Northern Australian Transport Link

(Mt Isa to Tennant Creek)

Technical Assessment Program
Project Summary Report

Contents

Abbreviations

Terms, abbreviations and acronyms	Meaning
AEP	Annual Exceedance Probability
ASRIS	Australian Soil Resource Information System
CHRA	Cultural Heritage Risk Assessment
CBIISC	Cross-Border Infrastructure and Investment Steering Committee
Cr	Creek
Cth	Commonwealth
DTM	Digital Terrain Model
ESR	Environmental Scoping Report
JTWG	Joint Technical Working Group
MCA	Multi Criteria Analysis
MITCR	Mt Isa Tennant Creek Rail
MITEZ	Mt Isa to Townsville Economic Development Zone
MOU	Memorandum of Understanding
NEGI	North East Gas Interconnector
NT	Northern Territory
Qld	Queensland
SBC	Sub-ballast capping
SOP	Strategic Options Paper
SRTM	Shuttle Radar Topography Mission
TAP	Technical Assessment Program
TEU	Twenty Foot Equivalent Unit
TLC	Transport and Logistic Centre
TMR	Department of Transport and Main Roads
TRA	Trial Route Alignment

Executive Summary

In June 2015, the Australian Government released Our North, Our Future: White Paper on Developing Northern Australia. This paper included a commitment to undertake freight rail feasibility studies in Northern Australia. A priority of the White Paper was to undertake a pre-feasibility study for a new railway link between Mount Isa and Tennant Creek known as the Mount Isa to Tennant Creek Rail proposal (MITCR). Included in this was the study of two multi modal / multi use facilities, one at Tennant Creek and one at Mount Isa.

To progress the initiative the Commonwealth, Queensland (Qld) and Northern Territory (NT) governments undertook the MITCR pre-feasibility study in two parts, a Strategic Options Paper (SOP) and a Technical Assessment Program (TAP).

The purpose of the SOP was to improve the understanding of the economic drivers of the Darwin to Townsville supply chain and to generate options to advance the MITCR. The TAP included a number of studies that provide a high level assessment of the key challenges and risks associated with constructing a rail line between Mount Isa and Tennant Creek.

The SOP identified that, although the desired outcome of the rail link is to increase economic growth, construction of a rail link is not currently commercially viable as the existing transport network can manage current freight volumes. The SOP did however identify that policy reforms and the right market conditions could increase economic growth and enhance the opportunity for the private sector to invest in new mining and agricultural production, driving possible viability of a new rail line.

This report summarises the studies that comprise the TAP including key findings and a revised strategic cost estimate associated with the trial alignment. The reports find that the railway is technically feasible and provides a starting point for understanding the risks and challenges as well as the additional work required to further de-risk the project in subsequent stages. Overall the conclusion is that the risks and challenges are manageable and there are opportunities to refine the alignment.

The TAP studies indicate that the key risks and challenges include environmental and cultural heritage risks, issues surrounding flooding, the extensive networks of caves and sinkholes, threatened species, the sourcing of water, the removal of waste, pastoral leases and land tenure issues of surrounding Native Title and national parks.

Further work will be required including detailed field observations to determine sources for construction materials (particularly ballast), the significance of geotechnical hazards and solutions and a better understanding of sink holes.

A vertical and horizontal alignment was identified based on a 1% AEP flood level. A strategic cost estimate was calculated using this flood level as the basis for designing the required infrastructure. The cost of the initiative at this prefeasibility stage is estimated at approximately $4.1B not including multi-modal / multi-use sites.

Preferred sites for multi-modal / multi-use terminals in Tennant Creek and Mount Isa have been identified and will cater for 1,800 metre trains. Both sites have concept of operations prepared and include high level cost estimates.

Introduction

The Mount Isa to Tennant Creek Rail (MITCR) proposal is a greenfield rail line to connect the Great Northern Line in Queensland (Qld) to the Alice Springs-Darwin Railway in the Northern Territory (NT), connecting the towns of Mount Isa in Qld and Tennant Creek in the NT.

The MITCR proposal is an Australian Government initiative (arising from the White Paper for developing Northern Australia 2015) to stimulate regional and national economic development and create regional employment opportunities.

The MITCR would be built to same standard gauge as the Alice Springs-Darwin Railway and consequently involve a break-of-gauge at Mt Isa to network to the Qld narrow gauge rail system. The initiative includes two multi modal / multi use facilities at Tennant Creek and at Mt Isa with sufficient capacity to handle freight transfer by rail and road.

If constructed the proposal would provide rail connectivity between the Port of Townsville and the Port of Darwin and potentially encourage the development of phosphate, agriculture, gas/liquids and other mineral exports along the rail corridor. It is also anticipated that industry would move some of the general freight transported between the NT and Qld from road to rail, reducing the impact of heavy vehicles in the region.

The NT and Qld governments have been working closely together in conjunction with the Australian Government to investigate and develop an understanding of the economic, commercial, technical, environmental and engineering aspects of the project.

The economic and commercial aspects of the project have been reported in a completed Strategic Options Paper (SOP).

This report provides a summary of the technical assessment program (TAP) undertaken including key findings and recommendations. It includes an assessment of the technical feasibility of the MITCR proposal based on the trial rail alignment (TRA) and a strategic cost estimate for the proposal at this pre-feasibility stage.

Background

The Australian Government’s White Paper for developing Northern Australia (2015) committed up to $5 million to undertake analysis of freight rail projects in northern Australia. The paper identified, as its first priority, the undertaking of a pre-feasibility study for a new railway line between Tennant Creek and Mt Isa to assess the viability and economic opportunities of a new freight link between Qld and the NT.

To progress the MITCR proposal, the Commonwealth, Qld and NT governments commissioned the SOP and the TAP. The Australian Government committed $1.5 million to undertake studies with the Qld and NT governments each contributing $350,000.

The SOP was commissioned to consider the broader strategic options, opportunities and implications associated with the MITCR link in the context of the broader Darwin to Townsville supply chain supported by an economic analysis, commercial and financial analysis. This work has been completed and is with the Qld and NT governments for their respective consideration.

1 Technical Assessment Program

The TAP was undertaken to develop a greater understanding of the proposal's key technical challenges and risks. The TAP outcomes included:

- Refinement of the corridor between Mt Isa and Tennant Creek using the trial alignment as the basis.
- Identification of major environmental / technical challenges / construction risks.
- De-risking the project for future stages by providing a better understanding of the risks.
- Refining the estimated indicative capital cost of the proposals.

1.1 Trial Route

Preliminary studies were carried out by both the NT and Qld governments to determine the optimal route. An initial Trial Route Alignment (TRA) between Mt Isa and Tennant Creek was prepared by the Qld government in consultation with the NT government and is shown in Appendix A.

The TRA was selected as the most logical alignment based on best available information. The alignment has been designed to run parallel to the southern side of the Barkly Highway for approximately 654 kilometres, to provide for ease of construction and ongoing maintenance. Overall it is also considered to generally provide the route offering the least hydrological and topographical challenges within the proposed multi-use infrastructure corridor area.

Mt Isa was considered the most likely location for a multi-modal / multi-use terminal including break-of-gauge facility in Qld. A junction with the existing Alice Springs - Darwin Railway just north of Tennant Creek was considered the most appropriate location for a similar terminal in the Northern Territory.

1.2 Scope of Technical Assessment Program

The agreed scope of work for the TAP comprised of eight project areas as follows with the lead agency indicated in brackets:

1. Photogrammetry survey and mapping (NT).
2. Hydraulic Assessment Report (Qld).
3. Construction materials supply (NT).
4. Geotechnical Investigations Report including data investigation (Qld).
5. Environmental Scoping Report / Cultural Heritage Risk Assessment (Qld).
6. Intermodal transport facilities concept and siting - Tennant Creek (NT).
7. Multi-user, multi-modal load out facility investigation - Mt Isa (Qld).
8. Project summary report (Qld).

2 Technical Assessment Program Summary

A summary of the key findings from the technical reports/activities undertaken are provided in this section with recommendations included as applicable. The information in this section is summarised from the individual reports prepared for each study. Prior to using this information the relevant report should be examined to ensure the appropriate context for the work including the limitations and assumptions behind the work are noted and understood.

2.1 Aerial Photography and Digital Mapping

Aerial photography and digital terrain modelling was required to support a number of assessment activities for the TAP. The NT Government engaged a contractor to undertake this work. The target capture area was determined based on the proposed TRA. A 3km target capture area was established surrounding the alignment, extending 0.5km north and 2.5km to the south. The total area surveyed was 1973 square kilometres.

The methodology used to capture the data is as follows:

Aerial Photography:

Aerial photography was acquired using a single perspective digital camera and differential GPS processing. Softcopy photogrammetric processes were undertaken to generate a seamless orthophotograph of the area. Aero-triangulation information was also delivered to support the extraction of digital terrain information (mapping).

Mapping:

Digital terrain information was derived from the aero-triangulation information through a combination of automated and manual processes.

2.1.1 Study Outputs

The datasets produced are as follows:

Aerial photography (to 95% confidence in areas of well-defined features)

- Orthorectified seamless mosaic
- Ground Sample Distance (Pixel Size): 15cm
- Horizontal Accuracy*: +/- 0.3m
- Vertical Accuracy*: +/- 0.3m

Digital Mapping (to 95% confidence in areas of well-defined features)

Bare-Earth Digital Terrain Model

2.5m Spot Elevation Grid enhanced with break-lines and break features

Contours - 1m contour interval

Features: fences, gates, signs, excavations, roads, tracks and watercourses

Mapping Scale: 1:2500

Horizontal Accuracy*: +/- 0.3m

Vertical Accuracy*: +/- 0.3m

The datasets were captured in two stages as outlined in Figure 1 and Figure 2.

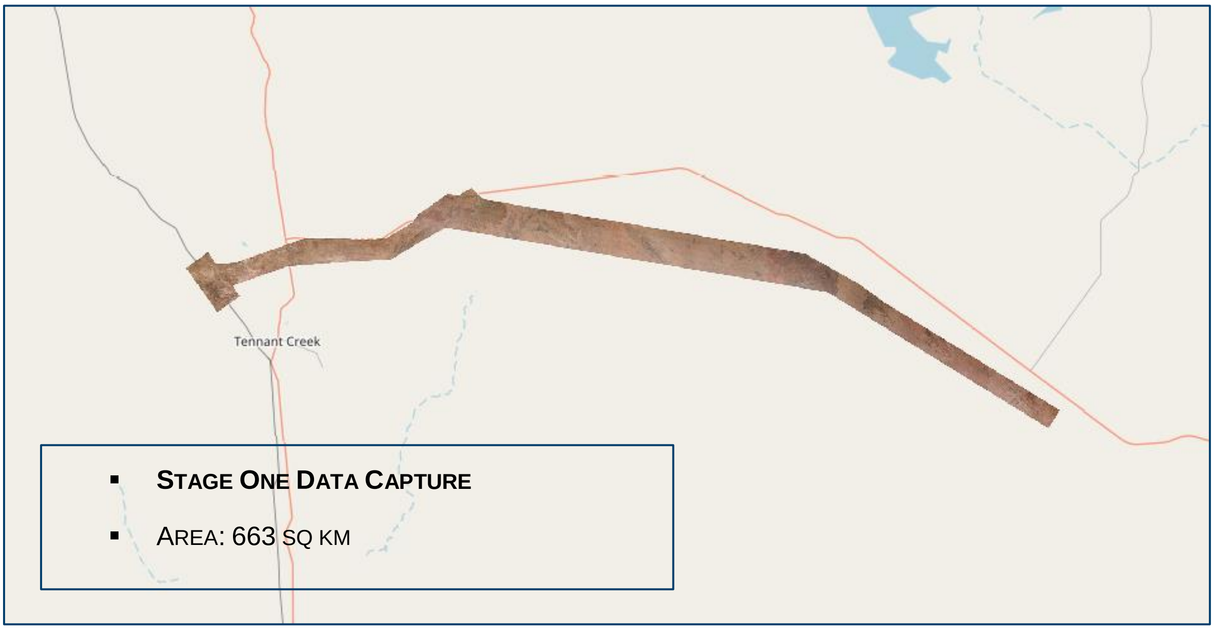


Figure 1: Stage 1 Data Capture.

