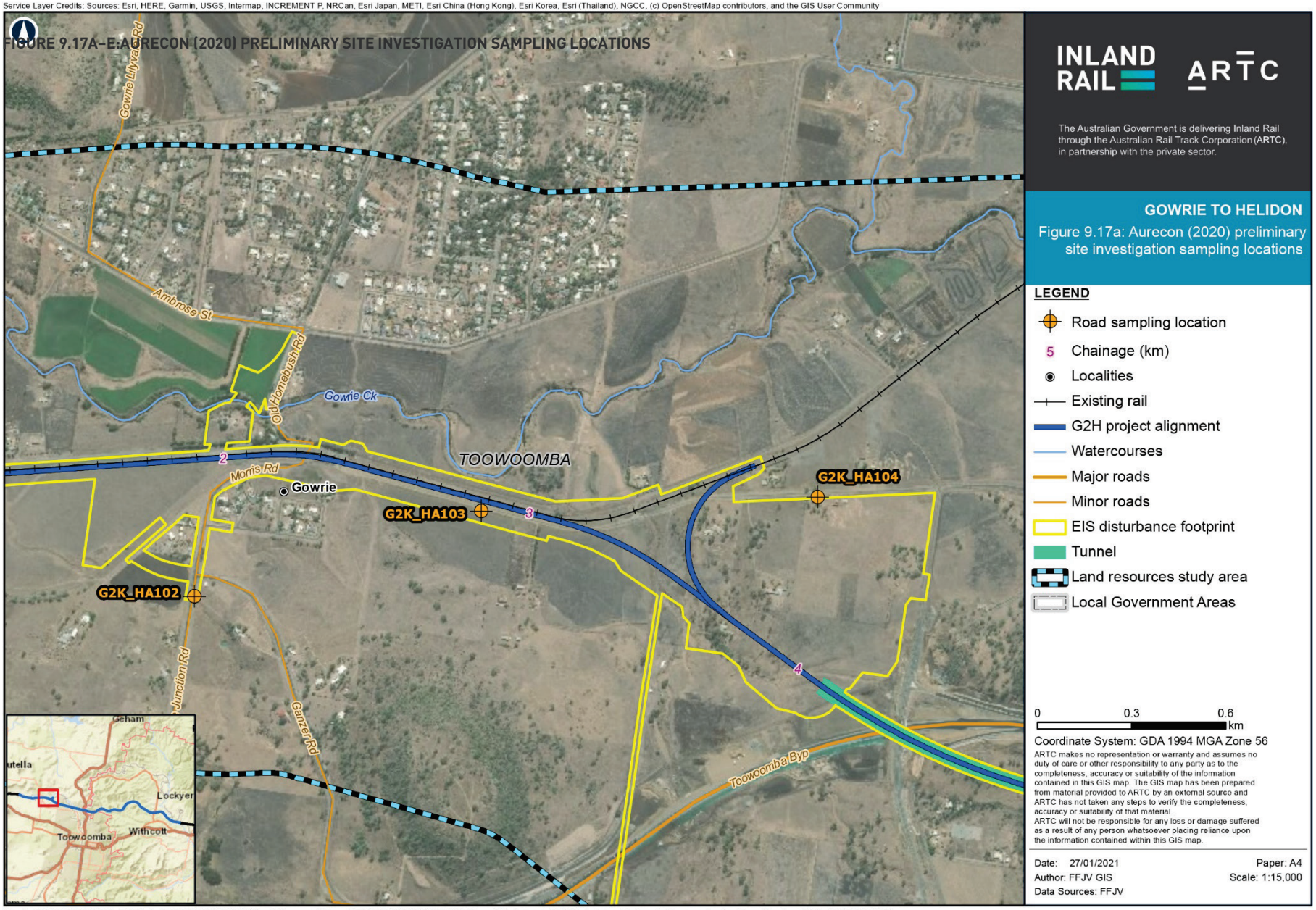
Table 9.20 provides a summary of the laboratory results that exceeded the adopted human health and ecological investigation levels, following soil and sediment sampling within the G2K disturbance footprint. Detailed laboratory results from the Aurecon (2020) PSI are provided in Appendix X: EMR Search Certificates and Laboratory Certificates.

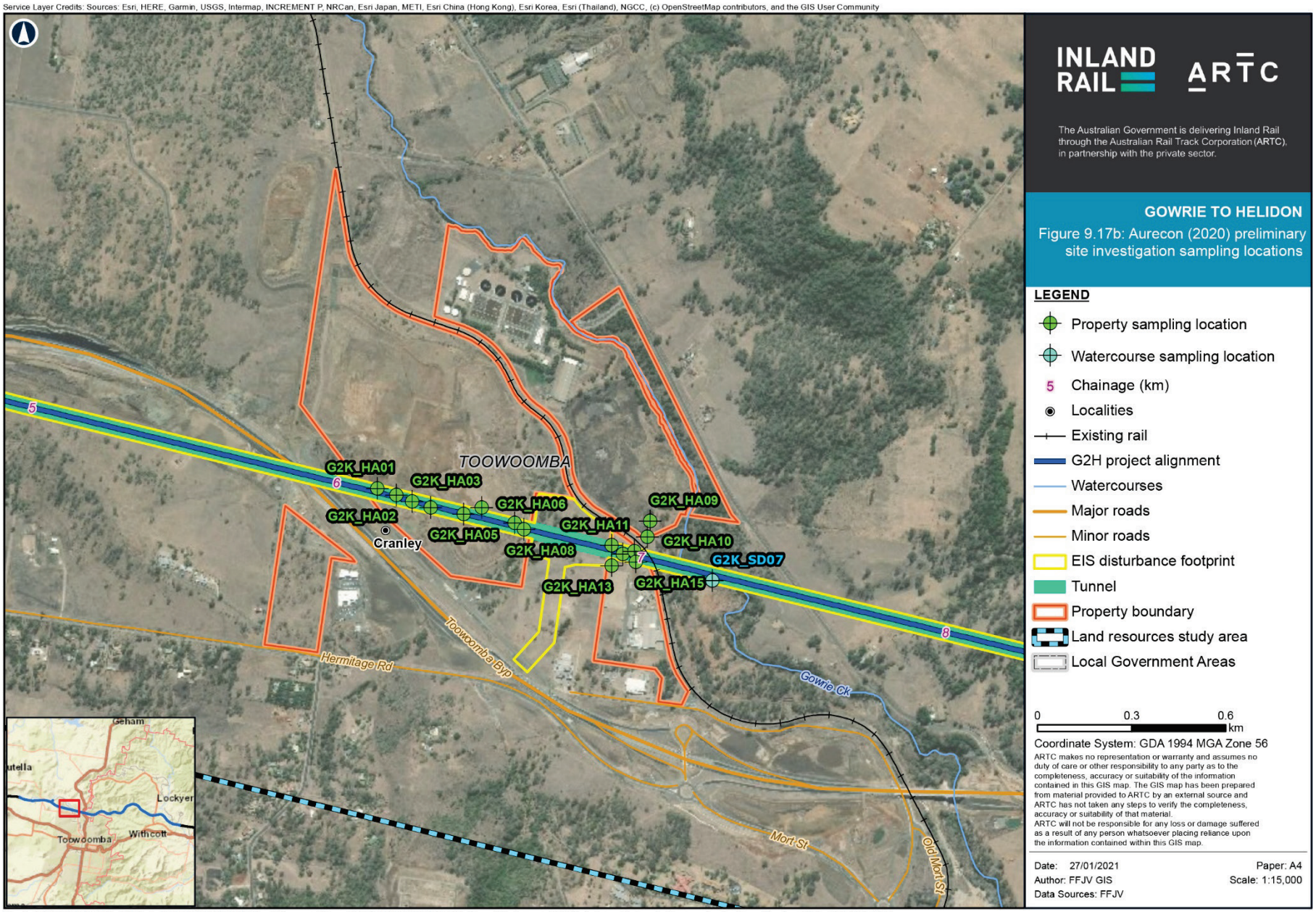
TABLE 9.20: SUMMARY OF AURECON (2020) LABORATORY RESULTS THAT EXCEEDED HUMAN HEALTH AND ECOLOGICAL INVESTIGATION LEVELS

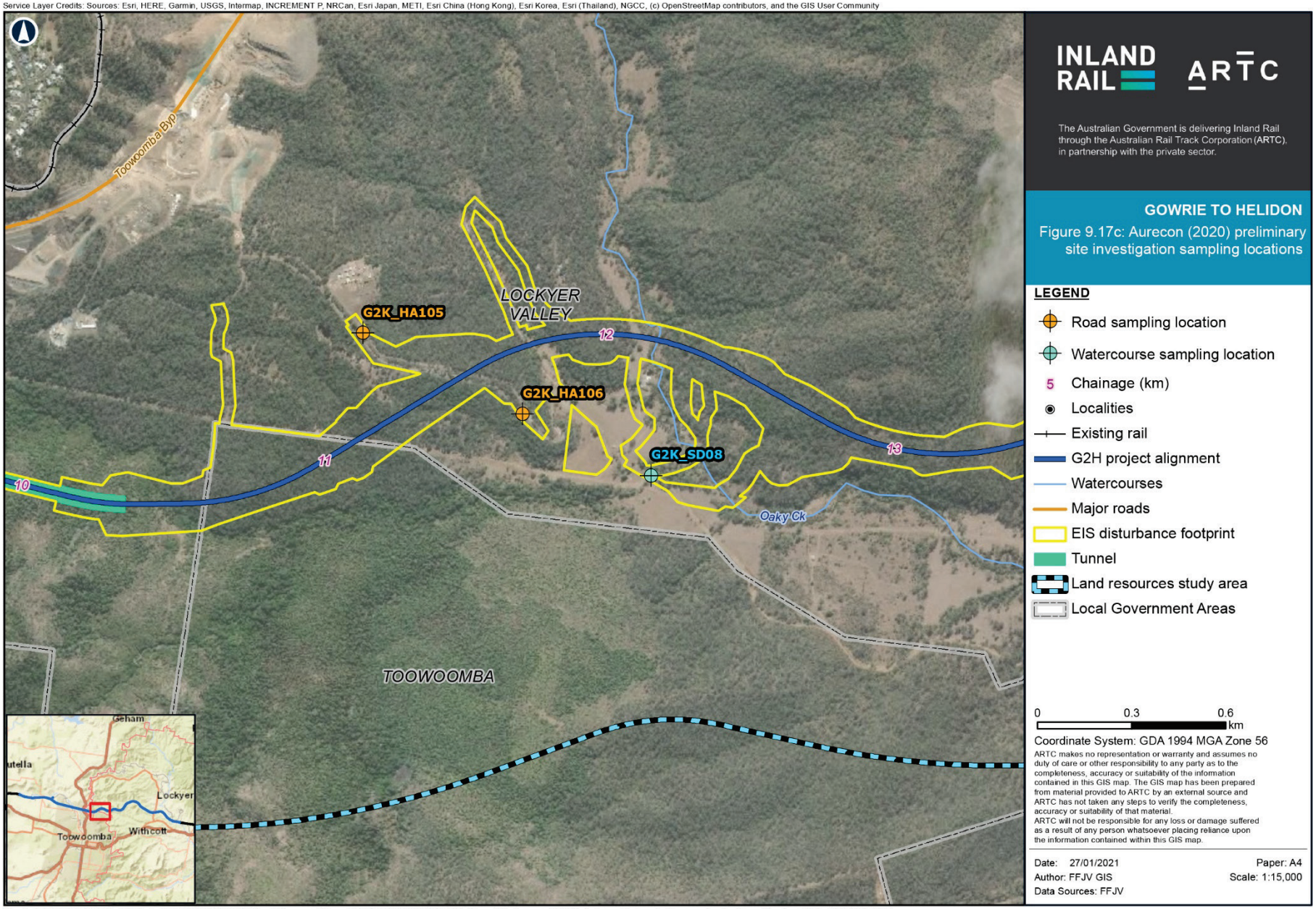
Location	Screening criteria exceedance	Comments
Property A (172SP227269)	▸ HIL (A): ▸▸ Lead—1 sample (G2K_HA07_0.0-0.3m) ▸ EIL (A): ▸▸ Chromium (III)—1 sample (G2K_QC201_200831/ G2K_HA06_0.4-0.5m) ▸▸ Nickel—16 samples (including 2 QA samples) ▸▸ Zinc—8 samples	▸ Lead was above the HIL (A) with a concentration of 409 mg/kg ▸ Chromium (III) at concentrations above EIL (A) with a maximum concentration of 230 mg/kg ▸ All samples (including QA) had nickel concentrations above the EILs at surface and depth ▸ Zinc concentrations exceeded EILs predominantly in surface samples (<0.3 m bgl), with the exception of G2K_HA08_0.3–0.4m (77 mg/kg)
Property B (1SP270010)	▸ EIL (A): ▸▸ Copper—1 sample (G2K_HA09_0.0-0.1m) ▸▸ Nickel—4 samples ▸▸ Zinc—3 samples	▸ Copper concentration was above EILs with a concentration of 231 mg/kg ▸ Nickel at concentrations above EILs with a maximum concentration of 249 mg/kg (G2K_HA09_0.4–0.5 m) ▸ Zinc at concentrations above EILs with a maximum concentration of 621 mg/kg (G2K_HA09_0.0–0.1m)
Property C (2RP144734)	▸ EIL (A): ▸▸ Chromium (III)—9 samples ▸▸ Nickel—10 samples ▸▸ Zinc—9 samples	▸ Chromium (III) above EIL (A) at all sample locations on Property C with the exception of G2K_HA12_0.0–0.1 m, with a concentration of 128 mg/kg. The maximum chromium (III) concentration was 18,800 mg/kg from G2K_HA14_0.3–0.4 m ▸ All samples collected at Property C had nickel concentrations above EILs, with a maximum concentration of 146 mg/kg (G2K_HA12_0.0–0.1 m) ▸ All but one sample (G2K_HA11_0.4–0.5m) collected at Property C had zinc concentrations above EILs, with a maximum concentration of 346 mg/kg (G2K_HA12_0.4–0.5 m)
Road reserves	▸ EIL (A): ▸▸ Nickle—8 samples (including QA samples) ▸▸ Zinc—2 samples (including QA sample)	▸ Nickel was detected at concentrations above the EILs (30 mg/kg) with a maximum concentration of 210 mg/kg at G2K_HA103_0.0–0.1 m ▸ Zinc was detected at concentrations above the EILs (70 mg/kg) with a maximum concentration of 77 mg/kg at G2K_QC201_200901
Key watercourse crossing	▸ Sediment GV-high: ▸▸ Nickel—2 samples ▸ Sediment DGV: ▸▸ Nickel—2 samples ▸▸ Chromium—1 sample (G2K_SD07_0.0–0.1m)	▸ Nickel was detected at concentrations above the GV-high (52 mg/kg) and the DGV (21 mg/kg) at Gowrie Creek (G2K_SD07_0.0–0.1m) with a concentration of 99 mg/kg and at Oaky Creek (G2K_SD08_0.0–0.1 m) with a concentration of 100 mg/kg ▸ Chromium (III) was detected at concentrations above the DGV (80 mg/kg), with a maximum concentration of 99 mg/kg at Gowrie Creek

Management measures are provided in the Aurecon (2020) *Preliminary Site Investigation Report* and in Section 9.8.2, following the limited sampling investigation undertaken. The samples collected from the road reserve exceeded the HIL (A) but were below the more appropriate HIL (C) and (D) criteria.

