Attachment 7.2

North Railway Design Criteria

(70 Pages)

Mary River Expansion Project

Railway Design Criteria and Design Rational

2017-11-28	0	Approved for Use	A. Aquil	F. van Biljon	F. van Biljon	F. Pittman
Date	**Rev.**	**Status**	**Prepared By**	**Checked By**	**Approved By**	**Approved By**
HATCH						**Client**

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1. General

1.1 Introduction

1.1.1 This revised document incorporates the adjustments made to the rail and embankment designs subsequent to the value improvement processes (VIP) workshop conducted on the outcomes of the initial pre-feasibility capital requirements for the project and should be read with document H352034-300-200-210-0001 – Rev. 0 as initial baseline for design.

1.1.2 It outlines the adjusted Design Criteria that govern the design for the Railway between the Iron Ore Mine at Mary River and Milne Port to the North and inclusive of the loading, discharging and maintenance facilities and rail infrastructure at each end. This project is specifically associated with the optimization of the Expansion Study – Stage II rail studies for Baffinland Expansion 12 million tonnes per annum (Mtpa) Mine Option.

1.1.3 The design codes and standards referenced in this document, engineering and other work done on the Steensby Project, the Tote Road, the Concept Scoping Studies for the rail line to Milne Port and the twice a day optimization progress calls with BIM, subsequent to the pre-feasibility VIP workshop, guided the optimization measures for the railway system's capital requirements.

1.2 Jurisdictional Authority

1.2.1 The railway will be operated and maintained by Baffinland Iron Mines (BIM) during the life of the mine as a private, dedicated railway system.

1.3 Project Scope Definition

1.3.1 The Mary River Expansion Study – Stage II Phase has been planned as a means to further develop the Mary River deposit and in an effort to curb high operating cost of the Tote road operation.

1.3.2 The adjusted aligned 110 km standard gauge rail line and railway system will be designed to allow year round railing of iron ore from Mary River Mine to Milne Port using the rolling stock and support equipment that will be able to remain functional in these extreme conditions in a sustainable manner.

1.3.3 Due to the unknowns regarding train operations in extreme weather for the site, provision has been made for the loss of 21 operating days per calendar year in designing train plans and operating plans and considering capacity issues.

1.4 Project Objectives

1.4.1 The objective of the project is to provide a reliable, all-season transport system to move 12 million tonnes per annum (Mtpa) of iron ore from the Mary River mine site to Milne Port, considering potential upgrades in future to exploit the full potential of the mine and the logistics chain. In an effort to optimize the capital requirements, the transport system will initially not make provision for the transportation of fuel, supplies, equipment and waste.

1.5 Project Language

1.5.1 The project language will be Canadian English.

1.6 Rail Classification

1.6.1 The railway system is classified as a standard gauge heavy haul system for permitting purposes, although other traffic might be operated on the line in future, the traffic allowed for in this optimized Mary River Expansion Study – Stage II, will be iron ore operating unit trains.

1.7 Design Context

1.7.1 The Rail Design Criteria will be based in general on AREMA but also following a "best practices" approach based on the Consultant's experience in rail design to incorporate other applicable codes and practises as well as on instruction from the client, BIM and their officials, inside the best practise approach for safe and optimized rail system operations. Section 2 to follow provides a representation of the codes, standards and practises consulted and applied in the design process.

1.8 Scope

1.8.1 The criteria in this document apply to the civil engineering and operational design of the railway system between Mary River Mine and Milne Port including all relevant and related infrastructure, equipment and facilities at the end points and potentially on route.

1.8.2 It includes an occupancy control system and the existing telecommunications back bone. The Tote road is supported by full coverage communications by microwave towers as back bone and repeaters along the road for full coverage. The Mary River Expansion Study – Stage II will need to assess if more repeaters are required for the rail route deviations, considering fiber optic connections between towers and repeaters as enhancement of the backbone, especially deviation 8 around km 67 hill, to support full rail coverage for crew to control room communications and uninterrupted support for the radio distributed power (RDP) for the locomotives on the ore unit trains.

1.9 Safety

1.9.1 The consideration of personnel safety in all stages of the design, construction and operation is paramount. Prime consideration will be given to safety and reliability to:

- Maximize health and safety for all personnel using the railway system and other systems adjoining and running in parallel to the railway system.
- Minimize environmental impacts during the design process to assist in construction and operation.
- Maximize the security of equipment.
- Maximize continuity and sustainability of service (i.e. minimize time any element in the rail system is out of service).
- Special attention is required by BIM to formalize operating rules regarding the access to failed trains for inspection and repairs, as the optimized design does not allow for shoulders on the sub-ballast layer that can serve as footpath for personnel.

- Ensuring safe layout and user rules for crossings at grade.

1.10 Units of Measure

1.10.1 The International System (SI) will be used as the project standard.

1.11 Limits of Project

1.11.1 The project limits of the rail system are from the Milne Port off-loading area and port yard facilities to Mary River Mine Site loading facilities, dead-end spur.