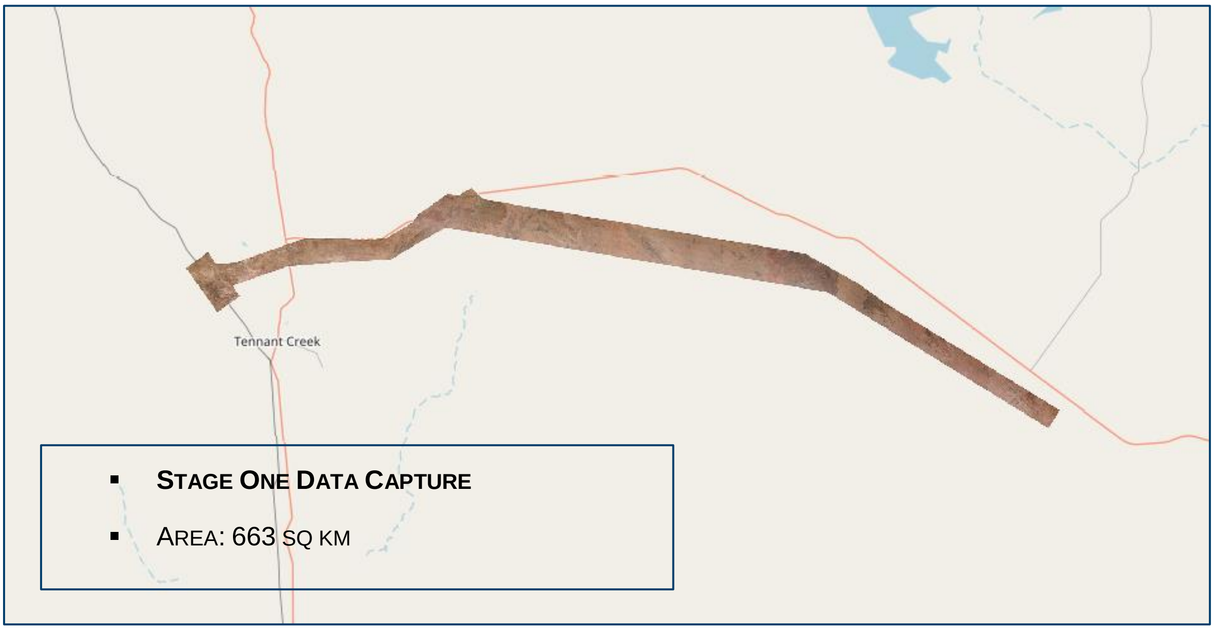


Figure 2: Stage 2 Data Capture.

Data Limitations

- The accuracy of projects acquired by remote sensing, including aerial photography, are influenced by a range of factors in the capture process. Photogrammetry has proven to be a reliable capture process which addresses many of the inflight anomalies through the aero-triangulation process.
- As the technique is based on visibility of the ground the accuracy of the dataset is expected to be 0.3m to 95% confidence in areas where the ground or features are clearly visible. Areas of dense vegetation may not reach this accuracy.

2.2 Environmental Scoping Report and Cultural Heritage Risk Assessment

WSP Australia Pty Ltd was commissioned by the Qld Government to undertake an Environmental Scoping Report (ESR) and Cultural Heritage Risk Assessment (CHRA) for the MITCR.

The scoping assessment concluded that the project has both a potentially high environmental and high cultural heritage risk, potentially impacting multiple environmental factors and triggering a range of environmental approvals. The need for extensive field environmental assessments during the design and pre-construction stages was identified.

Requirements for environmental assessment and approvals were identified across various factors pursuant to the *Environment Protection and Biodiversity Conservation Act 1999* (Cth), the *Environmental Assessment Act* (NT) and the *Environmental Protection Act 1994* (Qld). Detailed further assessments will be required to progress the project in accordance with State and Commonwealth environmental approval pathways.

2.2.1 Key Findings

A summary of key findings for the specific areas investigated are provided below:

1. Water

The project traverses, and is in proximity to, multiple mapped watercourses, drainage lines, waterholes, boreholes and farm dams. Flooding in the region is a risk to the project, especially within the eastern half of the project alignment where the greatest amount of watercourses are located. Further, the project itself may exacerbate the impact of flooding, given the potential for any rail embankment to act as a barrier (this issue is discussed in the hydraulics section).

2. Soil and Land Management

The project crosses two lithostratigraphic units which both contain an extensive network of caves and sinkholes, with the largest concentration found around the town of Camooweal. These areas may require additional assessment, incorporation of specialist design measures and result in additional construction costs to address the lithostratigraphy.

In addition, the black clay plains of the Barkly Tablelands, which underlie approximately 160km of the project corridor, are subject to significant expansion and contraction with seasonal rainfall. This will also need consideration in the project design, as well as in construction programming to avoid construction during peak rain periods. This issue is discussed further the geotechnical summary.

3. Biodiversity

Both State and Commonwealth protected and threatened species as well as habitat for suitable threatened species) were recorded within the project corridor. Subject to detailed ecological assessment, the project will require referral to the Commonwealth Government and may subsequently be considered a Controlled Action. It is likely the preparation of a Review of Environmental Factors and specialist studies will be required to support the Referral.

4. Cultural Heritage

The cultural heritage risk assessment determined that the project is Category 5 High Risk. There are a significant number of known Aboriginal cultural heritage sites and artefacts present across the region, and the potential for further heritage factors yet to be discovered within the project corridor.

Category 5 works are those that pose the highest risk of harming Aboriginal cultural heritage. This project should not proceed without further cultural heritage assessment and consultation with all relevant Aboriginal parties in order to manage the risk and ensure the project works comply with the duty of care.

While not as extensive as the Aboriginal cultural heritage, historical cultural heritage related to early exploration, mining and military uses are also present and will need further assessment during cultural heritage surveys required for future stages of the project

5. Public Amenity and Health

Although the project generally crosses remote and sparsely populated land, there are townships, Aboriginal communities and homesteads in close proximity to the project. In addition to direct impacts to land, there will likely be public amenity and health concerns regarding visual amenity, noise, air quality and vibration impacts on local residents. Detailed assessment, consultation and design consideration will be required within future project stages.

6. Resource use and management

The construction of a project this magnitude will result in significant resource use. This includes immediate construction resources for the railway itself such as quarry material, as well as key resources such as fuel and water.

Many of the waterways in the region are ephemeral and bores are used by land owners to support their own industry production. Therefore, local government authorities and land owners will require consultation regarding the sourcing of water to support construction.

There are limited facilities for waste management to dispose of wastes generated by the project during construction. Waste transportation will increase project costs necessary to transport construction materials, fuel for extended transport costs and labour to the site.

7. Special areas and Land Tenures

Properties traversed by the project represent substantial landholdings, many of which are pastoral lease tenures for stock grazing. The project dissects some properties, acting as a bounded corridor within the useable land for leaseholders, limiting access to pastoral land and stock movements. The project also crosses several designated stock routes, posing a risk to stock and/or a delay to operation of the train line when the stock routes are utilised.

The project crosses large areas of Aboriginal land and native title which will require consultation with Traditional Owners, or their representative.

The project alignment crosses between the township of Camooweal and the Camooweal Caves National Park. The project should seek to avoid the National Park, while also minimising the impact on the township. The alignment's positioning through the township/National Park pinch point will need to consider the impact on the township (i.e. access, public health and amenity) and the National Park (i.e. access, biodiversity), as well as the previously mentioned geotechnical and cultural heritage aspects.

8. Potential Environmental Offsets

The project will require ecological surveys and assessment to ground truth mapping and database results and confirm the presence or absence of threatened species and communities. Approvals will need to be sought for the project, which will potentially have specific conditions attached inclusive of offsetting requirements.

2.2.2 Key Points

- This study was high level and at an early stage of planning involving a 3km wide corridor. Much more detailed assessments will be required once the corridor is confirmed and narrowed.
- The project has the potential to have a high impact on the environment. Despite being classified as high risk, none of the above environmental factors are insurmountable, conditional to the appropriate assessment and mitigation in future project stages.
- The project has a high cultural heritage risk. Further work is required to clarify this risk and will require consultation with the impacted aboriginal parties. Learnings from the nearby Jemena pipeline project suggest a considerable amount of work may be required to gain the support of impacted aboriginal parties.
- The project is likely to require environmental assessment and approval pursuant to the *Environment Protection and Biodiversity Conservation Act 1999* (Cth), the *Environmental Assessment Act* (NT) and the Environmental Protection Act 1994 (Qld). Detailed further assessment and consultation will be required to progress the project in accordance with State and Commonwealth environmental approval pathways.
- The cost and scheduling implication for these approvals may be substantial and will require consideration during the planning of future project stages.
- Until a final alignment is determined and the impact on the environment quantified, other issues including offsetting requirements cannot be established.

2.3 Hydraulic Assessment Report

Jacobs Australia Pty Ltd were engaged by Qld Government to undertake a two-staged hydraulic assessment study of the TRA. The key study outcomes sought were to:

- Determine a vertical alignment for the TRA using the photogrammetry data made available as part of the TAP work.
- Recommend improvements to the horizontal alignment.
- Prepare a strategic cost estimate, including an assessment of the bridge / culvert requirements.
- Determine if there were any major impediments for the TRA.

The study consisted of two stages.

Stage 1

- Desktop assessment of hydrological issues / major risks to the trial alignment.
- Identification and mapping of catchments in the study area, with recommendations of catchments to be modelled in Stage 2 to inform vertical alignment.
- Refinement of the horizontal TRA based on an assessment of the terrain data and watercourse intersections.

Stage 2

- Development of flood models for 11 catchments.
- Propose a vertical alignment (using the 3 flood immunities levels agreed upon).
- Prepare a strategic cost estimate.

2.3.1 Stage 1 Findings

Using a 3km wide corridor, Jacobs' analysis identified 39 catchments within the TRA study area. The methodology and technique to identify, characterise and map the catchments is available within the Stage 1 report.

To assist in identifying a vertical alignment the JTWG determined three flood immunity levels to be assessed). These were: 2%, 1% and 0.2% Annual Exceedance Probability (AEP) flood events. A desktop risk assessment was undertaken based on known flooding issues, catchment sizes and design rainfall intensity.

A total of 11 catchments were identified to be the subject of detailed flood modelling in Stage 2.

Horizontal Alignment

With the benefit of 3D data (3km wide), Jacobs undertook an initial review of the TRA. This review indicated several opportunities for rationalisation and improvement, particularly in terms of constructability and reduction in capital cost, mainly through a reduce earthworks requirement and the provision for the adoption of simpler structures at water crossing points.