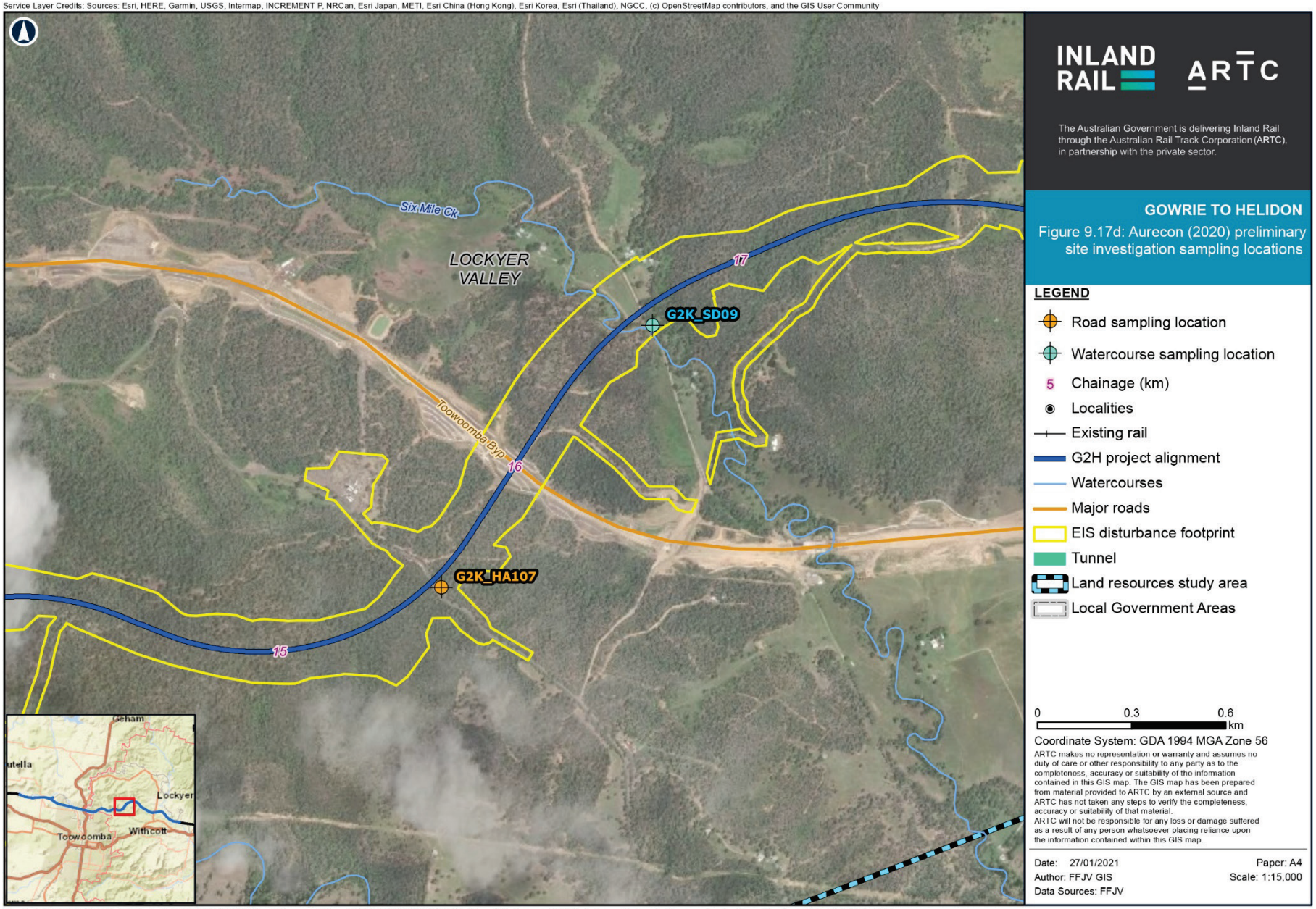
Exceedances of the sediment samples at key watercourse crossing may potentially be due to land uses activities upstream of the rail corridor.


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FIGURE 9.17A–E: AURECON (2020) PRELIMINARY SITE INVESTIGATION SAMPLING LOCATIONS
Gowrie Lilyvale Rd
Ambrose St
Old Homebush Rd
Gowrie Ck
TOOWOOMBA
Morris Rd
Gowrie
G2K_HA104
G2K_HA103
G2K_HA102
Junction Rd
Ganzer Rd
Toowoomba Byp
2
3
4
Geham
Lockyer
Withcott
Toowoomba
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GOWRIE TO HELIDON
Figure 9.17a: Aurecon (2020) preliminary site investigation sampling locations
LEGEND
Road sampling location
Chainage (km)
Localities
Existing rail
G2H project alignment
Watercourses
Major roads
Minor roads
EIS disturbance footprint
Tunnel
Land resources study area
Local Government Areas
0 0.3 0.6 km
Coordinate System: GDA 1994 MGA Zone 56
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Author: FFJV GIS
Data Sources: FFJV
Paper: A4
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Map by: TM Z:\GIS\GIS_3200_G2H\Tasks\320-EAP-201807091155_Land_Resource_Figures\320-EAP-201807091155_G2H_Figure 9.16_Aurecon_2020_Preliminary_site_investigation_sampling_locations_A4_v1.mxd Date: 27/01/2021 12:28


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ARTC
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GOWRIE TO HELIDON
Figure 9.17b: Aurecon (2020) preliminary site investigation sampling locations
LEGEND
Property sampling location
Watercourse sampling location
Chainage (km)
Localities
Existing rail
G2H project alignment
Watercourses
Major roads
Minor roads
EIS disturbance footprint
Tunnel
Property boundary
Land resources study area
Local Government Areas
TOOWOOMBA
Cranley
G2K_HA01
G2K_HA02
G2K_HA03
G2K_HA05
G2K_HA06
G2K_HA08
G2K_HA09
G2K_HA10
G2K_HA11
G2K_HA13
G2K_HA15
G2K_SD07
Hermitage Rd
Toowoomba Byp
Gowrie Ck
Mort St
Old Mort St
Geham
Lockyer
Withcott
Toowoomba
0 0.3 0.6 km
Coordinate System: GDA 1994 MGA Zone 56
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Toowoomba Byp
LOCKYER VALLEY
G2K_HA105
G2K_HA106
G2K_SD08
10
11
12
13
Oaky Ck
TOOWOOMBA
Geham
utella
Lockyer
Toowoomba
Withcott
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GOWRIE TO HELIDON
Figure 9.17c: Aurecon (2020) preliminary site investigation sampling locations
LEGEND
Road sampling location
Watercourse sampling location
5 Chainage (km)
Localities
Existing rail
G2H project alignment
Watercourses
Major roads
EIS disturbance footprint
Tunnel
Land resources study area
Local Government Areas
0 0.3 0.6 km
Coordinate System: GDA 1994 MGA Zone 56
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Data Sources: FFJV
Map by: TM Z:\GIS\GIS_3200_G2H\Tasks\320-EAP-201807091155_Land_Resource_Figures\320-EAP-201807091155_G2H_Figure 9.16_Aurecon_2020_Preliminary_site_investigation_sampling_locations_A4_v1.mxd Date: 27/01/2021 12:28

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GOWRIE TO HELIDON

Figure 9.17d: Aurecon (2020) preliminary site investigation sampling locations

LEGEND

- Road sampling location
- Watercourse sampling location
- 5 Chainage (km)
- Localities
- Existing rail
- G2H project alignment
- Watercourses
- Major roads
- EIS disturbance footprint
- Tunnel
- Land resources study area
- Local Government Areas

0 0.3 0.6 km

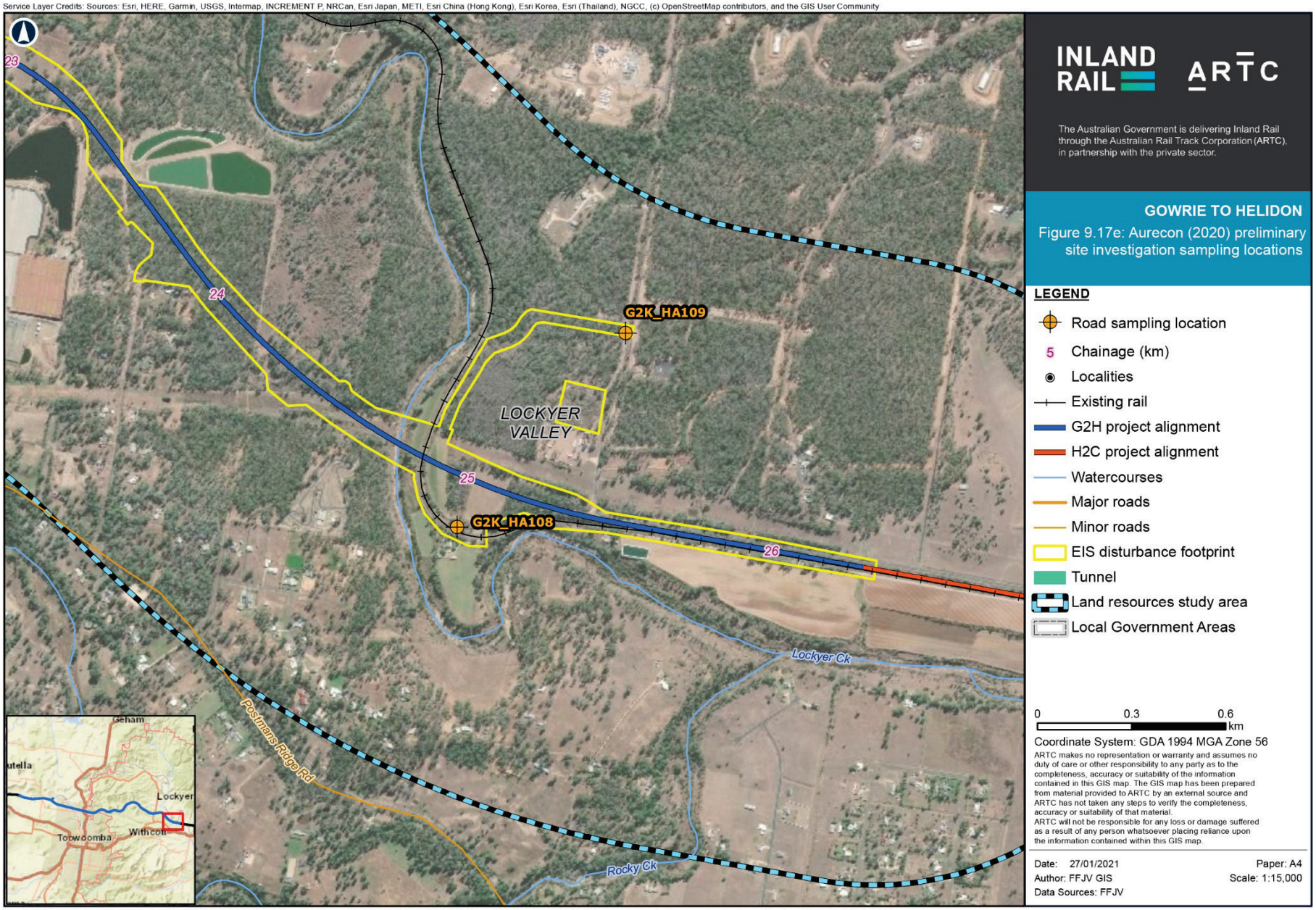
Coordinate System: GDA 1994 MGA Zone 56

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Data Sources: FFJV

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Map by: TM Z:\GIS\GIS_3200_G2H\Tasks\320-EAP-201807091155_Land_Resource_Figures\320-EAP-201807091155_G2H_Figure 9.16_Aurecon_2020_Preliminary_site_investigation_sampling_locations_A4_v1.mxd Date: 27/01/2021 12:28


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23
24
25
26
G2K_HA109
G2K_HA108
LOCKYER VALLEY
Lockyer Ck
Postmans Ridge Rd
Rocky Ck
Geham
Lockyer
Toowoomba
Withcott
INLAND RAIL
ARTC
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GOWRIE TO HELIDON
Figure 9.17e: Aurecon (2020) preliminary site investigation sampling locations
LEGEND
Road sampling location
Chainage (km)
Localities
Existing rail
G2H project alignment
H2C project alignment
Watercourses
Major roads
Minor roads
EIS disturbance footprint
Tunnel
Land resources study area
Local Government Areas
0
0.3
0.6
km
Coordinate System: GDA 1994 MGA Zone 56
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Data Sources: FFJV
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9.6.6.3 Golder contaminated land investigation

Background

Golder Associates Pty Ltd (Golder) (2020) undertook a preliminary soil contamination assessment of the Inland Rail alignment between Gowrie and Kagaru. The soil contamination assessment was developed to identify potential areas and contaminants of concern, as well as understanding data gaps to inform additional investigations.

The sampling locations for the Golder (2020) contamination assessment generally targeted areas where enhancements or upgrades to existing tracks are proposed, including where the Project is co-located with the Western Line and Main Line (of the West Moreton System).

Contaminated land investigation methodology

Selection of soil sampling locations was not based on a site history review of the alignment or identification of potential contaminant sources.

Between December 2019 and January 2020, soil samples were collected for analysis (ground level to 0.1 m bgl) from 26 test pit locations within the West Moreton System rail corridor relevant to the Project (refer Figure 9.18). An additional 11 locations were sampled in October 2020 (18 soils samples in total), using a truck-mount drill rig to a maximum depth of 0.5 m bgl.

Soil samples were analysed by ALS (primary) and Eurofins (secondary), NATA accredited laboratories, for similar analytes to those targeted in the Aurecon (2020) PSI, refer Table 9.19. Detailed laboratory results from the Golder (2020) contamination assessment are provided in Appendix X: EMR Search Certificates and Laboratory Certificates.