1.11.2 This includes construction of refuges for Hi-Rail on-track maintenance equipment, crossings and wayside condition monitoring equipment.

1.12 Assumptions and Exclusions

1.12.1 The design criteria for the standard gauge rail are based on the following assumptions:

- The primary usage of this railway is for transporting of primary crushed iron ore from the mine site loading facility to an off-loading facility above the stockyard for the crusher at Milne Port. Although other commodities will potentially be transported between the mine and port in future after further upgrades, such other usage is not considered for the optimization of the pre-feasibility design.
- The operating speed for all trains, loaded or empty, will be 60 km/h in both directions. The design speed will be 75 km/h. Operating speeds are unlikely to be adjusted upwards in future. The geometric design criteria for safe operation is based on these operational requirements and loading factors. Where these geometric design criteria cannot be met, due to site conditions imposed by impacts of permafrost, topography and cost, minimum acceptable geometric design criteria and mitigating operating rules like speed restrictions will be proposed.
- The typical heavy haul Diesel Electric Locomotives (3,280kW) that will be used on the line will have 33 tonnes axle loads (TAL), whilst the typical standard gauge gondola ore cars will have a practical capacity to carry 108 tonnes iron ore with a tare weight of 22 metric tonnes or 32.5 TAL.
- The railway will be operated and maintained by BIM as a privately owned railway system.
- The train operating plan, crew strategy and related functions are covered in Section 4.
- Rolling Stock and facilities are covered under Sections 9 and 10.

2. References, Acronyms, Design Codes, Standards and Regulations

2.1 Unless specifically stated elsewhere, the rail will be designed in accordance with this criteria read along with applicable sections of the latest revisions of the codes, specifications and standards listed alphabetically below. If there is any conflict between this criteria and other relevant design standards, the discrepancies will be assessed and recommended to include practical best practice for the extreme weather conditions and experienced based best practice on a case by case basis.

- AASHTO - American Association of State Highway and Transportation Officials.
- ACI - American Concrete Institute.
- All applicable federal, territorial and local laws and regulations.
- AREMA - American Railway Engineering and Maintenance-of-Way Association, Manual of Recommended Practice.
- AREMA - Communications and Signals Manual of Recommended Practice.
- ASTM - American Standards for Testing and Materials.
- AWS - American Welding Society.
- CAN/CSA-S6 Canadian Highway Bridge Design Code.
- CENELEC - European Committee for Electrotechnical Standardisation, Standards for Railway Signalling.
- CSA - Canadian Standards Association.
- *Developing and Managing Transportation Infrastructure in Permafrost Regions, TAC-ATC; 2010.*
- Fisheries Act (Canada).
- FRA - Federal Railway Administration (USA).
- IEC - International Electrotechnical Commission.
- ISO - International Standards Organization.
- Northern Land Use Guidelines: Access Roads and Trails, Indian and Northern affairs Canada; Volume 5; 2010.
- Ontario MoE, Stormwater Management Planning and Design Manual, 2003. 2.1.2 In addition, the design must comply with all laws and regulations of local authorities; in the event of conflicting requirements, the most stringent will govern as confirmed with the Engineer. TSB Transportation Safety Board (Canada).
- RTC – Rail Traffic Controller (modeling software).
- UFC - Unified Facilities Criteria, Subarctic Construction.
- USACE - United States Army Corp of Engineers Mine Health and Safety Act.

2.2 Other Regulations

2.2.1 All applicable federal, provincial and local laws and regulations apply to the Mary River Expansion Study – Stage II:

- INAC - Indian and Northern Affairs Canada.
- OSHA - Occupational Safety and Health Administration.
- OSHR - Occupational Health and Safety Regulations.
- NBCC - National Building Code of Canada.
- NFPA - National Fire Protection Association.
- CFEM - Canadian Foundation Engineering Manual.
- MNR - Ontario Ministry of Natural Resources.
- MOE - Ontario Ministry of the Environment.
- MSHA - Mine Safety and Health Administration Handbook Number PH99-I-4.

2.3 Other Project Design Criteria

2.3.1 This Design Criteria must be read in conjunction with other documents which may already exist or will be developed as the project proceeds. These documents include the following:

- Canarail: Railway Design Brief Report dated November 2011 to Baffinland Iron Mines Corporation, Steensby Project, Revised Feasibility Study.
- Hatch: Baffinland Iron Mines Corporation - Mary River Project, Optimization Study Report 28 March 2012.
- Sub-sections of design criteria and specifications, linked to these two studies as well as that of the Tote road.
- Minimum standards, like the lack of ballast shoulders or the lack of benches on high embankments, have been applied after a project optimization process was completed. So although this configuration is structurally sound it is not a conventional design approach.