An alternative horizontal alignment for the eastern half of the route heading south-west from Mt Isa was identified for future consideration. The advantage of the alternative alignment is it crosses lesser waterways, and reduces the length of alignment traversing poor ground conditions. The Qld Government's Geotechnical Section review of the alignment in Section 7 indicates some concerns with it particularly the increased length.

Factors such as land ownership, environment, heritage and geotechnical conditions were not considered in the proposed alternative TRA alignment and will need to be considered before a final horizontal alignment could be established.

Vertical Alignment

The assessment for vertical alignment was carried out in two stages which:

- Established the base vertical alignment for hydrology modelling.
- Refined the vertical alignment taking into account the hydrology study outcomes such as flood levels and the required flow capacities under bridges and through major culverts.

Three vertical alignments were derived for the three agreed flood immunities assessed (2%, 1% and 0.2% AEP).

The alignment model was analysed against the photogrammetry contour model to identify any non-conforming areas of the TRA and opportunities for improvement.

The vertical alignment of the TRA was reviewed and adjusted primarily to meet specified criteria as follows:

- Maintaining standard ARTC track design standards (assuming a speed of 100 km/h).
- Shortest alignment route to minimise construction costs whilst giving consideration to rail profile for train operational efficiency and formation earthworks optimisation.
- Avoiding existing infrastructure.
- Aligning crossings of major waterways to minimise waterway width and bridging length, with crossings on tangent track where possible.
- Where possible running adjacent to Barkly Highway to minimise property severance.
- Maintaining a minimum rail separation of 60 metres from the Barkly Highway. While this minimum 60m separation has been used in the initial realignment, further realignment as part of Stage 2 will consider locations where the route can be closer to the highway (to reduce earthworks and property resumptions).

2.3.2 Stage 2 Findings

In Stage 1, 11 flood catchments were identified to be modelled. Stage 2 identified further interactions between some catchments making it necessary to merge some of the flood models. This resulted in 8 rainfall-runoff models developed to derive inflows to the hydraulic models. However, only the hydrology model for Ranken River could be calibrated to one flood event due to a lack of recorded flood and rainfall data.

A total of nine 2D hydraulic flood models were developed to size culverts and bridges as well as provide inputs into the rail vertical alignment design. None of these were able to be calibrated to recorded flood levels.

Flood estimation methods based on the run off models were derived to calculate peak flows for other catchments not hydrologically or hydraulically modelled. Culvert and bridge estimates were then derived for these catchments (> 20km^2) based on limiting structure velocities and assumed depths of flow.

Design and Earthworks Volume Estimation

The vertical alignments for three flood immunities (2%, 1% and 0.2% AEP) were derived based on the flood levels from the developed flood models. The vertical alignments were then used to estimate approximate earthworks volumes based on a number of assumptions (refer to main report). Two key points from this assessment are:

- Earthworks volumes are in the order of 9.2 million m^3 of cut and 4.8 million m^3 of fill for 1% AEP.
- The earthworks volumes for these three flood immunities did not vary significantly for the three flood immunities.

2.3.3 Study Limitations

- The resolution of the 2D flood models is 10m. More accurate data could be obtained if the model resolution was improved to 5m.
- The 2D flood models required development of downstream boundaries. The assumed bed slopes for these boundaries are likely to have some minor influence on the flood behaviour at the rail alignment.
- There is a notable lack of flood records to inform the hydrology assessments hence design hydrology estimates were determined based on the best available information at the time of the study.
- The flooding behaviour of the large catchments and floodplains in the western portion of the route, particularly near Walkabout Creek and Goose River are poorly understood. It is likely that floodplain infiltration plays a significant role in this flood behaviour and the frequency of large flood flows across the route.
- Future use of the design flow estimates presented in this study should take into consideration the inherent uncertainty of the estimates.
- The supplied photogrammetry data covered a relatively narrow corridor. While this data was sufficient to carry out this assessment, there are locations where additional survey data is required to develop hydraulic flood models. The study has used low accuracy Shuttle Radar Topography Mission (SRTM) data in places to extend the flood models. Ideally, these areas would be improved with higher accuracy photogrammetry data.

2.3.4 Future Project Risks

The study has identified future risks for this project as it matures:

1. The lack of available rainfall data and flood records results in a large degree of uncertainty in flow estimations. This could have a large impact on the derivation of flood levels and waterway structure sizes.

2. The flooding behaviour of the large catchments and floodplains in the western portion of the route (e.g. Walkabout Creek, Goose River) are poorly understood. This uncertainty could have a large impact on the cost estimation.
3. The high-level design of the alignment has not been fully integrated with the geotechnical and environment / heritage assessments.

All three of these are likely to influence the design.

2.3.5 Recommendations

Jacobs provide a number of recommendations for future consideration / further work:

Data

1. Work with the Qld and NT governments on methods to collect more rainfall data for the study area. There is limited flood records available to inform the hydrology assessments. Specifically, there is only one gauged catchment crossing the corridor and very few rainfall stations in the catchments.
2. Gauging flood flows and coincident recording of catchment rainfall carried out in the following catchments:
    - Georgina River (possibly gauged at Camooweal using Barkly Highway bridge for flow measurement with rainfall gauging in Camooweal (or preferably further north and closer to the catchment centroid).
    - James River (possibly gauged at Avon Downs using Barkly Highway bridge for flow measurement with rainfall gauging at Avon Downs or preferably further north closer to catchment centroid).
    - Walkabout Creek or Goose River (possibly using maximum height recorders for water depths over Barkly Highway acting as a long weir for flow measurement with rainfall based on radar imaging although nearest radar is Mt Isa which is 400km from catchment).

Hydrology

3. Future use of the design flow estimates presented will need to consider the inherent uncertainty of the estimates, and the estimated error bounds presented for the Ranken River flood frequency analysis and catchment area flow relationships.
4. Information regarding initial and continuing losses was adopted based on guidance from the Standard ARR2016. This resulted in the majority of modelled catchments using an 80mm initial loss and less than 4mm continuing loss. Data including the high initial losses, low continuing losses and generally small differences in rainfall for long duration events are vital in determining both peak flows and the critical duration for most catchments. Further investigation including additional rainfall/streamflow monitoring is recommended prior to finalisation of detailed design of the railway.

Hydraulics

5. None of the nine 2D flood models developed to size culverts and bridges have been calibrated to recorded flood levels. More data is required as indicated above.
6. Additional survey data is required to further develop the hydraulic flood models, particularly where the study used low accuracy SRTM data to extend the flood models. The following models should be extended or supplemented with improved survey data in subsequent stages of assessment:
    - Buckley and Johnson Creeks – flood extent goes beyond available data.
    - Kiama and Happy Creeks - flood extent goes beyond available data.
    - Ranken River – extend upstream to Soudan Homestead to assess afflux.
    - Georgina River - extend upstream to include Camooweal to assess afflux.
    - James River extend upstream to include Avon Downs to assess afflux.
    - Wilfred Creek - extend upstream to include Barkly Highway to assess afflux.
    - Nowranie Creek extend upstream to include Barkly Highway to assess afflux.
7. The resolution of all of the 2D flood models is 10m. In subsequent assessment stages, the resolution of these models could be improved (for example, to 5m). While this may increase simulation times, advances in flood modelling software and hardware may negate this.
8. The 2D flood models required the development of downstream boundaries. The assumed bed slopes for these boundaries are likely to have some minor influence on the flood behaviour at the rail alignment. A larger extent of survey data (possibly at a lower resolution than the supplied photogrammetry) is recommended to extend the downstream limits of these flood models in subsequent assessment stages.
9. It is recommended further stages of investigation for this project include monitoring of flood flows across the Barkly Highway for a specific flood event with rainfall possibly estimated from satellite imagery.

2.4 Construction Material Supply

The Department of Infrastructure, Planning and Logistics in the NT engaged Golder Associates Pty Ltd to undertake a desktop assessment of the key geological / geotechnical components considered important for selecting a technically and economically feasible rail alignment. The scope of this work included:

- Identifying potential local sources of suitable materials for construction of rail ballast formation and embankments.
- Identifying the presence of potential geo-hazards likely to be encountered along the trial route including recommendations for solutions.

A secondary objective of the study was to provide information to contribute towards developing a scope of works for future field investigations should it be required for a later stage of this proposal.

2.4.1 Methodology

A desk top assessment was undertaken and involved:

- Reviewing a wide range of data sets including geographical maps, ortho-imagery, topography data and design information from previous projects in the study area.
- Detailed mapping within a 3 km area parallel to the proposed TRA using shaded relief imagery derived from a digital terrain model (DTM) in conjunction with georeferenced aerial imagery and existing published geological maps. The refined geological maps are available in the addendum to the Golder Associates report.
- Identifying potential borrow areas via a detailed review of mapped geological units and terrain analysis where specific soil and rock types and landforms were delineated to highlight areas where suitable material types may be sourced.
- Following the initial classification of the site stratigraphy and definition of the different terrain units, with data used to complete identification of the potential sources of materials required, including borrow sites for constructing purposes (for example, ballast and embankment). This process also identified potential geohazards.

The following specifications were taken into consideration when identifying potentially suitable ballast materials:

- Alice Springs – Darwin Railway Project – Ballast Specification. ADrail 2002 (Doc No. 04-2000-0003-Rev.1.
- Australian Standard AS 2758.7:2015. Aggregate and rock for engineering purposes. Part 7: Railway ballast.
- Australian Standard AS 1141.4-2000. Methods for sampling and testing aggregates. Method 4: Bulk density of aggregate.

2.4.2 Study Findings

The major findings from the desktop assessment are summarised below. More details of the study are available in the Golder Associates report (**Error! Unknown document property name.** Tennant Creek to Mt Isa Trail Route Alignment for Railway).

Terrain Units

Six different 'Terrain Units' were identified for sections of the TRA based on broadly similar geological and geomorphological conditions. The technique used to do this and the predominant geological, topographical and drainage conditions that generally characterise each of the terrain units are outlined in Section 4 of the main report. The six terrain units are:

- Tennant Creek Hills (Ch. 0 to Ch. 51).
- Sand Plains (Ch. 51 to Ch. 195.5 and Ch. 226.5 to Ch. 268).
- Rocky Plain (Ch. 195.5 to Ch. 226.5 and Ch. 268 to Ch. 329.5).
- Black Soil (Ch. 329.5 to Ch. 457.3).
- Camooweal Rise (Ch. 457.3 to Ch. 562).
- Mt Isa Hills (Ch. 562 to Ch. 637.7).

The terrain units provided an indication of the materials available to construct the railway as well as possible geo-hazard that could be encountered within the TRA. The following sections provide more specific detail on these aspects.

Ballast Requirements

Golder Associates estimated approximately 1.28 million tonnes of rail ballast would be required for railway construction.

The following key potential ballast quarry targets were identified located within 40km either side of the proposed rail corridor:

- Felsic Porphyry (map unit: EP_Ppy) – Quartz and/ or feldspar phenocrysts in a felsic aphanitic groundmass; massive to foliated.
- Wonarah Beds (map unit: MC_Lst) - Silicified limestone and dolomite, siltstone, chert silicified shale, leached carbonate rocks; fossiliferous.
- Shady Bore Quartzite (map unit: MP_Qtz1) - Flaggy to massive medium orthoquartzite: interbeds of fine sandstone, siltstone and dolomite.
- Camooweal Dolomite (map unit: C_Dol) - White crystalline dolomite with chert nodules and bands. Some dolarenite and marly interbeds. Minor quartz sandstone lenses.
- Cromwell Metabasalt Member (map unit: MP_MetaB1) - Metabasalt, amygdaloidal metabasalt, flow-top breccia, tuff.
- Dolerite (map unit: Dlr) - Coarse to medium pyroxene dolerite.
- Kitty Plain Microgranite (map unit: MP_Gr) - Slightly porphyritic, fine to medium-grained alkali granite to granodiorite; locally abundant metasedimentary and mafic xenoliths, as well as mafic pillows/enclaves.
- Leander Quartzite (map unit: MP_Qtz) – Orthoquartzite.