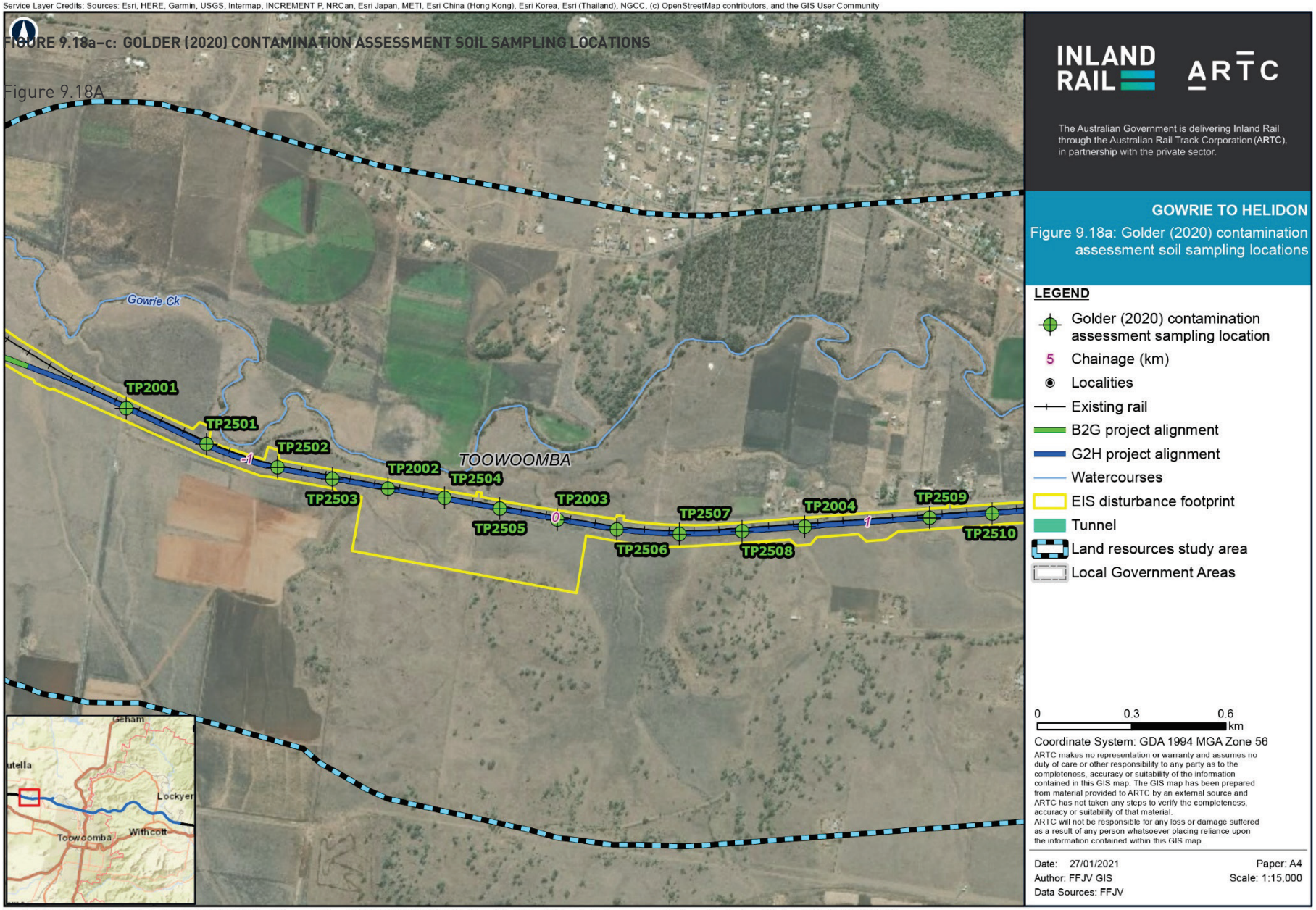
The Golder (2020) contamination assessment adopted the following ASC NEPM (2013) screening criteria:

- Health investigation and screening levels—commercial/industrial and low-density residential
- Ecological investigation and screening level—commercial/industrial and residential.

Findings

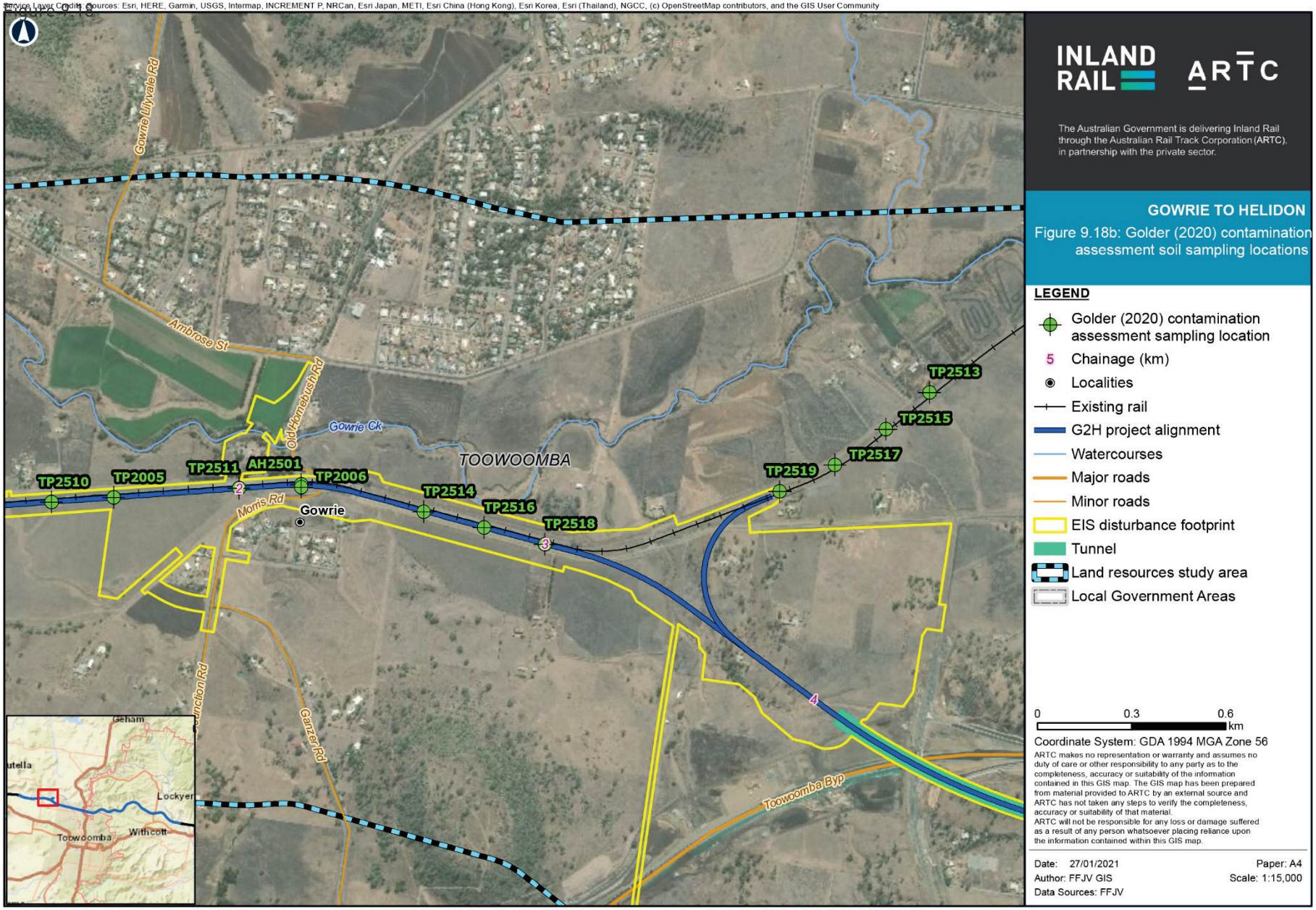
The key findings from the two sampling events are summarised below:

- No exceedances of the guidelines for commercial or industrial settings were noted across both sampling events, including the lots listed on the EMR (Hazardous Contaminants); however, an exceedance of the residential guidelines was noted at test pit 320-02-TP2006 on Lot 2 on RP34879, which is listed on the EMR (Hazardous Contaminants):
  - Lead concentrations exceeded the adopted residential human health investigation level (300 mg/kg), with a concentration of 361 mg/kg
  - Benzo(a)pyrene concentration exceeded the adopted ecological screening level for urban residential and public open space (0.7 mg/kg), with a concentration of 1 mg/kg.
- Detectable concentrations of heavy metals, such as arsenic, chromium, copper and lead, were generally reported at all locations and were consistent with natural levels.
- No asbestos was detected in any of the soil samples
- Visual observations did not identify any odours or staining in soil to indicate possible contamination or potential asbestos-containing materials.

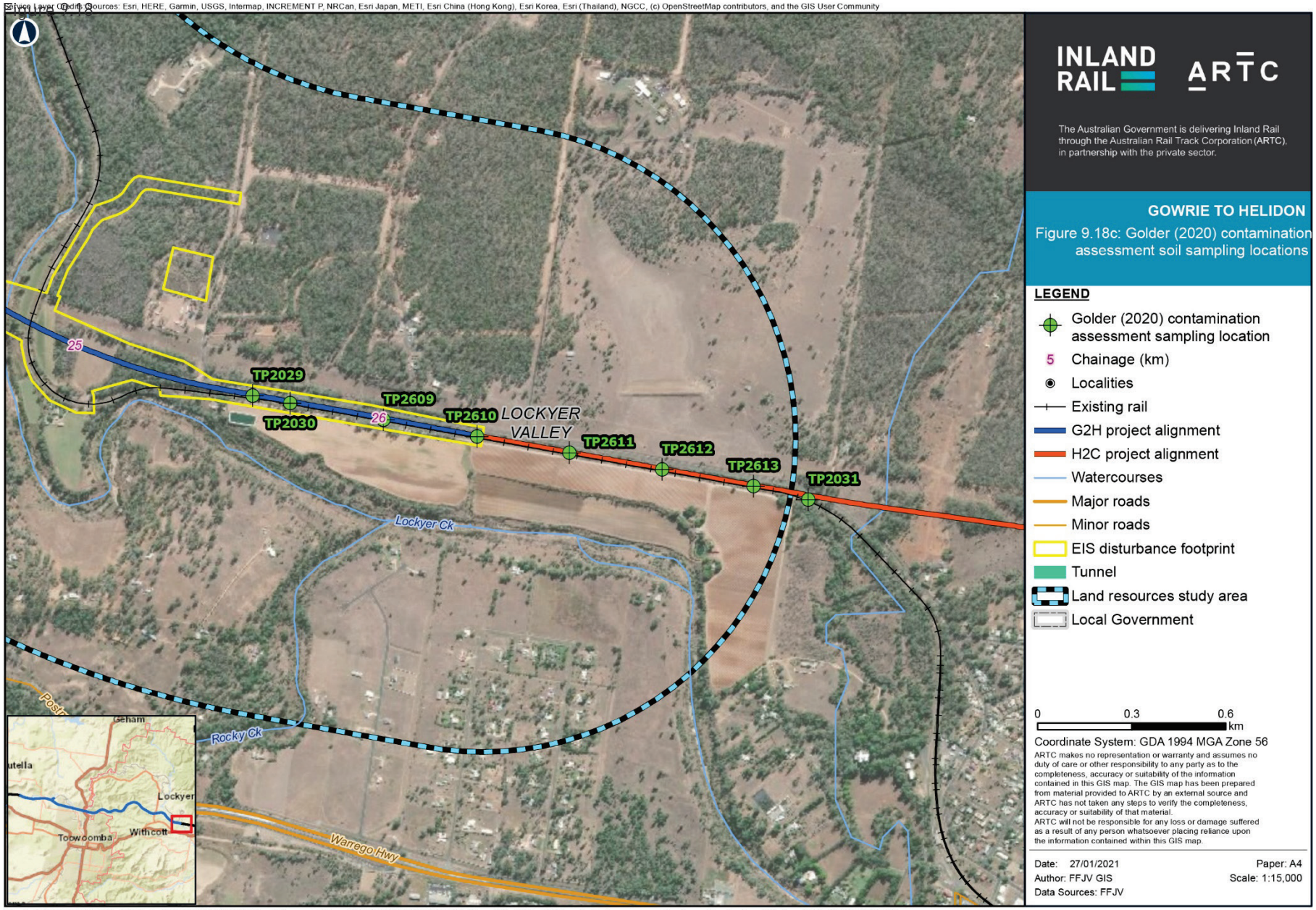

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FIGURE 9.18a–c: GOLDER (2020) CONTAMINATION ASSESSMENT SOIL SAMPLING LOCATIONS
Figure 9.18A
Gowrie Ck
TOOWOOMBA
TP2001
TP2501
TP2502
TP2002
TP2503
TP2504
TP2505
TP2003
TP2506
TP2507
TP2508
TP2004
TP2509
TP2510
Geham
Lockyer
Toowoomba
Withcott
INLAND RAIL
ARTC
The Australian Government is delivering Inland Rail through the Australian Rail Track Corporation (ARTC), in partnership with the private sector.
GOWRIE TO HELIDON
Figure 9.18a: Golder (2020) contamination assessment soil sampling locations
LEGEND
Golder (2020) contamination assessment sampling location
Chainage (km)
Localities
Existing rail
B2G project alignment
G2H project alignment
Watercourses
EIS disturbance footprint
Tunnel
Land resources study area
Local Government Areas
0 0.3 0.6 km
Coordinate System: GDA 1994 MGA Zone 56
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Date: 27/01/2021
Author: FFJV GIS
Data Sources: FFJV
Paper: A4
Scale: 1:15,000
Map by: TM Z:\GIS\GIS_3200_G2H\Tasks\320-EAP-201807091155_Land_Resource_Figures\320-EAP-201807091155_G2H_Figure 9.17_Golder_2020_contamination_assessment_soil_sampling_locations_A4_v1.mxd Date: 27/01/2021 13:08

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Figure 9.18



Map by: TM Z:\GIS\GIS_3200_G2H\Tasks\320-EAP-201807091155_Land_Resource_Figures\320-EAP-201807091155_G2H_Figure 9.17_Golder_2020_contamination_assessment_soil_sampling_locations_A4_v1.mxd Date: 27/01/2021 13:08


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25
26
TP2029
TP2030
TP2609
TP2610
TP2611
TP2612
TP2613
TP2031
LOCKYER VALLEY
Lockyer Ck
Rocky Ck
Warrego Hwy
Postr
Geham
utella
Lockyer
Toowoomba
Withcott
INLAND RAIL
ARTC
The Australian Government is delivering Inland Rail through the Australian Rail Track Corporation (ARTC), in partnership with the private sector.
GOWRIE TO HELIDON
Figure 9.18c: Golder (2020) contamination assessment soil sampling locations
LEGEND
Golder (2020) contamination assessment sampling location
5 Chainage (km)
Localities
Existing rail
G2H project alignment
H2C project alignment
Watercourses
Major roads
Minor roads
EIS disturbance footprint
Tunnel
Land resources study area
Local Government
0 0.3 0.6 km
Coordinate System: GDA 1994 MGA Zone 56
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9.7 Potential impacts

The construction and operation phases of the Project has the potential to result in impacts to land resources within the land resources study area. Potential impacts to land resources associated with the Project are related to:

- Permanent change to landform and topography
- Waste rock
- Loss of soil resources
- ASS
- Degradation of soil resources through invasive flora and fauna
- Salinity hazard
- Disturbance of existing contaminated land
- Creation of contaminated land.

9.7.1 Permanent change to landform and topography

Landform and topography are valuable for their ability to retain and move water within a soil catchment system. Project activities have the potential to permanently change the landform and topography of each catchment the Project traverses, through an increase in rock discontinuity/defects in cuts, erosion/ weathering of soil, and landslip associated with unstable material such as colluvium. Areas of the landscape particularly at risk include cuttings, embankments on side slopes as well as in-ground structures. Project activities may also alter localised contours in the landscape. Changes to landform and topography may cause secondary impacts to surface water, such as changes to flow patterns and infiltration, as well as groundwater; flow direction, particularly in floodplain areas where railway infrastructure can significantly impede floodwaters; and potentially redirect waters to sensitive receptors.