Borrow Sites - ballast

A total of 17 potential quarry sites were identified as part of the feasibility study along the proposed route. Consideration was given to:

- Inferred material quality.
- Distribution along the TRA.
- Potential equipment accessibility.
- Potential for future expansion.

The potential quarry sites are generally positioned every 100km along the rail, with clustering of quarry options around the Tennant Creek and Mt Isa areas where geology is more conducive. These considerations are summarised in the Golder Associates report and rated according to inferred potential of generating quality ballast material, proximity to rail and a requirement for additional access tracks.

Borrow Areas – select and general fill

The desktop analysis assessed the availability of general fill, select fill and sub-ballast capping (SBC) materials along the proposed rail alignment. Fill material is required for construction of the rail formation (embankment). The rail formation can be divided into:

- 'subgrade' (natural ground) or placed soil and rock fill, formed using general fill material to shape the lower parts of the railway embankment;

- ‘transition fill’ formed using general and select fill material placed towards the top of an embankment; and
- ‘sub-ballast capping’, which is the uppermost layer in the embankment on which the ballast sits.

Both the subgrade and the transition layers provide a stable foundation for the SBC and ballast.

Where possible, it is preferred to support the rail bed on existing ground, particularly in areas where fill sources are limited. The suitability of existing ground to support the rail bed depends on in situ strength, which may require additional treatment such as cement/lime stabilisation or geo-textiles.

The transition fill material forms a higher quality layer above the general fill and provides a stable, platform for the SBC. Ideally, transition layer is free of large voids, have a controlled particle size distribution, (to avoid piping of the sub-ballast capping) and be of a reasonable stiffness to prevent deformation under load.

The SBC layer is a high quality, high stiffness layer, generally comprising a well-graded sand/gravel material with low fines content to reduce the potential build-up of pore water pressures. In areas where poor quality SBC is available, high ballast maintenance should be expected as fouling of the ballast with SBC may occur relatively quickly.

Site assessment was also based on in-situ within 5 km of the rail. Generally, borrow sites have been spaced 10 km apart along the alignment. Where there was variability in ground conditions (particularly within the Black soils terrain unit), the spacing increased to 30 km.

Sub-ballast capping

For the SBC the assessment was based on a 300mm layer comprising granular materials with high strength clasts. Where available, preferred materials are to be sourced from within 5km from the rail alignment. In total 31 borrow areas have been identified with varying potential for sourcing SBC - potential sources were identified within each of the terrain units described previously.

Embankment and fill material

Fifty three 53 potential sources of general and select fill materials were identified, largely available within borrow sites located in the terrain units mentioned previously (details are available in Appendix D of the Golder Associates Report).

The same methodology for sourcing SBC materials was used for the general and select fill sources. Locations were selected to predominantly target mid- to toe-slopes of colluvial deposits located adjacent to bedrock outcrop topped hillsides. Other potential sources included areas of low topography with outcropping bedrock, with the aim of targeting weathered rock products.

Areas for general fill were also identified where limited fill source options are available and bedrock weathering properties may produce unfavourable soil products for select fills. These are in areas of sparse rock outcrop, adjacent to sandstone bedrock areas (likely producing high sand-content fill), siltstone (likely forming platey gravel clasts that will be difficult to compact) and granitic outcrops (likely to contain erodible clays and sands).

Based on the limited topographic variation of the TRA, general fill sourced from cuttings will be limited. At cutting locations, opportunity for widening and/or reducing cutting batter angles should be adopted to maximise materials generated from cuttings.

Sources of ballast and general fill materials may be limited within the Black soil terrain unit and other localised areas along the route.

2.4.3 Potential Geo-hazards

Golder Associates undertook an assessment of potential geo-hazards likely to be encountered at various locations along the route. These potential hazards will require additional investigation at the next stage of planning to fully address engineering measures and associated costs that may be required to construct a rail line. The four main hazards identified are briefly discussed below:

1. *Black Soils*

   The presence of highly reactive clay soils presents geotechnical engineering challenges. The desk top assessment included a review of Australian Soil Resource Information System (ASRIS) to define the approximate limits of areas along the alignment where there is a potential for encountering reactive clays.

   The desktop map review identified the ‘Black Soils’ terrain unit covers 128 km of the alignment (1km encountered in the Camooweal Rise terrain unit within topographic lows), of which approximately 100km is mapped as black soil.

2. *Flood Hazard areas*

   The TRA crosses multiple ephemeral drainage lines, broad floodplain areas and the black soils plain, which become active during the rainy season. The main risk is to rail embankments which have the potential to erode, resulting in deep scouring of embankments and risk of embankment failure.

   Review of available data indicates approximately 180km (28% of TRA length) of the TRA falls within geological units which include alluvial deposits, alluvial wash zones, floodplains and the black soil deposits, and are susceptible to inundation and flooding.

3. *Watercourse crossings*

   Watercourses (drainages, creeks, rivers) of varying widths and depths intersect the entire length of the TRA. Major river and creek crossings (crossings and river systems >15 m wide) are concentrated within the ‘Black Soils’ ‘Camooweal Rise’ and ‘Mt Isa Hills’ terrain units.

4. Sinkholes

A large portion of the alignment intersects bedrock formations containing limestone and dolomite lithologies. The geo-hazard associated with these rock types is the development of karstic landforms comprising buried cavities and sinkholes. These features are often prevalent in carbonate rich rocks as voids form through the dissolution of the rock material by slightly acidic groundwater, resulting in cavity formations. These cavities expand over time and may form sinkholes and or shallow, funnel shaped depressions (doline), depending on the nature of the overlying materials.

The desk top study identified an extensive cave network located within an approximate 60km x 30km area around the town of Camooweal (Ch. 457) and between Ch. 453 and Ch. 478.

2.4.4 Recommendations

The assessment identified a number of geo-technical challenges associated with the TRA broadly around two areas:

- Sourcing of construction materials from within the study area.
- Potential geo-hazards (black soils, danger to embankments from flooding, crossing of the many water courses and sinkholes).

None of the challenges or geo-hazards identified are considered insurmountable. Further assessment is required to further de-risk the proposal in the next stage. As no field investigations were undertaken for this assessment, recommendations for future targeted work as follows:

1. Geological Walkover and Geological Mapping

Undertake a ground reconnaissance survey along the rail alignment to:

- Visually assess the suitability of potential ballast quarry and embankment borrow areas identified during desk top study based on site surface observation.
- Based on visual observations, select borrow and quarry areas for further investigation through geophysics, test pitting or drilling.
- Assess right to use issues and logistical requirements for accessing areas of the alignment.
- Undertake geological/geotechnical mapping to provide additional information pertaining to the extent and boundaries of critical geological units e.g. black soils, floodplain and alluvial wash zones and to assess karst potential in areas identified in the report.

2. Targeted Geotechnical Investigations

Undertake targeted geotechnical and geophysical investigations to areas identified during this desk top study and a future reconnaissance within the investigation stages.

3. Detailed Geotechnical Investigations

Following the targeted investigations, a comprehensive geotechnical investigation should be undertaken and include:

- test pitting along the rail centreline to characterise each geological unit and determine likely foundation conditions; and
- test pitting within proposed borrow areas and a geotechnical drilling programme to investigate bridge locations, deep cuttings and locations of proposed quarry sites.

4. Geophysical Survey Methods

Targeted and alternative non-invasive investigation methods could reduce the cost of conventional intrusive approaches such as test pitting and drilling. Several methods could be undertaken during a targeted geotechnical investigation stage to assess site conditions prior to proceeding with more costly invasive investigations. The non-invasive methods are particularly useful in situations where independent landholders are reluctant to allow conventional investigation equipment on to their property. Options available include:

- Reconnaissance electromagnetic survey to assess extent of shallow rock in black soil areas during walk over survey.
- Seismic refraction survey to assess weathering profile, strength of rock mass and excavatability within shallow cuttings.
- Karst investigations to identify sub-surface voids within the Camooweal and Rocky Plains terrain units, which can be divided into the following levels of investigation detail.
- Reconnaissance Level Microgravity Survey - to produce a map of subsurface anomalies highlighting gravity lows associated with sinkholes and other karstic features.
- Intermediate Level – 2D and 3D ERI Surveys to identify karstic features (refer Figure 3). 2D ERI surveys are used to develop a ground model, which delineates the extent of the postulated karst limestone features.

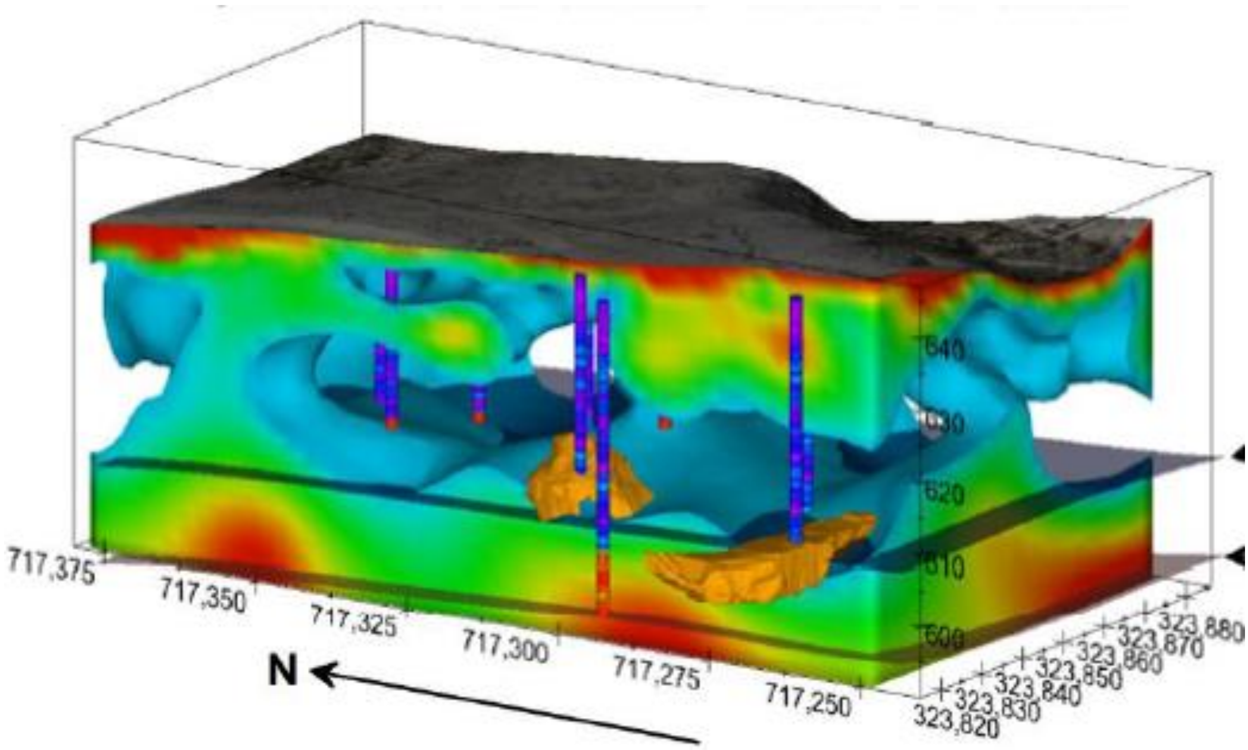


Figure 3: Example image of 3D ERI Survey through karst features.

- Detailed Level - Cross hole seismic tomography to identify karstic features, or detailed characterisation and quantitative definition of sinkhole and karstic features using borehole seismic tomography, typically used at location such as bridge abutments is the structure coincides with karstic terrain (Figure 4).

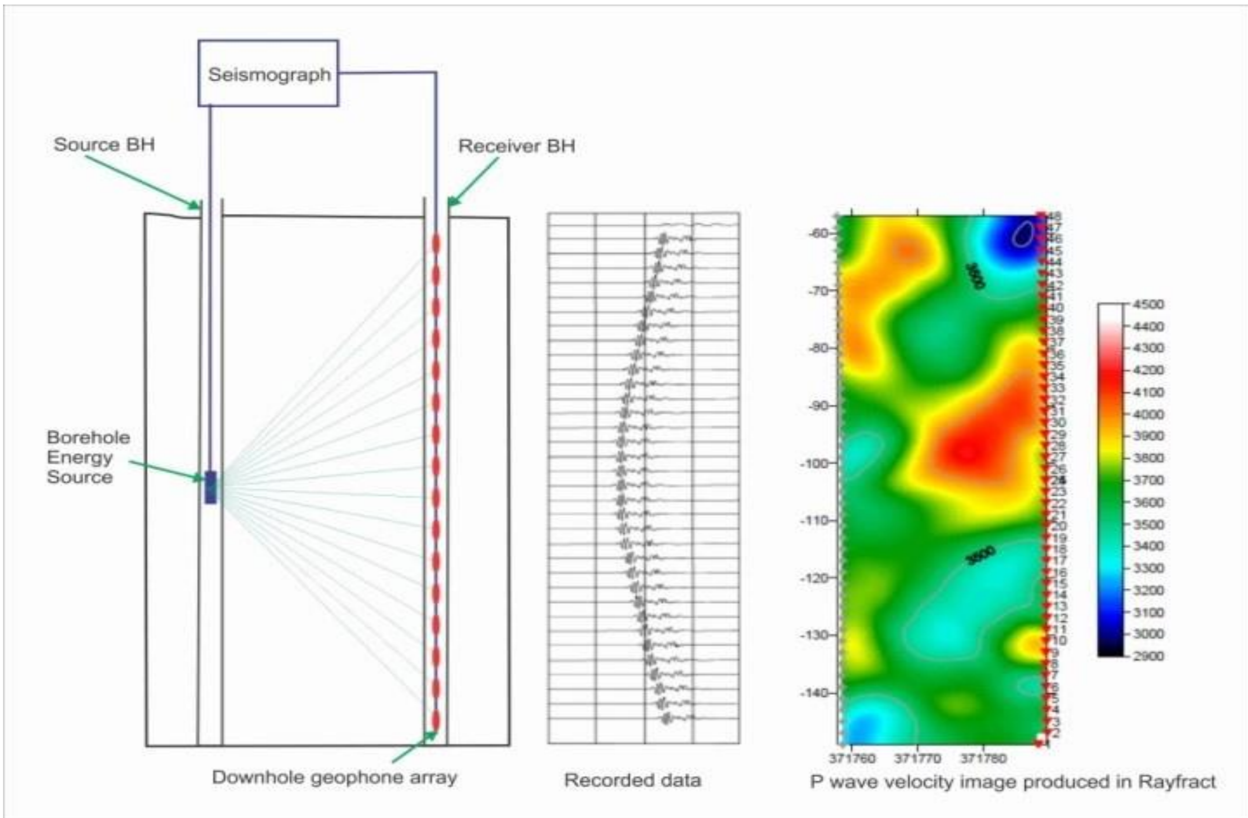


Figure 4: Example of residual Bouguer anomaly map through karstic limestone using borehole seismic tomography.

2.5 Geotechnical Investigations Report

The Qld Government geo-technical section undertook a preliminary geotechnical assessment of the TRA based on the following scope of works:

- Identify any hydraulic data required to assist in the geotechnical assessment.
- Document the geotechnical challenges to be considered in construction of the proposal using the TRA as the basis.
- Undertake a literature review and broad assessment of rail construction techniques and / or treatments for black soil areas, and where treatments could be further refined.
- Based on the geological context, provide advice on appropriate construction types and treatments for the rail line, bridging and culverts.
- Recommend technical standards for construction of rail over black soil geology.
- Undertake a material survey (field observation study) to identify the extent and location of sources for construction materials including ballast, embankment material and capping layers.

There was some overlap between the geotechnical works completed by the Qld Government and by the Department of Infrastructure, Planning and Logistics. Some of this relates to the research to identify the geological features required to undertake the respective scope of works. Points of difference with the work the Qld Government undertook included field observation surveys, assessment of suitable construction methods/techniques and more detailed analysis conducted regarding the potential sources of construction materials.

2.5.1 Study Findings

The key study findings in regard to construction materials are as follows.

Potential Borrow Sites (hard rock and sand)

A desktop analysis was undertaken to compile information on all existing road and rail construction material sources (existing quarry sites) located within 50km of the TRA. As the analysis only identified four existing quarries, the study was extended east beyond Mt Isa towards and past Hughenden to include additional quarries. The findings from this assessment are:

- Apart from the four identified existing quarries there are no existing and operational hard rock quarries in the vicinity of the proposed alignment.
- With the study area extended12 hard rock quarries with the potential for sourcing rail ballast and bulk earth materials were identified.
- Five sand and gravel quarries capable of producing fine concrete aggregate were identified. Three of these could also be capable of producing road base material, coarse concrete aggregate and potentially supply embankment and general fill materials.
- Two mine spoil sites (Robin Mine and Trekelano Mine) intermittently operate as quarries and may meet ballast and earthworks fill material standards required.

Further investigation would be required to confirm the suitability of these sites to meet the construction requirements / standards require for the rail proposal.

Potential Borrow Sites (fill)

A desktop analysis and a limited field reconnaissance survey was undertaken. A total of 108 site observation locations were recorded, noting both existing and potential new sites. Detailed information on 44 of these potential borrow was collected.

The preliminary assessment of these sites revealed 97 borrow source sites in the vicinity of the alignment within Queensland with the potential for producing material for bulk earthwork material (general embankment fill, selected fill and structural fill), capping layers, concrete aggregates and drainage blanket products within approximately 50km of the proposed rail alignment.

In the NT section of the proposed alignment the preliminary assessment revealed30 existing/possible borrow source sites in the vicinity of the TRA with the potential for producing material for embankment fill, general fill as well as concrete aggregate, rail ballast and capping layers.

Details of these sites, including location, terrain unit and approximate chainage were recorded. The field investigations revealed the potential of sites as follows:

- Forty potential sites within all the terrain units that could be used as general embankment fill material.
- The potential to source capping material 16 locations.
- Five sites having potential for concrete aggregate.
- Selective fill material potentially sourced from 25 sites.
- Drainage blanket material, potentially sourced from two sites.
- Armoured rocks or rail ballast material possibly sourced from four sites.

Provision of Rail Ballast

The logistics of quarrying and supplying rail ballast to the TRA project were assessed and the following matters were identified for further consideration.

- In terms of construction, the geology and geomorphology of the route is similar to sections of the Alice Springs-Darwin Railway and lessons from that project can be applied to this project.
- The only practical sources of quarry materials are located either at Tennant Creek, Mt Isa or further east. Quarries which have previously produced ballast already exist in these locations. It is extremely doubtful a new greenfield quarry along the TRA could produce ballast at a lesser cost than that of the existing quarries. The potential exception to this would be if a former quarry (that is with a fully developed face with high quality rock) was reopened to produce ballast using a large mobile crushing plant.

- One of the critical issues of ballast production is the proportion of ballast produced from a quarry is typically in the 25% to 35% range, with the remaining material generally “fines” (that is -26.5 mm material). These “fines” do represent a useful material with a potential for use as capping material or select material. However “fines” are less valuable a material than ballast hence uneconomical to transport over longer distances. In addition, there is a low recovery rate for ballast as it is not possible to crush to a ballast grade without producing large quantities of “fines”.
- The carbonate rocks which commonly occur along the route do not meet the required specification criteria of source rock having a wet strength 150 kN. Similarly duricrust materials are generally in deposits too thin to be economic for ballast production. The Mesozoic sediments also do not meet the source rock quality requirements. Ancient (Precambrian to Palaeozoic age) igneous, sedimentary (other than carbonates) or metamorphic rock types could include suitable source rock.
- A critical concern is the quantity of stripping of weathered rock required to expose the required quality source rock.
- To develop a new greenfield quarry site typically takes over seven years to address permit issues. While this time frame may be shortened in the case of the TRA, particularly if the project has significant political support, permitting would still take a significant timeframe which may make greenfield sources unacceptable in terms of timing and risk.
- Flood Rock - sources of “flood rock” will be required to protect embankments near and adjacent to bridges and culverts to protect the construction from erosion. Such materials would be available from existing quarry sources and / or the quarry locations identified for ballast sources.

2.5.2 Geotechnical Challenges

Potential geohazards that propose a challenge to the construction of the rail link include those identified by Golders Associates and some additional hazards as follows:

1. Black soils – the Qld Government investigation discovered a lack of site specific data on the thickness or engineering properties of black soils found along the TRA. The main challenges of rail line construction concern formation and foundation preparation as well as impacts from water flows and or ponded water. Treatments as outlined in the Western Queensland Black Soils Best Practice Guidelines are used.
   Floodwater – watercourses (drainages, creeks, rivers) of varying widths and depths intersect the entire length of the TRA. Major issues include the erosion of embankments or foundation soils by flowing water and / or the failure / movement of embankments / foundation soils by ponded water. This is particularly relevant to the black soil areas. Techniques to manage this issue are provided in the accompanying sections.
2. Karstic features (sinkholes and caves) – these features were identified in a number of areas as a risk to the project and will require further geotechnical investigations. Karstic features are considered the **worst** of the geotechnical hazards.
3. Erosive soils – results from soil testing undertaken for the Jemena Northern Gas Pipeline indicate there are highly dispersive soils between Ch 0 to Ch 70.

4. Abandoned mines and mine waste – there are a number of abandoned mines around Mt Isa on either side of the Barkly Highway. Issues including contaminated land will require further investigation once the alignment is refined.
5. Cut slope stability – mainly an issue with deep cuts. This issue will need to be assessed if / where there are excavations into rock.
6. Seismicity – seismic activity has been reported in the study areas, with shallow earthquakes in the Tennant Creek area up to 6.9 on Richter scale in 1988. Future geotechnical investigation, including appropriate seismic risk design for structures and a further check on soils prone to liquefaction are recommended.

2.5.3 Technical Standard for rail construction over black soils

The Qld Government's Geotechnical Section provided recommendations to use technical standards in the construction of rail line over black soils. Prior to adopting standards a range of considerations will require deliberation, including:

- Stakeholder requirements – the owner of the project, requirements of specific State and Local Governments, Landowners and the operations and operator.
- Standards of compliance – identify and adopt applicable standards for rail construction earthworks and ballast supply.
- Specifications and criteria – in respect to rail performance, consideration is required on the stiffness and longevity of the pavement layers, and the soil profile below subgrade.