Impacts to landform and topography will be an unavoidable result of the Project due to the need to maintain the operational gradient for the railway.

Within the brownfield area, where the Project is co-located with the existing West Moreton System, embankments and rail formations will be constructed across the Gowrie Creek floodplain and on the lower slopes of Helidon Hills. These structures will be of similar magnitude to the existing West Moreton System rail formation.

The greenfield section of the Project, approximately 22 km of the Project alignment, roughly the western tunnel portal to Lockyer Creek, will be at a 1:64 gradient. Achieving this operating grade will require significant earthworks and structures across the undulating landscape. The total length of cut for the Project will be approximately 6.65 km with a maximum cut depth of 45.7 m. The total fill requirements for the Project is estimated to be 2,120,000 cubic metres (m^3) of fill material, which will be needed for the construction of embankments for the Project, estimated to be 15.4 km in length with a maximum embankment height of approximately 33.3 m. The current construction methodology includes using the material from the cuts in the embankments works.

The excavated material from the tunnel is planned to be stockpiled at the western tunnel portal (within the rail corridor) and will alter the local topography of the area. Refer to Chapter 6: Project Description and Chapter 10: Landscape and Visual Amenity for further details on the stockpile and how it may sit in the landscape.

The alignment traverses steep to very steep terrain that is considered to be prone to landslides in the Tertiary Volcanics and Marburg Formations. Landslides were experienced during the construction of the Toowoomba Bypass and there is a probable landslide in the proximity of the eastern tunnel portal, which is consistent with the deep colluvium identified at that location.

The Geological Survey of Queensland states that the landslides occur predominantly in unconsolidated colluvial (hillslope) debris on slopes underlain by basalt lavas, and in colluvium and weathered rock, on slopes formed by the interbedded sediments of the Marburg Formation. Besides being common on the steeper slopes, the landslides also affect flat to gently sloping benches on the flanks of ridges, particularly benches developed on interbedded shale or siltstone. There, the landslides may occur in the weathered soft shale bedrock and affect considerable areas. The prime cause of the landslides appears to be the removal of forest cover since European settlement, which has reduced mechanical support for the slopes and allowed groundwater pressures to rise to critical levels.

During construction of the Project, there is potential for significant impact to landform and topography resulting from disturbance and exposure of subsurface soils vulnerable to accelerated erosion, dispersivity and/or salinity due to their physical and chemical characteristics.

Soils of particular concern for management and stability will be those that are dispersive, erosion-prone soils i.e. sodosols and, to a lesser extent, chromosols; however, regardless of soil type, erosion risk will be increased where the following activities occur:

- Clearing of vegetative cover
- Changes in topography, drainage patterns and localised concentration of storm water flows due to construction of both access tracks and the rail corridor
- Excavation or cuttings and stockpiling of material
- Construction during high rainfall events, particularly erosive rainfall events
- Constructing through areas with high soil erodibility risks (e.g. sodosols).

The design, construction and operation of a major rail route within various catchments will require careful planning to minimise impacts to the landform and topography. Further detail regarding geological hazards is provided in Appendix W: Geotechnical.

9.7.2 Waste rock

The potential for waste rock associated with the cuttings along the Project's alignment and particularly the tunnel have been reviewed to assess potential risks to causing environmental harm. Approximately 2,100,000 m^3 of the excavated material will be reused within the Project as fill, leaving an excess of approximately one million cubic metres as spoil. The majority of the excess material, approximately 730,000 m^3, will result from the construction of the tunnel (excluding the portals).

The excess material will need to be assessed against all relevant environmental requirements and potentially contaminating activities as per Australian Rail Track Corporation (ARTC) Earthworks Material Specification. Further details are provided in Appendix T: Spoil Management Strategy.

'Waste rock' is a term that is primarily associated with the exploration and mining industry, relating to overburden, interburden or coarse rejects from those activities. Waste rock in that sense is not relevant to this Project.

Key mineralogical and geochemical characteristics associated with waste rock generally include: asbestos, ASS, aggregate alkali reactivity and acid generating rock. The potential for environmental harm to be caused as a result of the Project was considered to be very low to negligible, based on the areas geological setting, geotechnical investigations and learnings from the Toowoomba Second Range Project.

The volume, characteristics and fate of spoil material is contingent on further detailed geotechnical investigations and detailed design being completed. However, the suitability and extent of the material intercepted by the Toowoomba Range Tunnel cannot be estimated with accuracy due to the variable nature of basalt flows deposited on the undulating Jurassic sedimentary paleo topography. Typically, the spoil characteristics are monitored as the excavation progresses with samples taken directly from a temporary stockpile. Further the construction methodology for the tunnel, tunnel boring machine, will crush and wet the rock, which may or may not impact on the chemical characteristics of the rock.

9.7.2.1 Asbestos

As outlined in Section 9.6.1.3, the geological history of the rock types that were encountered during the feasibility stage geotechnical investigation, together with the available petrographic analysis results, the rock is unlikely to contain NOA, which only occurs in metamorphosed basic and ultrabasic igneous rock.

No rocks that theoretically could contain asbestiform minerals were encountered during the site investigation, nor such occurrence has been reported in the published literature (Hendrix, 2009). Considering the above, the risk of encountering NOA along the Project alignment is considered insignificant.

9.7.2.2 Aggregate alkali reactivity

Aggregate alkali reactivity (AAR), also referred to as alkali silica reactivity (ASR) is a chemical reaction between the alkali cementitious paste and leachable silica from aggregates in concrete. Silica can leach from the aggregates if they contain either strained or micro/crypto-crystalline quartz. Both strained and micro/crypto-crystalline quartz occurs in quantities that could cause such chemical reactions in metamorphic rocks, where recrystallisation of the rock occurred.

Based on available petrographic reports and the geological history of the rocks that occur within the Project alignment, the sedimentary rocks and the basalt are likely to be innocuous to AAR/ASR. The sedimentary

rocks have very low potential to be used as concrete aggregate due to their low durability. Published geological data and experience with the basaltic rocks of the area indicates that the free silica content of the basalts is typically <1%. Consequently, the AAR/ASR potential of concrete aggregates produced from basalt is insignificant. This is supported by the fact that several commercial quarries operating in the wider area of the Project use basalt as their source rock to produce a wide variety of quarry products, including concrete aggregate.

9.7.2.3 Acid generating rock

The risk of rock spoil, particularly from the tunnel, containing acid generating rock has been assessed for the alignment and is considered to be negligible. No metallogenic deposits are known to occur in the rocks that are anticipated to be encountered along the Project alignment. Available petrographic assessment results and published literature indicates that the sedimentary rocks may contain traces of pyritic material, together with calcareous cement. The proportion of pyritic material and the presence of low acid neutralising capacity of the rocks indicates that the risk of acid mine drainage (AMD) is insignificant. No reports on AMD have been identified in the published literature for the wider project area.

The Main Range Volcanics (Basalt) does contain pyrite which can be acid producing however the quantity of the mineral is rare. The sedimentary rocks of the Koukandowie Formation are reported, both in the site-specific petrographic report and in the wider published literature, as containing negligible amount of pyrite, therefore negligible risk of generating leachable acid.

The UTS is a colluvial sediment which accumulated on the old land surface and is therefore well oxidised and not considered as a risk. Similarly, the Walloon Coal Measures rocks encountered on the Project alignment are in proximity to the former land surface and are generally extremely to highly weathered (oxidised) and if there was any acid producing potential, it would have been already spent by the weathering process.

9.7.3 Loss of soil resources

Construction of rail infrastructure within (or adjacent to) Class A, Class B and IAAs will result in the loss of natural soil resources and affect farming activities. Poor land management practice decisions can also cause loss of ground cover, leading to erosion from wind or water, increased dust levels and declining regional soil fertility over time.

Project activities can also lead to dust creation, compaction, contamination via foreign material, nutrient loss, leaching of soil, secondary salinisation of good quality soil and soil inversion, where mixing of subsoils and surface soils can potentially impact on natural soil processes and productivity, and introduce contaminants into soil horizons.

The Project will traverse less than 0.1 per cent of land in both the Toowoomba and Lockyer Valley LGAs classified by as being of Class A, Class B or IAA, respectively. At a local government level, within the Toowoomba LGA, the permanent disturbance footprint traverses approximately 47.03 ha of Class A (less than 0.1 percent), 0.02 ha of Class B (less than 0.1 percent), and 65.23 ha of IAA land (less than 0.1 percent). Within the Lockyer Valley LGA, the permanent disturbance footprint traverses approximately 4.61 ha of Class A (less than 0.1 percent), 3.01 ha of Class B (less than 0.1 percent), and 33.58 ha of IAA land (less than 0.1 percent).

Within the permanent disturbance footprint, outside the existing rail and road corridors, approximately 51.65 ha of land is classified as Class A agricultural land, 3.03 ha as Class B land and approximately 98.81 ha of land classified as IAAs. Within the temporary disturbance footprint, approximately 25.60 ha of land is classified as Class A agricultural land, 3.45 ha as Class B land and approximately 42.77 ha of land classified as IAAs (refer Chapter 8: Land Use and Tenure).

As no agricultural activities are undertaken within the existing West Moreton System rail corridor and the future intent of land in the Gowrie to Grandchester future state transport corridor is recognised by the State as future railway land, impact to soil resources is expected to be minimised. The proposed Toowoomba Range Tunnel will pass beneath Class A, Class B and IAA (refer Chapter 8: Land Use and Tenure).

Furthermore, the Project has attempted to minimise the loss of soil resources through minimisation of impact to fertile soils, where possible.

The Project disturbance footprint also includes land required on a temporary basis to enable construction of the Project, including for construction laydown, stockpile and storage areas. The temporary use of land for construction activities has the potential to result in damaged topsoil structure as well as compacted subsoil, due to increased traffic (vehicles, plant and pedestrians) and heavy loads. This is a particular risk in areas of clayey and silty soils, such as vertosols, particularly when wet.

Soil compaction can lead to:

- Poor root growth—which reduces crop yield through poor water and nutrient uptake
- Difficulties with soil cultivation and seedbed preparation
- A decrease in water entering the soil either as rain or irrigation
- A decline in soil structural stability
- A decline in fertiliser efficiency—as the large blocks of compacted soil provide few surfaces to retain and release fertiliser for crop growth
- A soil that requires more horsepower (and fuel) to cultivate—planting implements are less effective in compacted soil and poor germination is the result.

Land that is temporarily disturbed in support of construction activities (e.g. for access tracks, laydown areas, etc.) will be rehabilitated at the end of its use for construction in accordance with the Reinstatement and Rehabilitation Management Plan, unless otherwise agreed with the relevant landholder.

9.7.4 Degradation of soil resources through invasive flora and fauna

During the construction and operational phases of the Project, introduction of weed seed material through human actions may present a potential risk to land resources, through soil degradation. Weed species have the potential to adversely impact soil, influencing critical factors such as soil stability and fertility. Weeds are known to increase the rate of erosion in soil through inadequate soil protection, alter the soil's physical structure, and change soil nutrient status (Weidenhamer & Callaway, 2010).

The EIS ecological field assessments identified 17 restricted matters—flora species (under the *Biosecurity Act 2014* (Qld)) within the land resources study area and further detailed in Appendix I: Terrestrial and Aquatic Ecology.

The Project may also encounter potential impacts from feral animals, causing soil degradation from burrowing or tunnelling soil, over grazing and surface disturbance. Erosion of the soil, as well as adverse impacts to groundwater flow and/or infiltration of rainfall, may result from invasive fauna activity. Six non-native fauna species have the potential to occur in the land resources study area, including:

- Cane toad (*Rhinella marina*)
- Red deer (*Cervus elaphus*)
- Horse (*Equus caballus*)
- European hare (*Lepus europaeus*)
- Rabbit (*Oryctolagus cuniculus*)
- Common myna (*Acridotheres tristis*).

The land resources study area is not contained within any fire ant biosecurity zone, which restricts the movement of materials that could spread the imported species. Further details regarding fire ants and invasive fauna species are provided in Chapter 11: Flora and Fauna and Appendix I: Terrestrial and Aquatic Ecology.

9.7.5 Acid sulfate soils

The desktop assessment and field investigations concluded a low probability of encountering ASS (including inland ASS) and/or acid rock within the land resources study area, except for within permanent waterways (aquatic ecosystems). If ASS is present in permanent waterways in the land resources study area, it would only be encountered during works that involve sub-surface disturbance within, or immediately adjacent to, these waterways. Additional geotechnical investigation undertaken during the detailed design phase will target these locations in order to provide further details on the likelihood of occurrence of inland ASS in proximity to these waterways.

ASS have the potential to degrade ecosystems as metals, such as iron and aluminium, are mobilised under acidic conditions (Hicks et al., 1999). The mobilised metals, combined with acidic conditions, can result in degraded water quality, toxicity for fish and impacts to plant growth.

Project activities may expose potential ASS to oxygen through soil disturbance which, in turn, may result in the creation of sulfuric acid. In addition to the above-mentioned biological impacts, acidic conditions have the potential to corrode infrastructure built from concrete, steel and other materials (NRMMC, 2011). Potential ASS may be located in the land resources study area residing below the water table and present a risk during excavation of cuts or from tunnelling activities.

Acid rock generates/releases acid when the contained sulfide minerals are exposed to air and water. This process is accelerated through excavation activities, which increase rock exposure to air, water, and microorganisms. Acid rock has potential to produce neutral to acidic drainage, which may occur with dissolved heavy metals and significant sulfate levels. Based on the geological conditions in the land resources study area, the likelihood of encountering acid rock is considered to be low.

Visual examination of surface outcrops along the Project disturbance footprint for sulfide minerals or remnant products, indicative of sulfide mineralisation, will occur prior to the commencement of construction.

9.7.6 Salinity hazard

The salinity hazard assessment in Section 9.6.4.6, undertaken in accordance with Part B of the *Salinity Management Handbook* (DERM, 2011), concluded that sub-catchments within the land resources study area have either a moderate or high overall salinity hazard rating (refer Figure 9.14).

Project activities have the potential to cause secondary salinisation, which is salting resulting from human activities, through processes such as the removal of vegetation, altering waterways, general land use changes, constructing dams and extracting groundwater. Secondary salinisation can cause water table salting, irrigation water salting and erosion scalding (DERM, 2011).

Geological features and past patterns of weathering result in some landforms having more potential to express salinity through the presence of restrictions to groundwater flow that may cause the water table to rise to near the soil surface, resulting in a discharge area with evaporative salts. During the desktop salinity hazard assessment (refer Section 9.6.4.5), potential landforms (naturally occurring and currently present) were identified in the land resources study area with a risk for salinity formation, and are further detailed in Table 9.21.