2.5.4 Construction techniques and treatments – black soils

A review of as-constructed plans and inspections of road bridges along the Barkly Highway revealed two main foundation types were used in construction:

- Spread footings where suitable founding bedrock is at or near surface.
- Driven UC (H) steel piles where founding bedrock is relatively deeper, beneath more weathered layers or a covering layer of black soils or alluvial / residual soils.
- Exceptions to this are at Spear Creek where concrete cylinders belled out to 2.2m to support two piers, and, at Johnstone Creek where 1m diameter cast in place (CIP) piles support three piers.
- Multi-cell major culverts are constructed with a continuous reinforced concrete slab footing and a reinforced concrete apron.

For new rail bridges the following techniques are suggested:

- Bridge foundations for rail structures should be founded on either spread footings on rock at or near surface. Where a deeper footing is required due to poor founding conditions or to achieve fixity, cast in place piles (typically 0.9 m to 1.8 m diameter) should be used. Driven piles as used for road bridges are not specified at this stage as the fixity requirements for driven piles (steel or prestressed concrete) may not be achievable, particularly where black soils overly fresh or slightly weathered bedrock.
- Site Investigations to confirm suitable founding conditions for bridge foundations.

It is expected foundations for rail culverts will be similar to the road culverts technique listed above.

2.5.5 Water Supply

During construction, significant quantities of water will be required, particularly for construction of earthworks. The Qld Government estimates the water requirement for a typical road construction project to be at least 5 Ml to 10 Ml per km of water. This translates into about 3GL to 6GL for the MITCR, dependent on the soil type along the alignment. The black soil areas may require more water than areas with other soil types. Water consumption during construction will also be highly dependent on the climate during the construction period. Potential water sources include:

- Bores which were sunk to provide water during construction of the original Barkly Highway route from Mt Isa to Tennant Creek at approximately 10 mile (16 km) intervals from the Rankin River crossing westwards for 200 miles (320 km) . Of these bores only two were incapable of supplying adequate quantities of water. These bores may still be owned by government entities.
- Surface water - along the TRA very few permanent waterholes from which construction water could be obtained exist.
- Ground water - most of the stock water in the area is obtained from bores. It would be expected these will also be the source of most of the construction water. If it is proposed to use ground water, a significant period prior to commencement of construction will be required to obtain relevant approvals for accessing this resource.
- The Qld Government has on many occasions developed dams and or bores for the provision of construction water in advance of construction, particularly when working in remote areas of western and far norther Queensland. This option should be considered. It is general practice in such cases to develop the water resources at least two years prior to the commencement of construction to ensure that suitable quantities of water are available. The timing to construct such infrastructure is highly dependent of the climate. For example, during a drought, the construction of bores / dams may need to be brought forward, or, construction delayed.

2.5.6 Recommendations

The key recommendations from geotechnical assessment are:

- Ballast is sourced from each end of the project from existing quarries, or alternatively reviving disused large quarry with a workable high face in ballast-quality rock. It is considered both impractical and uneconomic to develop a greenfield quarry specifically for ballast production.
- Examine opportunities to source other lower value materials from quarries and borrow pits along the TRA.
- Commence the materials prospecting early within the project timeframe as long lead times may be required.

- As ground water is likely to be the source of water for construction, consideration needs to be given to developing other suitable water sources along the proposed route at regular intervals. In some cases this will need to be years prior to commencement of construction.

2.6 Multimodal Freight Transport Facility (Tennant Creek)

The NT government (Department of Infrastructure, Planning and Logistics) engaged AECOM Australia Pty Ltd to prepare a feasibility study for a multimodal freight transport facility in Tennant Creek.

The site investigated is located at the intersection of the existing Adelaide to Darwin Railway and the potential connection of the MITCR.

The study involved identifying the preferred location and configuration of a terminal and was undertaken in three stages:

1. Estimate potential freight volumes in the catchment area (Market Demand Assessment).
2. Select terminal location (through Multi Criteria Analysis).
3. Estimate terminal capital costs.

2.6.1 Demand forecast methodology

Potential demand forecasts for a multimodal facility in Tennant Creek were prepared considering three sources of demand:

1. Mineral freight flows, including the transportation of input and output products to and from mines in the region.
2. Road freight, to and from Tennant Creek, which may shift to rail if a multimodal facility were to be available.
3. Inputs to the hydraulic fracturing wells in the region.

A risk-adjusted annual rail tonnage profile was developed for both mineral and non-mineral freight volumes. The profile factored in the likelihood of development by an estimated annual mine production profile and the origin and destination location of road freight flows.

In addition to the risk-adjusted tonnage profiles, three scenarios were developed to represent potential "operating models" on the basis that one or more deposits are developed or non-mineral freight flows are transported through the facility. The scenarios are:

- High volume – including all mineral and non-mineral freight flows
- Medium volume – including high and medium likelihood mineral and non-mineral freight flows
- Low volume – including high likelihood mineral and non-mineral freight flows only.

2.6.2 Potential demand

The estimated risk-adjusted and scenario potential demand volumes (tonnes) at 5, 10 and 30 year intervals are presented in Table 1 below.

Table 1: Demand Scenarios.

Scenario	2022	2027	2047
Risk adjusted conceptual tonnage	811,310	839,790	541,955
High volume scenario	25,135,765	14,631,795	5,429,340
Medium volumes scenario	1,561,141	1,907,855	1,840,130
Low volume scenario	1,069,395	1,066,630	551,920

2.6.3 Site locations

Three sites were considered for the potential location of the terminal as discussed below:

Site 1: Warrego Road level crossing

Located close to Warrego Road, in the north-western corner of the study area on a parcel of land owned by the Northern Territory Government (Portion 7025). It is close to the intersection of the proposed Mt Isa to Tennant Creek rail line and the Adelaide to Darwin line.

Site 2: Existing rail siding

The second site considered is the site of the existing Tennant Creek rail siding. It is located south of the Tennant Creek township, alongside the Stuart Highway, approximately 5km from the Tennant Creek Airport. This location is the closest to the resident population of Tennant Creek, but is closest to the identified petroleum reserves in the southern end of the area and is the furthest site from the Port of Darwin.

Site 3: Barkly Highway/Stuart Highway intersection

Site 3 is along the proposed Mt Isa to Tennant Creek rail line at the intersection of the Barkly and Stuart Highways. It is approximately 20km from the Adelaide to Darwin rail line, and is the furthest from the residential population of Tennant Creek.

Sites 1 and 3 fall within areas of Native Title Determination areas. There are existing Indigenous Land Use Agreements (ILUA) covering both sites although these are not specific to rail infrastructure which may be required. Site 2 has no known active native title applications or determinations however the Town of Tennant Creek ILUA covers the northern half of the existing siding.

A desktop assessment of potential environmental and heritage impacts associated with the proposed multimodal facility was undertaken. Based on the assessment there were no major environmental constraints identified for any of the three site options.

A Multi Criteria Analysis (MCA) framework was developed and assessment undertaken to evaluate each site against relevant criteria, in order to identify a preferred site. Site 1 (Warrego Road) was identified as the preferred location for the Tennant Creek multi-modal terminal. The location was considered to have greater proximity to demand, be more flexible and scalable, align closer with current government plans and be suitable for stakeholders.

2.6.4 Design

The multi-modal / multi-use terminal layout developed for Site 1 is shown in Attachment B. It is an initial terminal design for further consideration. The site design includes for:

- 1,800m trains to be pulled through the site
- Additional sidings have been included in the design (not included in the costing)
- Site allows for multiple uses including cattle loading and cattle yard facilities, minerals handling and mineral storage in a large covered, separated shed and container handling facilities including hardstand areas and loading equipment.

2.6.5 Cost Estimate

The total cost of the terminal is estimated at $259 million as shown in Table 2. This includes infrastructure, construction and contingency. The cost of infrastructure includes a 36,000 m^2 shed costing $108 million (excluding equipment, services and associated infrastructure) for the handling of minerals including maintaining separation and walls for loading.

Table 2: Cost Estimates.

Item	Cost
Infrastructure	$173,049,435
Preliminaries and site establishment	$17,304,944
Contractors overheads and profits	$20,765,932
Contingency	$52,780,078
Total	$263,900,388

2.7 Multi-user, Multi-modal Load-out Facility Feasibility Report (Mt Isa)

The MITCR proposal will involve a break-of-gauge to the narrow gauge rail system at Mt Isa. The facility design is to cater for freight transfer by rail and road between the existing Mt Isa to Townsville rail line and the proposed MITCR line. The brief included identifying a suitable location for the facility.

Key study outputs included in this section include:

- Demand scenario with a time horizon of 2036.
- Concept of operations for the facility to cater for the demand scenario.
- Identification of three potential sites having regard to potential integration with other industrial, commercial and logistics hubs in the Mt Isa area and a comparative assessment of sites to determine a “preferred” site.
- Concept design for the preferred site, including staging options and preliminary capital cost estimates.

2.7.1 Rail demand

Previous demand studies have been inconclusive as to likely demand for rail freight generated in the Mt Isa region, or what rail freight would be attracted to the MITCR. The predominant inbound freight to the region is currently centred on railing to Mt Isa of industrial products (cement, distillate, mining and resource processing inputs), or road from Townville, South East Queensland or origins further afield. Domestic consumption goods are almost wholly transported by road, due to diverse origins, small quantities, and delivery timeliness.

Previous studies would suggest that rail land bridging to/from the major markets on the east coast would be not viable, given the significant landside cost and time disadvantages, greatly out-weighing the shorter shipping leg from Darwin to Asia. The most likely increase in rail freight demand will be dependent on new mine developments in the region, driving increases in both outbound and inbound freights.

The 2016 demand study undertaken by GHD derived a High Demand scenario as indicated in Table 3 below, and this has been adopted for preliminary planning purposes.

Table 3: Demand scenario adopted.

Task	Current nominal traffics (2015/16)	Possible additional 2036 demand
Containers – loaded/empty	50,000 TEU	80,000 TEU
Dry bulk freight	1,200,000 tonnes	1,500,000 tonnes

2.7.2 Rail Concept of Operations

Both a container terminal and bulk terminal operating modes will depend on required through-puts, train lengths and payloads, achieving an appropriate train turn-around time (loading and unloading rates), and desirably minimising the extent of shunting.

Changing gauge for bulk products is unlikely. Gauge transfer could occur in the container terminal however the quantum of this is uncertain. Utilisation of containers for bulk products (e.g. half height containers), could be a feature, and would be treated as an intermodal freight through the container terminal, either on single product trains or multi-product trains.

Features of operation:

- The container terminal would be designed with at least 2 loading roads (both ultimately dual gauge) and a locomotive run-around road.
- The bulk terminal would ideally include a balloon loop to minimise train turn-around time; but this is not an essential requirement.
- Loading equipment deployed will dictate terminal configuration, and choice would be subject to the tasks involved, expected duty cycle and demand, and preference of the terminal operator. For the purposes of this preliminary investigation and costing, reach stackers have been assumed for deployment in the container terminal, permitting access to 2 adjoining tracks.
- The nominated reference intermodal train lengths and freight volumes would likely make rail mounted gantries non-viable; however forklifts could be deployed with a loading siding either side of a centre hardstand.
- Loading of dry bulk products is assumed as being by wheeled loaders. Use of overhead bin loadout/s is unlikely to be viable for the expected volumes involved.