TABLE 9.21: LANDFORMS WITH SALINITY FORMATION RISK IDENTIFIED DURING DESKTOP SALINITY HAZARD ASSESSMENT

Feature	Information contributing to salinity investigations	Potential impact	Existing salinity formation risk within land resources study area
Landform feature identification: ▸ Geology ▸ Waters	PEA: Basalt over sandstone interface	Potential to have a more permeable basalt layer contacting with a less permeable sandstone geology underneath. This landform type can cause a restriction to downward water movement with seepages occurring at the interface area	High
	PEA: Confluence of streams	Potential for the junction of a minor stream with a major stream to have a reduction in flow velocity and resultant deposition of suspended particles and salts	Low
	PEA: Catena	Potential to have a change in hydraulic gradient similar to a barrier in water movement. Salting arising from infiltration of water into the soil and lateral movement through the weathered parent horizon or through more permeable soil	Low
Soil properties	PEA: Soil salt store	Potential for soluble salts to be sitting within the soil profile	Medium
	PEA: Artificial restriction, roads	Potential to have a reduction in water transmission, sufficient to cause salting upslope of the road	Low
Known salinity expressions	Known salinity expressions	Active or stable sites along the alignment	Low
Overall salinity hazard	Total PEAs	Potential for various methods of salt build up and transportation	Medium to High

Identified landforms (refer Table 9.21) with a medium to high risk of salinity formation were considered at risk from Project activities. The residual risk of Project activities to salinity hazard is presented in Section 9.9.

Salinity also presents a risk to infrastructure in saline areas, predominantly through corrosion (Searle et al., 2007). A number of naturally occurring and man-made assets in the land resources study area, or adjacent, could potentially be affected by salinity. It should be noted, however, that rail corridors generally have a low potential to create secondary salinity in the environment, as during the construction phase of the Project, compaction around the railway is expected to be limited and occurring over a short duration, and surface water drainage will be included as part of the design to minimise ponding or creation of hydraulic barriers.

Problems associated with salinity or sodicity are greatest in drier climates where rates of evaporation are usually very high. Excessive amounts of water applied during construction or operational phases of the Project can have the potential to move past the root zone and contribute to rising water tables. Leakage from water storages may also contribute to rising water tables.

Sodic waters, if used during construction or operation, may contain higher levels of sodium salts compared to calcium and magnesium salts and can result in soil dispersion, with subsequent soil surface sealing, crusting, erosion and poor water entry.

The desktop salinity hazard assessment adopted a precautionary approach and limitations existed in the quantity/quality of data available as well as the interpretation method. Soil sampling undertaken as part of geotechnical and soils investigation were also limited and reflects only specific points along the land resources study area where salts are available in soil.

The creation of secondary salinity from Project activities along the alignment will be minimised adequately through mitigation measures proposed in Section 9.8. Detailed investigation of areas of proposed disturbance within the finalised Project disturbance footprint will be undertaken during the detailed design phase to ensure that the physical and chemical characteristics of soils and subsurface materials are understood.

9.7.7 Disturbance of existing contaminated land

Project activities have the potential to disturb existing contaminated land resources during the construction and operational phase. The disturbance of contaminated soil or groundwater during Project activities has the potential to contaminate previously unaffected soil, surface water, groundwater, flora/fauna and affect human health through ingestion as well as dermal contact with contaminants.

Upon a desktop review of existing contaminated land in Section 9.6.6.1 and identifying potential sources of contamination within the land resources study area, as well as their relative risk, Table 9.22 links the identified potential sources, pathways and receptors derived from existing contaminated land based on the desktop assessment, which may be further exacerbated through Project activities.

TABLE 9.22: POTENTIAL EXISTING CONTAMINATED LAND SOURCE, PATHWAY AND RECEPTOR LINKAGES

Potential source	Contaminants	Potential pathway	Potential receptor
Existing potential contamination			
Agricultural land (within Project disturbance footprint)	Pesticides and herbicides	▸ Direct contact ▸ Dispersion of soil and dust from wind and water ▸ Surface water runoff.	Human health: ▸ Ingestion, inhalation, dermal contact ▸ Current and future site users, construction workers, site visitors, surrounding land users. Ecological: ▸ Terrestrial fauna/flora—direct contact and consumption (including bioaccumulation) ▸ Aquatic ecosystems—direct contact and consumption (including bioaccumulation).

Potential source	Contaminants	Potential pathway	Potential receptor
	Hydrocarbons (fuel and oil storage and use)	▸ Direct contact ▸ Dispersion of soil and dust from wind and water ▸ Surface water runoff.	Human health: ▸ Current and future site users, construction workers, site visitors, surrounding land users. Ecological: ▸ Potential risk to surrounding ecological areas ▸ Aquatic ecosystems.
	Asbestos and lead paint	▸ Direct contact ▸ Ingestion ▸ Inhalation ▸ Dispersion of soil and dust from wind and water ▸ Surface water	Human health: ▸ Current and future site users, construction workers, site visitors, surrounding land users. Ecological: ▸ Terrestrial ecosystem ▸ Aquatic ecosystem.
Agricultural land (within Project disturbance footprint)	Livestock dips or spray races arsenic, DDT, DDE, DDD	▸ Direct contact ▸ Ingestion ▸ Dispersion of soil and dust from wind and water ▸ Surface water runoff.	Human health: ▸ Ingestion, inhalation, dermal contact ▸ Current and future site users, construction workers, site visitors, surrounding land users. Ecological: ▸ Terrestrial fauna/flora—direct contact and consumption (including bioaccumulation) ▸ Aquatic ecosystems—direct contact and consumption (including bioaccumulation).
Housing/ sheds (in Project disturbance footprint)	Hydrocarbons (fuel and oil storage and use), pesticides and herbicides, lead paint and asbestos	▸ Direct contact ▸ Ingestion ▸ Inhalation ▸ Dispersion of soil and dust from wind and water ▸ Surface water runoff	Human health: ▸ Landowners, current and future site users, construction workers, site visitors, surrounding land users ▸ Ecological: ▸ Terrestrial fauna/flora—direct contact and consumption ▸ Aquatic ecosystems—direct contact and consumption (including bioaccumulation).
Rail corridor/ railway yard (within Project disturbance footprint)	Metals/metalloids, asbestos, hydrocarbons, pesticides/ herbicides, polycyclic aromatic hydrocarbons	▸ Direct contact ▸ Dispersion of soil and dust from wind and water ▸ Surface water runoff.	Human health: ▸ Ingestion, inhalation, dermal contact ▸ Current and future site users, construction workers, site visitors, surrounding land users. Ecological: ▸ Terrestrial fauna/flora—direct contact and consumption ▸ Aquatic ecosystems—direct contact and consumption (including bioaccumulation).

Potential source	Contaminants	Potential pathway	Potential receptor
Landfilling/ waste storage/ treatment plants	Hydrocarbons, pesticides/herbicides, metals, asbestos ▸ 172SP227269 (landfill)	▸ Direct contact ▸ Dispersion of soil and dust from wind and water ▸ Surface water runoff ▸ Leaching to groundwater.	Human health: ▸ Current and future site users, site workers, site visitors, surrounding land users. Ecological: ▸ Terrestrial fauna/flora—direct contact and consumption (including bioaccumulation) ▸ Aquatic ecosystems—direct contact and consumption (including bioaccumulation).
Quarry operations	Petroleum hydrocarbons (benzene, toluene, xylene, naphthalene), lead and other heavy metals/ metalloids ▸ 2RP844703 (Petroleum product or oil storage)	▸ Direct contact ▸ Dispersion of soil and dust from wind and water ▸ Surface water runoff ▸ Leaching.	Human health: ▸ Current and future site users, site workers, site visitors, surrounding land users Ecological: ▸ Terrestrial fauna/flora—direct contact and consumption (including bioaccumulation) ▸ Aquatic ecosystems—direct contact and consumption (including bioaccumulation).
Roads (within Project disturbance footprint)	Metals, hydrocarbons, pesticides/ herbicides, polycyclic aromatic hydrocarbons	▸ Direct contact ▸ Dispersion of soil and dust from wind and water ▸ Surface water runoff.	Human health: ▸ Ingestion, inhalation, dermal contact ▸ Current and future site users, construction workers, site visitors, surrounding land users. Ecological: ▸ Terrestrial fauna/flora—direct contact and consumption ▸ Aquatic ecosystems—direct contact and consumption (including bioaccumulation).
'Other' UXO areas (within Project disturbance footprint)	UXO	▸ Surface water runoff ▸ Groundwater flow ▸ Dispersion of soil from excavation, water and wind	Human health: ▸ Inhalation, dermal contact ▸ Current and future site users, construction workers, site visitors, surrounding land users. Ecological: ▸ Terrestrial fauna/flora—direct contact ▸ Aquatic ecosystems—direct contact and consumption (including bioaccumulation).
Industrial (explosives manufacture and storage)	Explosives and associated chemicals ▸ 125CP907566 ▸ 67CP839425	▸ Surface water runoff ▸ Groundwater flow ▸ Dispersion of soil from excavation, water and wind	Human health: ▸ Inhalation, dermal contact ▸ Current and future site users, construction workers, site visitors, surrounding land users. Ecological: ▸ Terrestrial fauna/flora—direct contact ▸ Aquatic ecosystems—direct contact and consumption (including bioaccumulation).

Many of the potential sources identified in Table 9.22 do not impinge on the Project disturbance footprint and, as a result, are unlikely to be a potential source of contamination during Project activities. The residual risk of Project activities to existing contaminated land is presented in Section 9.9.

Table 9.23 provides a preliminary conceptual site model for the EMR-listed properties based on the Aurecon PSI. Noting that two of the sites are located above the Toowoomba Range Tunnel (Property A and C) and Property B is located outside of the Project disturbance footprint.

TABLE 9.23: AURECON (2020) PRELIMINARY CONCEPTUAL SITE MODEL FOR IDENTIFIED EMR PROPERTIES

			Pathway		
Property	**Activity**	**Source (potential contaminants)**	**Migration pathway**	**Exposure route**	**Receptors (current and future)**
Property A 172SP227269	Landfill—disposing of waste (excluding inert construction and demolition waste)	▸ Metals/ metalloids (including Cr, Ni, Zn, Pb) ▸ TRH ▸ PAH	▸ Exposure to impacted soil during excavation and construction activities or during future land use activities ▸ Dispersion of soil and dust from wind and water	▸ Ingestion ▸ Inhalation ▸ Dermal contact ▸ Root uptake	▸ Current and future site users, construction/ maintenance workers, site visitors, surrounding land users ▸ Terrestrial and downstream aquatic ecosystems receiving surface waters
Property B 1SP270010	Waste storage, treatment or disposal	▸ Metals/ metalloids (including Cr, Cu, Ni, Zn) ▸ TRH	▸ Exposure to impacted soil during excavation and construction activities or during future land use activities ▸ Dispersion of soil and dust from wind and water	▸ Ingestion ▸ Inhalation ▸ Dermal contact ▸ Root uptake	▸ Current and future site users, construction/ maintenance workers, site visitors, surrounding land users ▸ Terrestrial and downstream aquatic ecosystems receiving surface waters
Property C 2RP144734	Operating a tannery or fellmongery or hide curing works or commercially finishing leather	▸ Metals/ metalloids (including Cr, Ni, Zn) ▸ TRH	▸ Exposure to impacted soil during excavation and construction activities or during future land use activities ▸ Dispersion of soil and dust from wind and water	▸ Ingestion ▸ Inhalation ▸ Dermal contact ▸ Root uptake	▸ Current and future site users, construction/ maintenance workers, site visitors, surrounding land users ▸ Terrestrial and downstream aquatic ecosystems receiving surface waters

Following the Golder (2020) contamination assessment of the existing West Moreton System rail corridor, several areas may potentially require further contaminated land investigations due to gaps in the sampling frequency and/or detection of contaminants above ASC NEPM (2013) human health and/or ecological investigation levels.

The final Project disturbance footprint and construction methodology will be subject to confirmation through the detailed design phase. Following confirmation of these aspects, further assessment may be required to identify potential contaminated land that is within the final Project disturbance footprint and will be disturbed by construction activities. Potentially contaminated sites, including the existing rail corridor and EMR-listed sites, that will be disturbed will require specific management controls to be developed by a suitably qualified person to outline the process to identify, document and manage contamination in these locations. In some instances, further environmental site investigation may be warranted, in accordance with ASC NEPM. The outcome of the investigations will inform measures to prevent exacerbation or spread of contamination and ensure contamination does not adversely affect the Project or surrounding areas.

Depending on the type and levels of contamination encountered, contaminated material may be reused for construction activities within the rail corridor, such as through encapsulation within zoned embankment (refer to Appendix T: Spoil Management Strategy). In some instances, contaminated material may require treatment prior to being suitable for reuse. The onsite management and remediation of contaminated soil would be further informed by a review of sampling results, exposure risks, onsite treatment or encapsulation opportunities and requirements for ongoing management.

A soil disposal permit from DES will also be required for the transportation and disposal of contaminated soil from a lot listed on the EMR/CLR by a licensed service provider to an appropriately licensed facility.

The disposal and management of spoil is further detailed in Chapter 21: Waste and Resource Management, as well as Appendix T: Spoil Management Strategy.

9.7.8 Creation of contaminated land

The following Project activities during the construction and operation phases of the Project have the potential to contaminate land resources through:

- Transport or movement of existing contaminated soil/groundwater leading to migration of contaminants to previously uncontaminated soil/groundwater and affecting human health through contact with contaminants
- Leaks or spills leading to migration of contaminants through surface water/soil/groundwater or exposure to human health risks through ingestion/dermal contact to contaminants from:
  - Permanent/mobile fuel/chemical storage
  - Waste storage areas/facilities (including storage tanks, sewage).

Table 9.24 further details identified potential sources, pathways and receptor linkages resulting from Project activities during the construction and operation phases of the Project.

TABLE 9.24: POTENTIAL CREATION OF CONTAMINATED LAND SOURCE, PATHWAY AND RECEPTOR LINKAGES

Potential source	Contaminants	Potential pathway	Potential receptor
Construction			
Hydrocarbon leaks and/or spills	Hydrocarbons	▸ Direct contact	Human health: ▸ Ingestion, inhalation, dermal contact ▸ Current and future site users, construction workers, site visitors, surrounding land users. Ecological: ▸ Terrestrial fauna/flora—direct contact and consumption ▸ Aquatic ecosystems—direct contact and consumption.
		▸ Overland flow/runoff to surface water bodies ▸ Migration to groundwater	Human health: ▸ Ingestion, dermal contact ▸ Current and future site users, construction workers, site visitors, surrounding land users (drinking water supply impacts). Ecological: ▸ Terrestrial fauna/flora—direct contact and consumption ▸ Aquatic ecosystems—direct contact and consumption.
Leaks and or spills from waste storage areas/ facilities (including storage tanks, sewage)	Biological waste (sewage), other wastes	▸ Direct contact	Human health: ▸ Ingestion, inhalation, dermal contact ▸ Current and future site users, construction workers, site visitors, surrounding land users. Ecological: ▸ Terrestrial fauna/flora—direct contact and consumption ▸ Aquatic ecosystems—direct contact and consumption.