2.7.3 Terminal Siting Assessment

Three site options were identified and evaluated under a multi criteria assessment. The three sites as shown in Appendix B are:

- Northern site adjacent to the Barkly Highway and north of the Airport, alongside the proposed Transport and Logistics Centre (TLC).
- Central site adjacent to or incorporating the current Aurizon terminal, and located adjacent to the existing Northridge industrial area.
- Southern site to the south west of the residential suburb of Happy Valley, and north of Mica Creek

The MCA included:

- Land use / environmental Impacts.

- Site footprint constraints.
- Rail and road network connectivity.
- Site engineering features.

The northern site was selected as preferred site to take through to the more detailed concept design and capital cost estimate stage. Site selection was based both on the initial assessment, and on a selection of alternate weightings of the assessment criteria. The northern site aligns with Mt Isa City Council's and MITEZ's aspirations for the proposed TLC. The container terminal siting has been located on the western edge of this area to maximise suitable area for the TLC.

2.7.4 Terminal Design and Capital Costs

The initial intermodal (container) terminal and bulk terminal's staging (3 stages) and capital costs estimates are as summarised in Table 4 below.

Assumptions around the configuration of stage and cost estimates include:

- A first mover TLC tenant requiring adjacent rail access would drive initial rail construction. Capital cost estimates assume the TLC has been established with basic services including road access to the Barkly Highway and appropriate services (power, water supply).
- The TLC development triggers construction of the 5.75 km long narrow gauge rail link from near Northridge Road to the southern end of the Intermodal Terminal, including bridging Spear Creek.
- The location of the dry bulk loading terminal is proposed just to the north of the full-length intermodal terminal, and comprises a double ended loading siding and locomotive run-around road (future DG main line). Costings for this only include the basic rail infrastructure and a loading siding length to accommodate a 300 metre long loading area, and excludes any associated storage and loading facility.

Stage 1 Assumptions:

- The costing for the intermodal terminal is based on a 900 metre long hardstand to cater for a full length NG container train. The equipment includes two loading sidings and loco run-around road configured to suit reach stacker operation. Track work would be built with dual gauge PSC sleepers, to facilitate future addition of 3rd rail for connecting to the MITCR.
- Capital cost includes a 900 x 25 metre concrete hardstand for reach-stacker operation, with adjoining 20 metre wide gravel hardstand for container storage.

Stage 2 Assumptions

- Upgrade of the intermodal terminal to cater for 1,800 metre long SG train, but with hardstand retained at 900 metre long.

Stage 3 Assumptions

- Stage 3 Intermodal Terminal development would involve extension of the hardstand when warranted for operational or capacity reasons.

The intermodal terminal capital costs below exclude any lifting equipment, locomotive provisioning facility, or office amenities, which are subject to required terminal through-put and peak handling rates, terminal manning levels, and terminal operator preference.

Table 4: Capital Cost Estimates.

Stage	Features	Capex (2017 $)
NG connecting link	5.75 km long NG track. Includes bridging Spear Creek	$33.9 M
Stage 1 intermodal terminal	2 x 900 m loading sidings, 3.2 km of track, floodlighting, and road connection to Logistics Hub	$34.7 M
Stage 2 intermodal terminal	Assumes NATL built and terminal track work is extended and existing track converted to DG to fit a full 1,800m SG train. Need to break SG train to fit in the 900m hardstand area.	$16.5 M
Stage 3 intermodal terminal	Extend hardstand to fit full 1,800m SG train	$20 M
Bulk terminal – track connection only	Includes 6.1 km of new track, built to NG but with DG sleepers. This assumes the main line track has already been constructed to the northern extent of the intermodal terminal site.	$21.7 M

2.7.5 Staging considerations

A decision to not proceed with an MITCR, nor any substantive first mover development of the TLC requiring adjacent rail connectivity, would drive a re-consideration of the recommended terminal locations as outlined above. Alternate, lower cost siting options could include:

- The existing Aurizon terminal extended from its current 500 metre length to around 850 metres, providing for significant growth of containerised freight, at a modest cost compared to constructing a new terminal
- A NG dry bulk terminal located to the west of the Aurizon terminal, with reasonable road access to the north via Northridge Road, obviating the need for an eight km extension of the NG rail line to a northern bulk terminal site and excluding the need to bridge Spear Creek.

These alternate siting options would rate favourably on all the MCA selection criteria, in the absence of the MITCR and TLC catalysts.

2.7.6 Recommendations

- The northern option main line connection corridor and both intermodal and bulk terminal sites should be protected in Council's Planning Scheme.
- The planning and site allocation for the TLC should be optimised for significant rail users gaining access to the container terminal, including any requirement for private siding access.

3 Technical Assessment Project Costs

The budget allocation and expenditure for each of the 8 TAP work areas outlined in Table 5 reveal the actual expenditure is under the budgeted amount. In part this is due to the final summary report being prepared internally. If a decision is made to publicise the TAP outcomes sufficient funds are available to engage a resource to undertake this work.

Table 2: Final TAP expenditure.

	Technical Assessment Program (TAP)	Budget	Actual
1	Aerial Imagery and Mapping (NT)	123,000	151,105
2	Hydraulic Assessment Report (Qld)	200,000	199,076
3	Construction materials supply in NT/ NWQ (NT)	150,000	150,000
4	Geotechnical Investigations Report (Qld) Geotechnical Investigations Data*	70,000 30,000	121,158
5	Environmental Scoping Report (Qld)	50,000	29,818
6	Intermodal (Tennant Creek) - transport facilities concept and siting (NT)	200,000	188,895
7	Intermodal (Mt Isa) - multi-user, multi-modal load out facility investigation (Qld)	70,000	68,000
8	Project Summary Report (Qld)	70,000	0
	TAP Total	978,000	908,052

*The geotechnical investigations data was undertaken as part of the Geotechnical report.

4 Strategic Cost Estimate

Jacobs prepared a high level strategic cost estimate for each of the three flood immunities (0.2%, 1% & 2% AEP) that were agreed upon. The cost estimates are shown in Table 6. Behind these estimates are numerous assumptions and exclusions (listed in the final report).

The outcome of their assessment is summarised below and does not include the multi-modal / multi-use terminals at Mt Isa and Tennant Creek:

The estimated direct cost of the 1% AEP flood immunity is $ 4.1 billion including contingencies but excluding client costs and escalation.

- Cost estimates for the other two flood immunities only vary by less than 1%.
- Costs of the major transverse drainage elements (bridges and culverts) comprise 15% of the direct job costs (i.e. excluding contractor on-costs and contingencies) and 7.5% of the total cost estimate.

- Costs of earthworks comprise 26% of the direct job costs (i.e. excluding contractors on-costs and contingencies) and 12.5% of the total cost estimate.
- Based on the assessments by Jacobs a total of 3.25km of bridges and 11.9km of culverts would be required to meet the stated afflux requirements (1% AEP).
- A deterministic allowance of 40% was applied to the contractor's costs, including direct costs, indirect (on and off site) costs, profit and margin, and design costs.
- The vertical alignment of the western portion could be lowered to reduce costs but with a lower flood immunity.

The initial cost estimate of the TAP was estimated between $2.7M and $3.4M.

Table 3: Strategic Cost Estimate ($M).

Element	0.2% AEP	1% AEP	2% AEP
Contractor Direct Costs	1,959 M	1,975 M	1,977 M
Contractor Indirect Costs and Design	956 M	964 M	965 M
Contingency	1,166 M	1,176 M	1,177 M
Estimated Total	4,081 M	4,114 M	4,118 M

5 Trial Alignment Refinements

The work undertaken to develop the trial alignment (as discussed in Section 3.1) generally follows the Barkly Highway and was detailed in 2D. With the benefit of aerial photography and digital terrain modelling data both Jacobs (Hydraulic Assessment) and the Qld Government's Geotechnical Section were required to recommend alignment refinements. The review of the TRA was constrained by the limited amount of detailed topographical information which generally comprised photogrammetry data in a 3km wide strip for the entire TRA.

Jacobs' review identified a number of alignment improvements to the TRA that provide potential construction cost savings. These are primarily associated with reduced earthworks, simplifying structural requirements (for example, reducing bridge length by minimising the skew angle at waterways) and reducing the number of crossings of the Barkly Highway. These refinements are intended to simplify the construction process and potentially allow standard bridge designs to be utilised. Details of these refinements are outlined in the Stage 1 Jacobs Hydraulic Assessment Report.

The analysis undertaken by the Qld Government's Geotechnical Section indicates that while the rationale for the TRA to generally parallel the Barkly Highway is sound, the road alignment itself may not be the most optimal between Mt Isa and Tennant Creek. The Barkly Highway was developed as an inland defence road in World War II and the philosophy for route selection was primarily speed of construction, avoidance of black soil areas, and the upgrade, with minor deviations, of existing station access roads. In this context an alternative alignment was investigated as is described later.

The Qld Government assessment of the TRA identified two further considerations if the TRA is to be adopted:

- The North East Gas Interconnector (NEGI) project currently underway, involves the construction of a buried 300 mm diameter gas pipeline from Tennant Creek to Mt Isa. This route is essentially a straight alignment between two end points, and varies from about 3 km (near Tennant Creek) to 80 km (near Camooweal) south of the Barkley highway route. Details of the construction of this project should be reviewed as part of the alignment review for this project.
- The proposed TRA would sit between the Barkly Highway and NEGI route. There is a potential conflict between the TRA and the NEGI pipeline at about TRA Ch. 24 which may necessitate a minor realignment to separate the two structures.

As part of the assessment alternative alignments to the TRA were proposed. The benefits and constraints associated with these are briefly introduced here, with full details outlined in the respective reports. Figure 5 illustrates the proposed alignments. One alignment is to the south of the TRA while the other alignment is to the north. A brief summary of these follows:

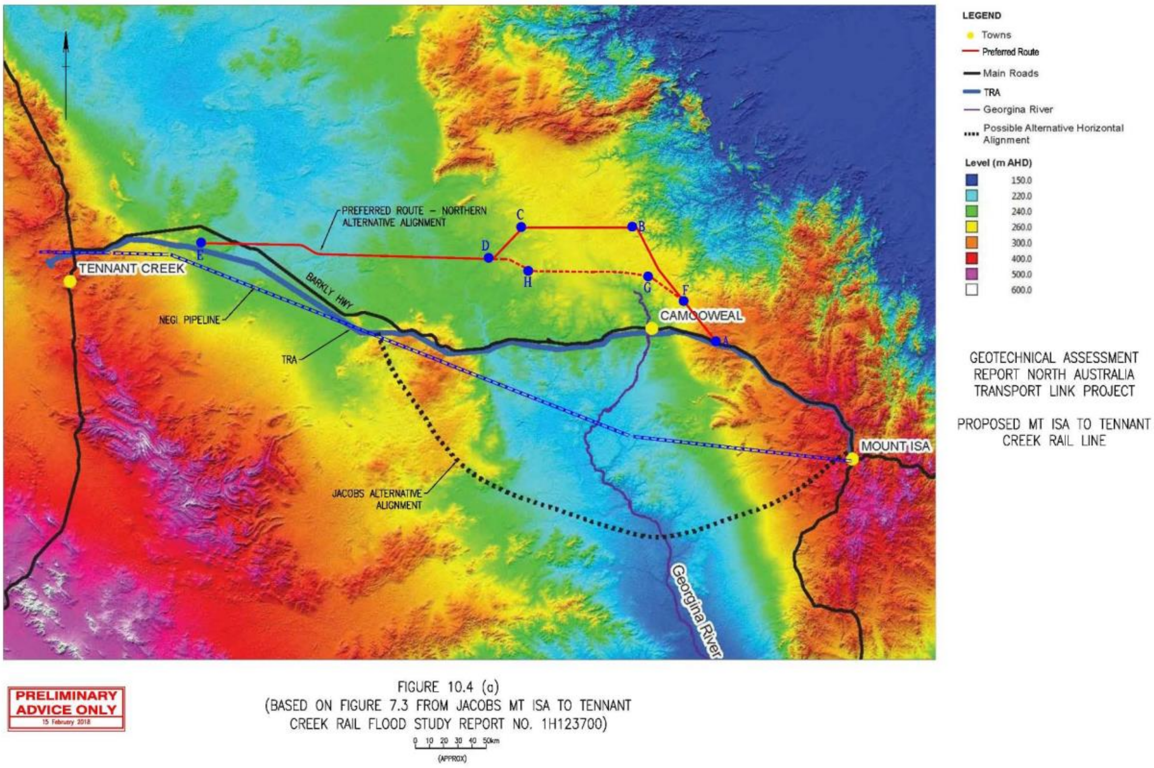


Figure 5: Proposed alternative alignments.