Potential source	Contaminants	Potential pathway	Potential receptor
		▸ Overland flow/runoff to surface water bodies ▸ Migration to groundwater	Human health: ▸ Ingestion, dermal contact ▸ Current and future site users, construction workers, site visitors, surrounding land users (drinking water supply impacts). Ecological: ▸ Terrestrial fauna/flora—direct contact and consumption ▸ Aquatic ecosystems—direct contact and consumption.
Operation			
Hydrocarbon leaks and/or spills	Metals and hydrocarbons	▸ Direct contact	Human health: ▸ Ingestion, inhalation, dermal contact ▸ Current and future site users, construction workers, site visitors, surrounding land users. Ecological: ▸ Terrestrial fauna/flora—direct contact and consumption ▸ Aquatic ecosystems—direct contact and consumption.
		▸ Overland flow/runoff to surface water bodies ▸ Migration to groundwater	Human health: ▸ Ingestion, dermal contact ▸ Current and future site users, construction workers, site visitors, surrounding land users (drinking water supply impacts). Ecological: ▸ Terrestrial fauna/flora—direct contact and consumption ▸ Aquatic ecosystems—direct contact and consumption.

Chapter 20: Hazard and Risk, further details contamination that may arise as a result of Project activities and provides an assessment of impacts as well as mitigation measures.

9.8 Mitigation measures

This section outlines both the land resources mitigation measures included as part of the Project design and the mitigation measures that are proposed for the Project overall, to manage predicted environmental impacts. The impacts are initially assessed with consideration of the design mitigation measures and then reassessed to determine residual risk after the implementation of the proposed mitigation measures.

9.8.1 Design considerations

The mitigation measures and controls presented in Table 9.25 have been incorporated into the Project design. These design measures have been identified through collaborative development of the design and consideration of environmental constraints and issues. These design measures are relevant to both construction and operation phases of the Project.

TABLE 9.25: INITIAL MITIGATION THROUGH DESIGN RESPONSES

Aspect	Initial mitigations

Land resources	▸ The Project is generally located within existing road–rail infrastructure, where possible, minimising the need to develop land that has not previously been subject to disturbance for transport infrastructure purposes. This will minimise impacts of Project activities to land resources.
	▸ The quantity of spoil to be generated by the Project has been reduced through development of the reference design to achieve as close to a net balance in earthworks as is practicable. For the most part, this has been achieved through:
	  ▸ The width of the Project rail corridor has been minimised, as much as practically possible, to a typical width of about 62.5 m. This width is designed to minimise disturbance to existing land resources
	  ▸ Aligning the Project to avoid, where possible, steep terrain and topographical constraints to minimise earthworks and provide for more efficient track geometry and grade
	  ▸ Considering the shape and size of batters to encourage cut-and-fill balancing
	  ▸ Optimising the number, width and depth of cuts to avoid the generation of material that would be considered surplus to Project requirements and minimisation of transport requirements.
	▸ A draft spoil management strategy (refer Appendix T: Spoil Management Strategy) has been developed to guide the decision-making process for the management of spoil material generated by the Project. The purpose of the spoil management strategy is to provide overarching principles to guide the storage, treatment, reuse or disposal of material (including contaminated material) generated during construction of the Project.
	▸ Geotechnical investigations have been undertaken within the Project footprint to determine geotechnical conditions. Investigations have been targeted to specific locations, such as:
	  ▸ Locations of bridge abutments
	  ▸ Locations of significant cuts
	  ▸ Locations of significant fill.
	▸ Geotechnical and soils data has been used to derive design criteria for structures, rail formation and scour protection. This has enabled the Project to be designed to cater for field-verified geotechnical and soil conditions.
	▸ Design and ratings of earthworks in support of culverts, viaducts, and bridges are in accordance with AS 5100 Bride Design (Standards Australia, 2017x) and AS 7363 Railway Structures (Standards Australia, 2013) and other applicable standards.
	▸ The Project involves a 6.24-km tunnel under the Toowoomba Plateau avoiding changes to the local topography in this area, surface geology and soils, high-risk areas for salinity and agricultural lands
	▸ A cut-and-cover and mined tunnel are proposed at the eastern tunnel portal to mitigate risks during construction and operation from slope stability and landslips.
	▸ The Project includes 6.7 km of viaducts minimising cut-and-fill requirements, reducing the impacts on topography soils.

9.8.2 Proposed mitigation measures

In order to manage Project risks during the construction phase, a number of mitigation measures have been proposed for implementation in future phases of project delivery, as presented in Table 9.26. These proposed mitigation measures have been identified to address Project-specific issues and opportunities, legislative requirements, accepted government plans, policies and practices.

- Table 9.26 identifies the relevant Project phase, the aspect to be managed, and the proposed mitigation measure, which is then factored into the assessment of residual risk in Table 9.27. Some of the aspects described above are discussed in more detail in other sections of the EIS, including Chapter 8: Land Use and Tenure and Chapter 11: Flora and Fauna.
- The draft Outline EMP (refer Chapter 23: Draft Outline EMP) provides further context, and the framework for implementation of these proposed mitigation and management measures.

TABLE 9.26: LAND RESOURCES MITIGATION MEASURES

Delivery phase	Aspect	Proposed mitigation measures

Detailed design	Additional investigations	▸ Additional soil data, from the current soil sampling assessment along the Inland Rail alignment from Gowrie to Kagaru, will be incorporated into the Final EIS and will enable identification of potential/actual problematic soils including: acid sulfate, reactive, erosive, dispersive, saline, acidic, alkaline and liberation of contaminants.
		▸ Soil conditions across the Project disturbance footprint will be appropriately characterised at a suitable scale by a suitably qualified soil practitioner through additional geotechnical surveys during the detailed design phase of the Project, to inform design of structures, embankments, erosion control, soil treatment, soil reuse, as well as rehabilitation works. Subject to land access, the soil sampling will be of an intensity to enable mapping at a 1:10,000 scale. Soil investigations will be in accordance with the *Guidelines for Surveying Soil and Land Resources* (CSIRO/McKenzie et al., 2008), the *Australian Soil and Land Survey Field Handbook* (CSIRO, 2009) and the *Guidelines for Soil Survey along Linear Features* (Soil Science Australia, 2015). This includes identification of potential/actual ASS, acid rock, reactive soils, erosive soils, dispersive soils, salinity, acidic soils, alkaline soils, wetness, depth and contaminated land. Examples of soils that will require specific design consideration include:
		  ▸ The high naturally occurring sodicity of sodosols predominantly found east of the GDR escarpment
		  ▸ Vertosols or cracking clays predominantly found west of the GDR escarpment
		  ▸ Saline soils, particularly in high-salinity hazard areas like the Lockyer Valley.
		▸ Additional geotechnical investigations will be undertaken to inform the design of earthworks and foundations for structures, suitability of borrow and quarry material, and construction planning for the Project. Additional geotechnical investigations will specifically target locations such as:
		  ▸ Cuts
		  ▸ Embankments
		  ▸ Bridge piers and abutments.
		▸ The volume, characteristics and fate of spoil material is contingent on further detailed geotechnical investigations and detailed design being completed. The suitability and extent of the material intercepted by the Toowoomba Range Tunnel cannot be estimated with accuracy due to the variable nature of basalt flows deposited on the undulating Jurassic sedimentary paleo topography. Typically, the spoil characteristics are monitored as the excavation progresses with samples taken directly from a temporary stockpile.
		  Additional geotechnical investigations along the tunnel are proposed to confirm the geological characteristic of the material to assist in determining :
		  ▸ Amount of material of excavated material in particular basalt as a stabilised structural fill and/or capping layers in accordance with ARTC's *Earthworks Material Specification* (refer Appendix T: Spoil Management Strategy)
		  ▸ The amount and characteristics (e.g. contaminated or structurally unsuitable) of excavated material that may not meet the specifications for reuse
		  ▸ The viability of the reuse of excavated material as high-quality general fill or structural fill to minimise the import of rock amour
		  ▸ The viability of the reuse of dispersive and sodic soils as generally fill in embankments and/or formations
		  ▸ The viability of the material within the Project disturbance footprint for reuse as per the ARTC Earthworks Material Specification and the Earthworks and Material Management Framework, including extent of material that may need treatment (e.g. soil sampling and where applicable additional contaminated land surveys in accordance with relevant guidelines and procedures)
		  ▸ Risk of environmental harm (e.g. contamination, acid rock etc.) from the stockpile at the western poral and level of treatment (if any).

Delivery phase	Aspect	Proposed mitigation measures
Detailed design [continued]	Landform and material use	▸ Optimise the number, width and depth of cuts to avoid the generation of material that would be considered surplus to Project requirements. ▸ Review cut-and-fill balance for the Project based on the detail design, to minimise the external sourcing of fill. Based on reviewed cut-and-fill balance, determine the number of borrow pits and volumes from each that is required to supply the confirmed material demand for the Project. ▸ Review and update the draft spoil management strategy (refer Appendix T: Spoil Management Strategy) for the Project to reflect anticipated cut-and-fill quantities at the end of the detail design process. ▸ Cut batter angles will need to be appraised during detail design, based on material strengths and other geotechnical properties. Stability analysis will be required to assess the factor of safety of these cut slopes. Slopes of 1V:2H and the application of topsoil and seeding have been assumed for the reference design. The appropriateness of this gradient and erosion protection will require confirmation through trials and further testing, as part of the detail design. ▸ Stability of creek/waterway banks and areas of erosion will be assessed, and treatment measures be designed to control erosion and sediment movement.
	Erosion and sediment control	▸ Project clearing extents are limited to the Project disturbance footprint, which will be minimised to that required to safely construct, operate and maintain the Project. ▸ Erosion and Sediment Control Plans (ESCPs) will be developed by a Certified Practitioner in Erosion and Sediment Control (CPESC) in accordance with the International Erosion Control Association Best Practice Erosion and Sediment Control (IECA, 2008) and with reference to the *Soil Conservation Guidelines for Queensland* (DSITI, 2015b), and will be implemented during construction of the Project. The plans will detail the following procedures and protocols relevant to potential impacts identified in Section 9.6.6.2: ▸ Soil/land conservation objectives for the Project ▸ Temporary/permanent erosion and sediment control measures ▸ Workplace health and safety requirements relating to management of contamination and UXO risk ▸ Management of problem soils (e.g. acid sulfate soils, erosive, dispersive, reactive, acidic, sodic, alkaline soils) ▸ Stockpiling and management/segregation of topsoil where it contains native plants seedbank or weed material ▸ Vehicle, machinery and imported fill hygiene protocols and documentation ▸ Requirements for training, inspections, corrective actions, notification and classification of environmental incidents, record keeping, monitoring and performance objectives for handover on completion of construction.
	Hazardous materials handling and storage	▸ A Contaminated and Hazardous Materials Management Plan will be included as a component of the CEMP to eliminate, minimise and manage spills. The sub-plan will be required to: ▸ Identify the materials and chemicals required to be stored and used in support of construction, including volumes of each, such as: – Fuel and oil – Greases – Blasting chemicals – Concreting – Welding gases – Pesticides ▸ Identify the laydown areas that will be used for storage of hazardous materials and designated locations for storage of hazardous within the bounds of those laydown areas

Delivery phase	Aspect	Proposed mitigation measures
Detailed design [continued]	Hazardous materials handling and storage [continued]	▸ Specify how dangerous goods and hazardous materials will be handled, stored and transported for the Project ▸ Describe the response procedures in the event of an incident involving hazardous materials or dangerous goods ▸ Establish the waste storage and disposal procedures for hazardous materials and dangerous goods. ▸ Design of bunding containment will be in accordance with Australian Standard (AS) *1940:2017 for the storage and handling of flammable and combustible liquids* (Standards Australia, 2017). ▸ Although unlikely, based on the UXO assessment for the Project, where a risk of encountering known or possible UXO is identified, assessment and identification of management options must be carried out by a suitably qualified person.
	Reinstatement and/or rehabilitation	▸ The ESCPs will align with the Reinstatement and Rehabilitation Plan and will include progressive stabilisation of earth materials and soil consolidation, to prevent erosion and sedimentation in areas in the Project disturbance footprint that do not form part of the permanent works (e.g. temporary construction compounds and laydown areas, etc.). ▸ A Rehabilitation and Landscaping Management Sub-plan will be developed for the Project, as a component of the CEMP. This sub-plan will be based on the Inland Rail Landscape and Rehabilitation Strategy, in addition to location and property specific reinstatement commitments. The plan will include and clearly identify: ▸ Location-specific objectives for rehabilitation, reinstatement and/or stabilisation. Outside of the rail corridor, property-specific and township-specific rehabilitation and landscaping requirements may apply. Within the rail corridor, maintaining operational safety and rail formation stability will be the driving factors ▸ Objectives and timeframes for rehabilitation and/or reinstatement/stabilisation works (including biodiversity, vegetation establishment and erosion and sediment control outcomes to be achieved) ▸ Details of the actions and responsibilities to progressively rehabilitate, regenerate, and/or revegetate areas, while minimising the duration of exposure in disturbed areas ▸ Include rehabilitation requirements such as: – Milling and removal of bitumen pavement – Removal of any decommissioned culverts – Tyning and ripping of base and sub-base material – Application of soil ameliorants – Topsoiling and/or compost blanket – Stabilisation and rehabilitation (e.g. planting and or seeding) ▸ Native flora species endemic to the Darling Downs and Toowoomba regions or other suitable species appropriate to the landscape context and nursery/seed stock sources ▸ Consideration for maintenance or performance issues of rehabilitation e.g. use of groundcover that does not grow and obscure signals or impact the longevity of rail infrastructure ▸ Procedures, timeframes, measurable performance objectives and responsibilities for monitoring the success of rehabilitation and/or reinstatement/stabilisation areas. ▸ Corrective actions if the outcomes of rehabilitation and/or reinstatement/stabilisation are not achieved.

Delivery phase	Aspect	Proposed mitigation measures

Detailed design [continued]	Land and soil	▸ Minimise risks through implementation of appropriate detailed design processes where reactive or problem soils are present or suspected.
		▸ Cut-and-fill balance and minimisation of transport requirements for import/disposal of spoil will be considered as part of the design process.
		▸ The quantity of spoil to be generated by the Project has been reduced through optimising the number, width and depth of cuts to avoid the generation of material that would be considered surplus to Project requirements.
		▸ Detailed design to demonstrate assessment and viability of opportunities for:
		  ▸ Re-use of local sources of aggregate and treatment of dispersive and reactive materials to improve mass haul
		  ▸ Re-use of material excavated below the rail embankment for less critical parts of infrastructure
		  ▸ Re-use of excavated material as a stabilised structural fill
		  ▸ Re-use of ballast as high-quality general fill or structural fill to minimise the import of rock amour.
		▸ A Soil Management Plan will be developed to provide the framework for stripping, storage, treatment and reuse of topsoil.
		▸ Where dispersive material may be allowed as part of the earth fill, adequate design and construction practices will be implemented to reduce the risk of damage to the embankment. Suitable mitigation measures may include containment of the dispersive soil by non-dispersive and low permeability outer layers, high level of compaction at optimum moisture content, lime stabilisation or other similar methods.
		▸ Ensure that temporary earthworks and permanent landform for the Project are designed to avoid unwanted ponding of water. This objective will be achieved through surface levelling and use of cross-drainage and longitudinal drains within the rail corridor.
		▸ A Biosecurity Management Plan will be developed and implemented and will include measures to address the risk of impacts from feral animals grazing, trampling, digging and/or burrowing in rehabilitated/landscaped areas.
		▸ Existing biosecurity matter (plants, animals and diseases that is restricted under the *Biosecurity Act 2014* (Qld), or listed as locally significant under a local government biosecurity management plan, will be appropriately managed.
		▸ The transport of biosecurity matter and biosecurity matter carriers to and from site will be appropriately managed.
		▸ Movement of biosecurity matter and carriers across biosecurity zones will be in compliance with Biosecurity Regulation 2016 and Biosecurity Instrument Permits, where applicable.

	Contamination, land and soil	▸ As required, a Contaminated Land Management Strategy will be developed and implemented by a suitably qualified professional, as recognised under the EP Act, incorporating consultation outcomes from landholders and other relevant stakeholders. This will:
		  ▸ Be developed based on the contaminated land strategy presented in Figure 9.19
		  ▸ Specify controls for works on land that is known or suspected of being contaminated and will outline the process to identify, document and manage contaminated sites
		  ▸ Seek to minimise soil disturbance in areas listed on the EMR (refer Table 9.15). A Soil Disposal Permit under the EP Act is required if contaminated soil is to be moved from a lot listed on the EMR.
		  ▸ Establish the methodology and sampling and analysis plan for environmental site investigation, where soil disturbance is required on an EMR site in the potentially contaminated area
		  ▸ Establish an unexpected finds protocol/procedure in the event that potentially contaminated materials, including UXO, ASS/acid rock are encountered during construction activities

Delivery phase	Aspect	Proposed mitigation measures
Detailed design [continued]	Contamination, land and soil [continued]	▸ A detailed contamination assessment of EMR-listed sites and other areas of potential contamination will be undertaken (if required and determined by a Contaminated Land Suitably Qualified Person) once detailed design, Project disturbance footprint and the cut-and-fill balance are finalised, in accordance with the requirements of ASC NEPM. ▸ Any imported fill material will be clean, certified pest and contaminant free. ▸ Where geotechnical/drilling activities require drilling fluids or muds, environmentally neutral and biodegradable materials will be selected. Mobile plant, drill rigs and equipment will be maintained in accordance with manufacturer requirements, and inspected frequently to minimise breakdowns and decrease the risk of contamination.
	Acid sulfate soils / Acid rock	▸ If ASS / acid rock is identified through further geotechnical investigations and will be disturbed by construction activities, an ASS Management Plan will be developed, if required, in accordance with the *Queensland Acid Sulfate Soil Technical Manual: Soil Management Guidelines v4.0* (DSITI, 2014a) and the *State Planning Policy*.
	Secondary salinity	▸ Ensure that temporary earthworks and permanent landform for the Project are designed to avoid unwanted ponding of water. This objective will be achieved through surface levelling and use of cross-drainage and longitudinal drains within the rail corridor. ▸ Design water retention structures, such as sediment basins, to prevent downward leakage of water, with the use of lining or similar. ▸ Avoid, where possible, the need for diversions or alterations to waterways. ▸ The ultimate water sourcing strategy for the Project will be documented in a construction water plan. The quality of water from available sources will be considered in the development of the Plan.

Pre-construction	Materials handling and storage, hazardous waste	The CEMP will include the following provisions relevant to managing potential impacts on land resources:
		▸ A pollution incident response procedure will be prepared for accidental spills, leaks and other polluting incidents. The supervisor or person in charge of the work activity will be notified immediately. The matter will be recorded on the reportable environmental incident checklist and in accordance with ARTC's Emergency Management procedure (ARTC, 2019b).
		▸ All bunding, hydrocarbon and chemical storage areas will be routinely checked, and their integrity and functionality maintained as per design capacity.
		▸ Appropriate controls will be in place to prevent environmental incidents, including leaks/spills from refuelling activities, and to protect the environment in the event that incidents occur.
		▸ Personnel involved in ground-disturbing works will be trained in the unexpected finds protocol/procedure and in:
		  ▸ The identification of potential contaminated soil/material and relevant controls such as how to recognise potential contaminated material (colour, texture, odour, presence of asbestos, metal, ash) from inert waste or materials
		  ▸ Stop work and corrective/containment actions
		  ▸ Classification and notification of incidents procedures.
		▸ Identification of contaminated, hazardous or potentially contaminated material onsite (i.e. soil/formation, etc.) will be subject to a risk assessment.
		▸ Review or certification of contaminated, hazardous or potentially contaminated material will be undertaken and recorded.
		▸ Transportation of hazardous substances, wastes and/or dangerous goods will be undertaken by appropriately licensed contractors and a register of waste transfer certificates will be maintained for the Project.

	Spoil management/ excavated material	▸ A Construction Spoil Management Plan will be developed and implemented to document and manage the stockpiling and storage, onsite reuse, removal, transport and disposal of excavated material. ▸ Any imported fill material will be clean, certified pest and contaminant free.

Delivery phase	Aspect	Proposed mitigation measures
Pre-construction [continued]	Contamination	▸ Suspected contaminated soils or materials, if encountered, will be managed in accordance with the unexpected finds protocol/procedure documented in the Contaminated Land Management Strategy (refer above). ▸ Opportunities to treat and re-use contaminated materials within the rail corridor will be assessed and subjected to a risk assessment.
	Erosion and sediment control, land and water, water quality	▸ The ESCP will include water quality monitoring requirements, as defined in the Surface Water Sub-plan, to assess the effectiveness of erosion and sediment controls and reinstatement and rehabilitation programs.
	Land and soil	▸ Closure or realignments of local roads will be undertaken in accordance with the Reinstatement and Rehabilitation Plan. ▸ Wherever practical, topsoil shall be transferred directly to placement as planting media. ▸ Where stockpiling of topsoil is required, it must be carried out in accordance with the Soil Management Plan and in a manner which ensures that the properties of the topsoil are not permitted to degrade such that it becomes unsuitable as planting media. The Soil Management Plan will establish: ▸ Limitation for height of stockpiles ▸ Limits for the width of the base of stockpiles ▸ Requirements for adopting batter slopes, protective covers and drainage, which reduce potential for erosion and/or segregation ▸ Limits for the period of stockpiling to a minimum practical time ▸ Requirements for carrying out herbicide spraying or other treatment of the stockpile at intervals required to prevent weed growth and ensure the stockpile faces are weed-free prior to use. ▸ Develop and implement a Biosecurity Management Plan as part of the CEMP to include: ▸ Requirement for pre-clearing survey to determine the risk of weeds or pest animals being present ▸ Map of the existing severity and extent of weed infestations and weed management requirements ▸ Pest animal management (including fire ant and fire ant biosecurity zones) ▸ Site hygiene and waste management procedures to deter pest animals ▸ Weed surveillance and treatment during construction and rehabilitation activities ▸ Requirement in relation to pesticide and herbicide use and documentation, including any limitations on use, such as restrictions on use in sensitive environmental areas; drainage lines that flow to waterways and aquatic habitats; and ensuring that broad scale use does not result in an increase erosion and sediment risk ▸ Vehicle, machinery and imported fill hygiene protocol and documentation ▸ Erosion and sediment control risk associated with broad-scale weed removal or treatment ▸ Mitigation or remediation measures contained in the Biosecurity Management Plan will be developed in accordance with relevant agencies and local government.
	Hazardous waste	▸ A contaminated and hazardous material survey will be undertaken prior to relocation of infrastructure (e.g. signalling boxes and equipment) and the demolition of structures (e.g. sheds, housing/buildings and, where applicable, existing rail infrastructure). In the event that asbestos or other hazardous materials are identified in these structures, a Contaminated and Hazardous Materials Management Plan will be developed and implemented. The Contaminated and Hazardous Materials Management Plan will contain procedures to ensure that removal is undertaken in accordance with the *How to Safely Remove Asbestos Code of Practice* (Safe Work Australia, 2018b).

Delivery phase	Aspect	Proposed mitigation measures
Construction and commissioning	Erosion and sediment control, land and water, water quality	▸ Appropriate erosion and sediment control measures will to be implemented and continuously revised for the construction works, in accordance with the Erosion and Sediment Control Plan developed and maintained specifically for the Project. ▸ Install permanent erosion control measures, such as sediment retention basins and scour protection, in accordance with the detail design. ▸ Excavation will be undertaken in a manner to prevent erosion or landslip, working faces shall be limited to safe height and slopes, with surfaces drained to avoid ponding and erosion. ▸ Monitor the effectiveness of erosion controls installed as part of the environmental inspection schedule for the Project, as prescribed in the CEMP. ▸ Controls that are found to be failing or not performing as intended will either be modified or replaced, as required.
	Contamination	▸ For work activities undertaken, properties identified on the EMR within the Project construction boundary, or any other sites identified as part of the actions under the Contaminated Land Management Strategy, the Contaminated Site Management Plan will be implemented to reduce the risk of adverse impacts to the surrounding environments. ▸ If suspected contaminated land or material in drums, tanks, bags or plastic containers are encountered during excavation works, all work will stop in the affected area and measures to manage the contamination will be implemented, as per the Contaminated Site Management Plan. ▸ Contaminated waste must be transported and disposed of in accordance with the EP Act and procedures within the Waste Management Sub-plan (refer Chapter 21: Waste and Resource Management). ▸ Asbestos containing materials will be transported by a licensed service provider and disposed of at an appropriately licensed facility, in accordance with the requirements of the *Waste Reduction and Recycling Act 2011* (Qld) and the EP Act. ▸ The reuse or retention of contaminated or potentially contaminated material onsite (i.e. soil, ballast) will be subject to a risk assessment.

	Materials handling and storage	▸ Appropriate registers and records of chemicals, hydrocarbons, and hazardous substances and materials onsite will be maintained and kept up to date. Where appropriate, this will include a relevant risk assessment prior to the substance coming to, and being used onsite, plus a Safety Data Sheet (SDS) Register.
		▸ Where an incident occurs that threatens or causes environmental harm, the service provider will take all reasonable steps, including allocation of additional trained resources or specialists, to remediate and manage the incident.
		▸ Bulk storage areas for dangerous goods and hazardous materials will be located away from areas of social (e.g. residential areas) and environmental receptors (e.g. watercourses) such that offsite impacts or risks from any foreseeable hazard scenario will not exceed the dangerous dose for the defined land use zone, i.e. either sensitive, commercial/community, or industrial, in accordance with the intent of the SPP.
		▸ Licensed transporters operating in compliance with Australian Code for the Transport of Dangerous Goods by Road & Rail will be used for the transportation of dangerous goods.
		▸ Chemicals stored and handled as part of construction activities will be managed in accordance with relevant legislation and where applicable:
		  ▸ *AS 2187.2:2006: Explosives–Storage, transport and use* (Standards Australia, 2006a)
		  ▸ *Australian Code for the Transport of Explosives by Road and Rail*, 3rd edition (Australian Government, 2009)
		  ▸ AS 1940:2017 Storage and Handling of Flammable and Combustible Liquids (Standards Australia, 2017)
		  ▸ AS 3780:2008 The Storage and Handling of Corrosive Substances (Standards Australia, 2008a)
		  ▸ The requirements of chemical safety data sheets.

Delivery phase	Aspect	Proposed mitigation measures
	Secondary salinity	▸ Surface levelling of the site will occur, to prevent inadvertent ponding of water. ▸ Water that is dispersed for vegetation establishment, landscaping and rehabilitation will be consistent with the quality requirements specified for irrigation and general water use in the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, 2000). ▸ Ensure efficient water application, so as to avoid prolonged oversaturation of soils within and adjoining the Project footprint.
	Rehabilitation	▸ Reinstatement, stabilisation and rehabilitation of temporarily disturbed areas (such as laydown, site offices and temporary access tracks) will be undertaken progressively, consistent with the Reinstatement and Rehabilitation Plan and the Landscape and Rehabilitation Management Plan.
	Hazardous waste	▸ Hazardous and/or dangerous waste (e.g. asbestos, chemicals, oils) will be correctly stored and managed onsite and/or correctly disposed of by a licensed contractor, to a registered waste facility in accordance with the draft Outline EMP and CEMP.
Operation	Land and soil contamination	▸ Ongoing management and maintenance of the corridor will be in accordance with the Inland Rail Environmental Management System (EMS) and corridor management procedures. ▸ ARTC's Emergency Management procedure (ARTC, 2019b) will be used for emergency management, including emergency response and emergency planning. The freight transportation of dangerous goods on the Project will be in accordance with the Australian Dangerous Goods Code (National Transport Commission, 2018). Freight carts will be required to display appropriate Hazchem Signage, including placards, and carry appropriate spill containment equipment to be used by emergency services personnel in the event of an emergency.

The approach for the further assessment and investigation of contaminated land in the Project disturbance footprint will be documented in the Contaminated Land Management Strategy and will be based on Figure 9.19.

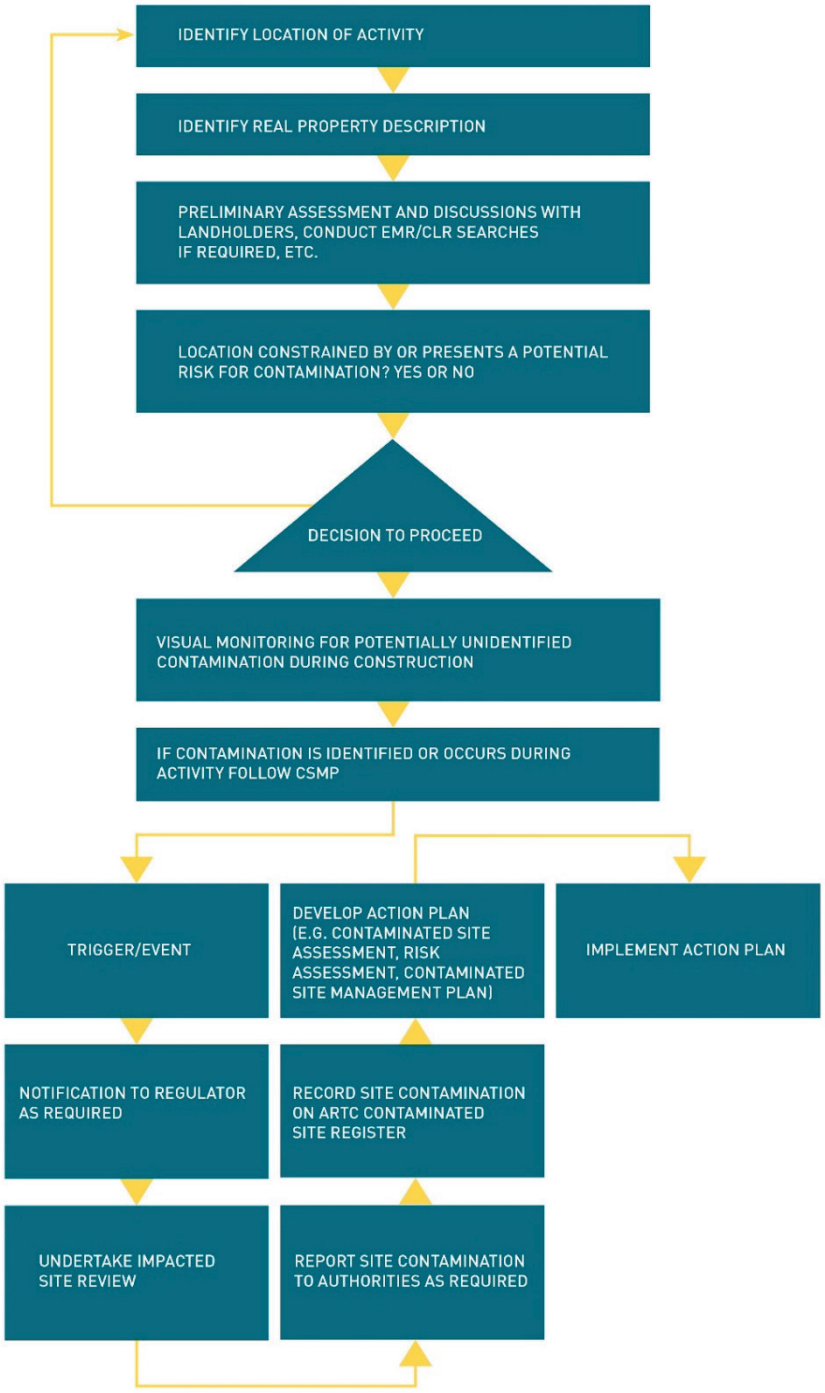


FIGURE 9.19: STRATEGY FOR THE ASSESSMENT AND INVESTIGATION OF CONTAMINATED LAND IN THE PROJECT DISTURBANCE FOOTPRINT

9.9 Impact assessment

Potential impacts to land resources associated with the Project in the construction and operation phases are outlined in Table 9.27. These impacts have been subjected to a risk assessment as per the methodology detailed in Chapter 4: Assessment Methodology.