Jacobs alternative southerly alignment

Jacob's review of topographical features which lie outside the coverage of the photogrammetry data suggests a corridor may exist further to the south. Jacob's assessment concluded this corridor appears to contain significantly fewer waterways and less arduous topography which would result in fewer structures and reduced earthworks.

The route is aligned essentially west from Mt Isa and then swings to the west-south-west to cross the Georgina River south of its confluence with the Templeton River and then swings to the north-west to re-join the existing route about 50 km west of Soudan. Part of the rationale for this was to avoid the heavy earthworks sections between Mt Isa and Camooweal. The main advantage of this options are:

- Reduced number of waterway crossings requiring less bridges / culverts and having less potential of cultural heritage impacts.
- Reduced length of alignment crossing poor ground conditions.

The additional length of this alternative horizontal alignment is in the order of 10% (i.e. 30km over 300km). The reduction in the required number of structures and reduced earthworks would more than compensate for the additional track length, however the operational aspects would need to be understood with regard to additional trip length.

The Qld Government Geotechnical Section review of the Jacobs alternative alignment indicates a number of matters that require further investigation:

- South west of Mt Isa the alignment traverses a highly productive mineral province and could result in the potential sterilisation of mineral deposits.
- The proposal would involve a very significant crossing of the Georgina River with a large bridge and a long section of culverts requiring a very long section of protected embankments, potentially of the order of 10 km.
- The construction and operation costs from the additional alignment length.

The Qld Government's geotechnical analysis resulted in an alternative route to the north as shown in Figure 5. This route is proposed based on two fundamental criteria:

- To avoid major stream crossings specifically the Georgina, James and Rankin Rivers, the alignment follows the drainage divide between the Lake Eyre streams (flowing essentially south) and the Nicholson River basin (flowing north to the Gulf of Carpentaria).
- Where practical, minimising the severances of properties by following property boundaries. In this regard a major east west cadastral alignment exists along the boundary of East Rankin / Alexandria, West Rankin / Alexandria, Dalmore Downs / Alroy Downs, the southern boundary of Rockhampton Downs.

Both proposed alternative alignments require more detailed assessments of their potential to understand if there are opportunities and if they outweigh the benefit of moving the TRA from the proposed 'infrastructure corridor' between Tennant Creek and Mt Isa.

6 Technical Assessment Program Conclusion

The TAP work undertaken consisted of targeted studies to provide a high level assessment of the key technical challenges and risks associated with constructing a rail proposal of this size between Tennant Creek and Mt Isa.

The findings from the TAP work provide a good basis for understanding these challenges and risks as well as identifying additional work to further de-risk the project in subsequent stages. The work undertaken to date indicates there are no major complexities associated with the trial alignment. The challenges and risks identified are manageable and there are opportunities to refine the alignment.

A limitation of the TAP was that the program of works were predominately undertaken concurrently and hence there was little scope for each technical area to benefit from another technical area's findings. As this initiative progresses, the next stage will be to holistically evaluate the findings of the environmental, cultural heritage, geotechnical and hydraulic / hydrology assessments and ascertain how these collectively impact on the alignment and subsequent refinements.

Each individual report identified further work to be undertaken and the long lead times to consider as part of any next steps. Many of the identified challenges and risks require further understanding and will require good project management and appropriate processes to minimise them.

The MITCR proposal has been assessed as having a *potentially high* environmental risk and having a *high* cultural heritage risk. Although they are not considered insurmountable, further work is required to understand, manage and mitigate risk. The Jemena Pipeline project which traverses a similar study area will provide a wealth of project learnings to assist this task.

Flood and hydraulic models were prepared to assist in determining vertical and horizontal alignments from which infrastructure requirements and strategic cost estimate for the TRA could be determined based on an agreed 1% AEP flood level. It was identified early in the study that there was limited hydrological data available and hence a limited understanding of the water behaviour in the key catchments. The limited data also impacted on the calibration of the hydraulic models developed to help determine infrastructure requirements. As a result, there could be a high level of viability with the vertical and horizontal alignment.

The collection of hydrological data in advance of the next stage of the project (or as part) will allow a better understanding of the water behaviour in the study area catchment. This in turn would provide more confidence in determining the alignment and ultimately help in reducing infrastructure and ongoing maintenance costs. The opportunities to collect further data should be investigated with both the Qld and NT Governments.

At this pre-feasibility stage the work by Jacobs indicates there are opportunities to refine the trial alignment and reduce construction costs (for example, shorter bridge lengths and reduced earthworks).

The main challenge for sourcing construction materials are the potential borrow site locations and the associated supply chain logistics. The Qld Government's in-house assessment concluded that is it both impractical and uneconomical to develop greenfield quarries for ballast materials and existing or closed quarry sites will need to be investigated for their potential ability. Long lead times for approvals are likely and will need to be factored in early.

Water for construction is another major project risk that requires adequate consideration. This also is likely to involve long lead times for approvals as well as being subject to climatic variability.

There are a number of geotechnical hazards with the TRA which will require close management. Sink holes are considered the biggest risk and methods to reduce this risk were identified. Construction techniques for the black soils found in the study area (around 15% of the alignment) have been recommended to help mitigate this risk.

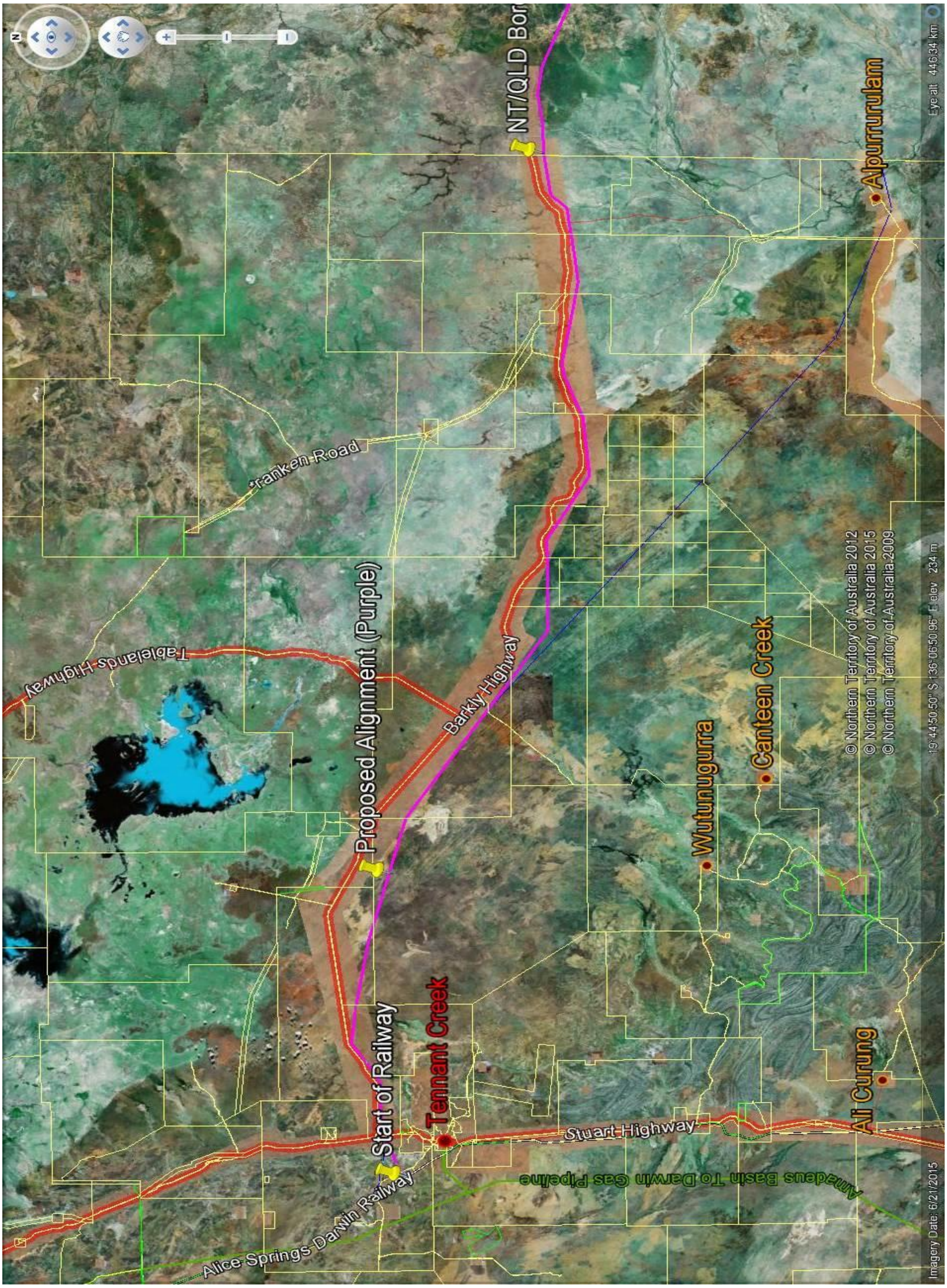
Preferred sites for multi modal / multi use terminals in Tennant Creek and Mt Isa have identified. The respective reports for each site include demand scenarios and staged operational concepts. Both concepts have costs estimates which allow for 1,800 metre trains. The Tennant Creek terminal costs also include a purpose built 36,000 m^2 shed.

In 2015, the indicative capital cost for the 646 km MITCR proposal was originally estimated at between $2.7B and $3.4B. This did not include Native Title considerations or multi-modal / multi-use facilities and was based on a horizontal alignment only. With the benefit of 3D data undertaken as part of the TAP work, a strategic cost estimate based on a 1% AEP flood level was provided. This 2017 estimate is approximately $4.1B and like the original cost estimate does not include multi-modal / multi-use facilities. The estimates included a large contingency (35%) and a large allowance within direct costs (40%) which with further work to de-risk the initiative could reduce this cost.

Two alternative alignments were proposed for consideration by the Qld Government. Both of these alignments require further investigation to establish if either has more benefit than the TRA with construction and access close to the Barkly Highway. Further work is required to determine if there is sufficient merit in either the southern or northern alternative routes.

The North East Gas Interconnector project learnings will be a valuable source of information for the next stage of this project. The pipeline is expected to be completed in late 2018 and runs in an approximate straight line between Tennant Creek and Mt Isa. For the entire length the TRA is located between the pipeline and the Barkly Highway. In particular the timing of the environmental and cultural heritage planning and approvals processes required as well as the stakeholder approval / engagement processes required will be invaluable to informing this project.

Appendix A – Trial Route Alignment



Appendix B – Site Options