The initial risk assessment is undertaken on the assumption that the design measures (or initial mitigation) have been incorporated into the Project design (refer Table 9.25).

Proposed mitigation measures, including those listed in relevant Sub-plans, were then applied, as appropriate, to the relevant phase of the Project to reduce the level of potential impact.

The residual risk level of the potential impacts was then reassessed. The initial risk assessment levels were compared to the residual risk levels in order to assess the effectiveness of the mitigation and management measures.

TABLE 9.27: IMPACT ASSESSMENT FOR POTENTIAL IMPACTS ASSOCIATED WITH LAND RESOURCES

			Initial risk[1]			Residual risk[2]		
Aspect	**Potential impact**	**Phase**	**Likelihood**	**Consequence**	**Risk**	**Likelihood**	**Consequence**	**Risk**
Land and soil	Change to landform and topography	Construction	Likely	Moderate	**High**	Likely	Minor	**Medium**
	▸ Erosion ▸ Loss of natural contours ▸ Landslip	Operation	Possible	Minor	**Low**	Possible	Minor	**Low**
Erosion and sediment control, land and soil	Loss of soil resources	Construction	Likely	Moderate	**High**	Likely	Minor	**Medium**
	▸ Loss of Class A, Class B and IAAs within Project disturbance footprint ▸ Decline in soil fertility ▸ Loss of groundcover ▸ Soil inversion	Operation	Possible	Minor	**Low**	Possible	Minor	**Low**
Land and soil	Disturbance of	Construction	Unlikely	Moderate	**Low**	Unlikely	Minor	**Low**
	▸ Existing ASS ▸ Potential ASS ▸ Acid rock	Operation	Unlikely	Moderate	**Low**	Unlikely	Minor	**Low**
Erosion and sediment control	Disturbance of soil resources through invasive flora and fauna	Construction	Likely	Minor	**Medium**	Likely	Not significant	**Low**
	▸ Reuse of soil in landscape and rehabilitation activities ▸ Erosion ▸ Alter soil properties or groundwater flow ▸ Infiltration	Operation	Likely	Minor	**Medium**	Likely	Not significant	**Low**
Land and soil	Salinity hazard	Construction	Possible	Moderate	**Medium**	Possible	Minor	**Low**
	▸ PEA: Basalt over Sandstone Interface ▸ PEA: Soil Salt Store	Operation	Possible	Minor	**Low**	Possible	Minor	**Low**

			Initial risk[1]			Residual risk[2]		
Aspect	**Potential impact**	**Phase**	**Likelihood**	**Consequence**	**Risk**	**Likelihood**	**Consequence**	**Risk**
Contamination, land and soil	Disturbance of existing contaminated land ▸ EMR-listed properties ▸ Agricultural land ▸ Housing/sheds ▸ Rail ▸ Landfilling/waste storage/ treatment plants Roads ▸ Industrial (Explosives manufacturing)	Construction	Likely	Moderate	**High**	Likely	Minor	**Medium**
		Operation	Possible	Moderate	**Medium**	Possible	Minor	**Low**
Material handling and storage	Creation of contaminated land ▸ Leaks or spills ▸ Permanent and mobile fuel and chemical storage ▸ Waste storage areas and facilities ▸ Project infrastructure	Construction	Possible	Moderate	**Medium**	Possible	Minor	**Low**
		Operation	Possible	Minor	**Low**	Possible	Minor	**Low**

Table notes:
1. Includes implementation of initial mitigation specified in Table 9.25
2. Assessment of residual risk once the land resources mitigation and controls, as identified in Table 9.26, have been applied

9.10 Cumulative impacts

Cumulative impacts were assessed using the methodology identified in Chapter 22: Cumulative Impacts, for 15 projects within the vicinity of the Project.

Multiple projects occurring in close proximity to the land resources study area may potentially exacerbate impacts on the region's soil properties, as well as agricultural and contaminated land. The major potential impacts identified as a result of the Project are common to all projects throughout the region and are therefore cumulative in nature. As a result, six projects were identified as having the potential to contribute to land resources impacts in combination with the Project and are highlighted in Table 9.28.

TABLE 9.28: OTHER PROJECTS IN THE VICINITY OF THE PROJECT DISTURBANCE FOOTPRINT

Project and proponent	Location	Description	Project Status
Border to Gowrie (B2G) (ARTC)	Rail alignment from NSW/QLD Border to Gowrie	Approximately 146 km of new dual-gauge track and 78 km of upgraded track from the NSW/QLD border, near Yelarbon, to Gowrie Junction, north west of Toowoomba in Queensland.	Draft EIS being prepared by ARTC
Helidon to Calvert (H2C) (ARTC)	Rail alignment from Helidon to Calvert	47 km single-track dual-gauge freight rail line running from Helidon to Calvert including a tunnel through the Little Liverpool Range	Draft EIS being prepared by ARTC
InterLinkSQ	13 km west of Toowoomba	200 ha of new transport, logistics and business hubs. Located on the narrow-gauge regional rail network and interstate network. Located at the junction of the Gore, Warrego and New England Highways.	Approved, construction underway
Mt Lofty Development (DHA)	Toowoomba, suburb of Mount Lofty	Former rifle range redeveloped into a master-planned residential community comprising of 342 lots. Some lots will be retained by DHA on which homes will be built for Defence members and their families with remaining lots available for public purchase.	On hold.
Wetalla Water Pipeline (New Acland Coal Pty Ltd, a subsidiary of New Hope Corporation Limited)	From the Wetalla Wastewater Reclamation Facility in Toowoomba to the New Acland coal mine, 35 km northwest of the city	A 45-km underground water pipeline to supply up to 5,500 megalitres of treated waste water to the New Acland coal mine	EIS approved with conditions in 2008. The Wetalla Water Pipeline has been completed.
New Acland Coal Mine Stage 3 project (New Acland Coal Pty Ltd, a subsidiary of New Hope Corporation Limited)	35 km north-west of Toowoomba	Expansion of the existing New Acland open-cut coal mine to up to 7.5 Mtpa.	EIS approved with conditions in 2014.

The potential projects mostly comprise of rail- and mining-related infrastructure development. The six projects were considered due to their location, in relation to the Project, and potential impacts to land resources during construction and operation phases. Cumulative impacts are, however, expected to be low, provided all potential projects in the region will apply appropriate mitigation measures to minimise land resources impacts. The potential impacts that are likely to be common for the six projects in the region, if not managed appropriately, may include:

- Soil conditions not appropriately characterised
- Leaks or spills leading to migration of contaminants
- Loss of soil resources
- Disturbance to existing contaminated land
- Disturbance of ASS

- Changes to landform and topography
- Salinity hazard
- Erosion potential—leading to increased total dissolved solids in run off
- Introduction of invasive flora and fauna.

Table 9.29 details the potential cumulative impacts for the Project, with the impact significance rating considering mitigation measures implemented by the Project for land resources, within the land resources study area.

The spoil that is generated for the Project alone, and the adjacent Inland Rail projects, have been assessed independently. Matters relating to the management of the spoil are provided in the Spoil Management Strategy (refer Appendix T: Spoil Management Strategy) and is consistent with the waste management hierarchy, which seeks to reuse the material for beneficial purposes in close proximity to the Project.

Where possible, the generation of waste and disposal to landfill will be minimised; however, there will still be some residual waste remaining as a result of the Project activities, which will need to be disposed of at licensed waste management facilities. Due to the extent of the Project, the western portion and tunnel-related work areas may seek to use waste facilities in the Toowoomba region while those in the east will be in a position to efficiently use waste disposal and composting facilities in the Lockyer Valley, such as Gatton Landfill and Transfer Station.

TABLE 9.29: POTENTIAL CUMULATIVE IMPACTS

Potential cumulative impact	Aspect	Relevance factor*	Sum of relevant factors**	Impact significance***	Comments
Soil conditions in the proposed area are not appropriately characterised to inform what the railway corridor will encounter, how it will be impacted and when it will be impacted. This includes the identification of reactive soils, erosive soils, dispersive soils, saline and sodic soils, contaminated land.	Probability of the impact	1	4	**Low**	Once the final Project disturbance footprint is known, a suitably qualified person will undertake an assessment as to whether additional soil samples will be required to meet management requirements. Will be managed by Project CEMP and relevant Sub plan(s). Specific conditions unlikely to be necessary. Monitoring to be part of general Project monitoring program.
	Duration of the impact	1			
	Magnitude/intensity of the impact	1			
	Sensitivity of the receiving environment	1			
Leaks or spills leading to migration of contaminants through surface water/soil/groundwater or increased human health risk through ingestion/dermal contact to contaminants from: - Permanent/mobile fuel/chemical storage - Waste storage areas/facilities - Proposal infrastructure	Probability of the impact	2	6	**Low**	Will be managed by a Contaminated Site Management Plan and specific conditions are unlikely to be necessary. Monitoring to be undertaken as part of the Project's CEMP.
	Duration of the impact	2			
	Magnitude/intensity of the impact	1			
	Sensitivity of the receiving environment	1			

Potential cumulative impact	Aspect	Relevance factor*	Sum of relevant factors**	Impact significance***	Comments
Permanent loss of soil resources within the Project disturbance footprint	Probability of the impact	2	7	**Medium**	Mitigation measures are likely to be necessary and specific management and design practices are to be applied. Specific conditions are likely. Targeted monitoring program required through Project CEMP to identify IAA disturbance from works.
	Duration of the impact	2			
	Magnitude/intensity of the impact	2			
	Sensitivity of the receiving environment	1			
Disturbance to existing contaminated land and acid sulfate soils (including the potential to disturb ASS)	Probability of the impact	1	6	**Low**	Negative impacts need to be managed by standard environmental management practices. Special conditions unlikely to be necessary. Monitoring to be part of general Project monitoring program.
	Duration of the impact	2			
	Magnitude/intensity of the impact	2			
	Sensitivity of the receiving environment	1			
Change to landform and topography	Probability of the impact	2	7	**Medium**	Mitigation measure likely to be necessary and specific management practices to be applied. Specific conditions are likely. Targeted monitoring program required, where appropriate.
	Duration of the impact	3			
	Magnitude/intensity of the impact	1			
	Sensitivity of the receiving environment	1			
Salinity hazard (insitu, soil)	Probability of the impact	2	6	**Low**	Negative impacts will be managed by standard environmental management practices. Special conditions unlikely to be necessary. Monitoring to be part of general Project monitoring program.
	Duration of the impact	2			
	Magnitude/intensity of the impact	1			
	Sensitivity of the receiving environment	1			
Erosion	Probability of the impact	2	7	**Medium**	Will be managed by an Erosion and Sediment Control Plan. Specific conditions are unlikely to be necessary. Monitoring to be part of the general Project monitoring.
	Duration of the impact	2			
	Magnitude/intensity of the impact	2			
	Sensitivity of the receiving environment	1			

Potential cumulative impact	Aspect	Relevance factor*	Sum of relevant factors**	Impact significance***	Comments
Weed Management	Probability of the impact	1	4	**Low**	Will be managed by Project CEMP and relevant sub-plan(s), for example ARTC's Biosecurity Management Plan. Specific conditions unlikely to be necessary. Monitoring to be part of general Project monitoring program.
	Duration of the impact	1			
	Magnitude/intensity of the impact	1			
	Sensitivity of the receiving environment	1			
Feral Animal Management	Probability of the impact	1	4	**Low**	Will be managed by Project CEMP and relevant sub-plan(s), for example ARTC's Biosecurity Management Plan.. Specific conditions are unlikely to be necessary. Monitoring to be part of the general Project monitoring.
	Duration of the impact	1			
	Magnitude/intensity of the impact	1			
	Sensitivity of the receiving environment	1			

Table notes:

* Relevance factors between 1 and 3 were determined using professional judgement to select most appropriate factor for each aspect and summing

** Sum of relevant factors definition:

Low (1–6): Negative impacts need to be managed by standard environmental management practices. Special conditions unlikely to be necessary. Monitoring to be part of general Project monitoring program.

Medium (7–9): Mitigation measure likely to be necessary and specific management practices to be applied. Specific conditions are likely. Targeted monitoring program required, where appropriate.

High (10–12): Alternative actions will be considered and/or mitigation measures applied to demonstrate improvement. Specific conditions expected to be required. Targeted monitoring program necessary, where appropriate.

*** Impact significance considered the risk of impact after implementation of mitigation measures for land resources for the Project, within the land resources study area.

9.11 Conclusions

This chapter has been prepared to evaluate potential impacts of the Project on land resources and has identified existing conditions of the land resources study area in accordance with industry standard methodology, relevant legislation and the ToR. Through an assessment of existing conditions, Project impacts with the potential to adversely impact land resources were identified. Various Project activities at different phases of the Project can impact land resources, via:

- Permanently changing landform and/or topography
- Causing the loss of soil resources on farming and other economically valuable land
- Degrading soil resources through an introduction of invasive flora and fauna, altering physical and chemical properties of soil
- Exposing potential ASS and acid rock to oxygen during excavation and earthworks
- Exacerbating existing soil salinity and sodicity or creating new impacts
- Disturbing existing contaminated land
- Contributing to creation of contaminated land.

A majority of potential impacts to land resources through Project activities were found to have low residual risk, on implementation of initial mitigation measures during the design phase and implementation of proposed additional mitigation measures during the subsequent phases of the Project. Change to landform and topography, loss of soil resources and disturbance of existing contaminated land during the construction phase of the Project, all remain a medium residual risk after the implementation of mitigation measures.

The mitigation measures detailed in Section 9.8 are intended to sufficiently manage all identified potential impacts for land resources as a result of Project activities. As the rail alignment follows the existing West Moreton System rail corridor, potential impacts are expected to be further reduced.