2.4 Reference Documents

2.4.1 Reference will be made to the following documents when reading these criteria:

- Baffinland Rail Scoping Study.
- H353004-00000-200-078-0008, the standard specification for Site Data, dated 2016-12-14.
- NB102-00181/39-A.01, Updated Design Peak Flow Assessment, by Knight and Piésold dated, 2016-12-13.
- H352034-3000-228-030-0001, the Project Hydrology Review Memo on the assessment of the Tote road Hydrology, dated 2016-08-18.

- H353004-00000-200-024-0001, Hydraulic Design of Drainage Structures, dated 2017-02-02
- H352034-3000-224-030-0003, Rail Tie Type Trade-off for Extreme Cold Weather Heavy Haul Operations.

3. Site Conditions

3.1 The standard gauge rail line follows the Tote road alignment between Mary River Mine and the Milne Port to a large extent with 10 pertinent deviations of which deviation 8 around/over the hill at 67 km is the most challenging due to the nature of the topography and the non-cohesive sands and sand and gravel of the undulated hills.

3.2 Site conditions are referenced from document H353004-00000-200-078-0008, the standard specification for Site Data, dated 2016-12-14.

3.3 Refer to the Site Conditions Specification for design temperatures, design wind parameters, seismic parameters, hydrology and snow load design parameters.

4. Operations

The operating requirements dictate the design parameters and criteria for the track, supporting infrastructure and systems that need to be developed inside the environmental and other constraints to support a sustainable operating model irrespective of the optimizing measures taken.

Operating conditions are extreme for equipment, infrastructure and personnel. Consensus has been reached that an initial reasonable operating plan needs to be adapted now with the view to exploit the learning curve of operations experience and the behaviour of the optimized infrastructure to consider adjustment for better efficiencies.

4.1 Traffic

4.1.1 The primary usage of this railway is for transporting of primary crushed iron ore from the mine site loading facility to an off-loading facility above the stockyard for the crusher at Milne Port. Other commodities initially considered for transportation by rail between the mine and port, will continue to be road transported over the Tote.

4.1.2 The ore trains will be unit trains dedicated to ore traffic configured to remain as a complete train-set throughout the operation cycle with at least one locomotive at each end. Trains will only be uncoupled for other than daily provisioning for planned or emergency maintenance purposes on cars or locomotives. “Not-to-go” (bad order cars) will be replaced as required, mainly port side. Train sets and locomotives need to be turned at the portside triangle on a frequency to be determined to ensure even wheel wear.

4.1.3 The railway will transport 12Mtpa of dry primary crushed iron ore equivalent to approximately 12.24Mtpa of wet iron ore (2% moisture content).

4.1.4 The mixed other traffic will be road transported over the Tote road during at least the first 5 years of operation, when further upgrading of the rail line can potentially be considered.

4.2 Axle Load

4.2.1 The typical heavy haul Diesel Electric Locomotives (3,280 kW) that will be used on the line will have 33 tonnes axle load (TAL), whilst the ore cars to be procured will have capacity to carry 108 metric tonnes iron ore with a tare weight of 22 tonnes or 32.5 TAL. During the ramp-up phase cars can be loaded to a payload of 98 tonnes per car or 30 TAL while the track and formation settles in after which full capacity loading will be considered and authorised.

4.2.2 The system and support infrastructure will be designed for 32.5 TAL.

4.3 Speed

4.3.1 The operating speed for all trains, loaded or empty, will be 60 km/h in both directions. The design speed will be 75 km/h. The design speed has basically the purpose to calculate dynamic forces for bridge structures and other support infrastructure as well as rail superstructure on the main line.

4.3.2 Higher operating speeds are not recommended due to the very small impact faster running times will have on the total cycle time. RTC modelling indicated that a 10 minute saving on running time applies at 65 km/h relative to 60 km/h for the loaded train as an example, as the loaded train can’t maintain 60 km/h or 65 km/h continuously over the whole line due to the topography and the alignment. Higher speeds increase the maintenance effort on the track exponentially, so the higher speed value trade-off is debateable, whilst terminal dwell time makes up the largest part of the cycle time in any way.

4.3.3 The geometric design criteria for safe operation is based on these operational requirements and loading factors. Where these geometric design criteria cannot be met, due to site conditions imposed by impacts of permafrost, topography and cost of earthworks, minimum acceptable geometric design criteria and mitigating operating rules like speed restrictions are proposed.

4.3.4 During the spring/summer thaw period there is a possibility that temporary speed restrictions might be imposed over sections of the line if the effects of the permafrost prove to be a concern. This will be determined by intensified track and substructure inspection and monitoring on a daily basis or even on a train by train basis where the maintenance engineer can decide to what speed the operating speed could be reduced or even to suspend operations for a determined period.

4.4 Ore Trains

4.4.1 The ore train configuration and recommendations are presented in the revised static evaluation combined with the Rail Traffic Controller (RTC) dynamic simulation report H352034-3000-200-230-0001.

4.4.2 A specific train configuration is recommended for the optimized alignment and facilities as a workable and sustainable solution. This configuration, as do all the others analyzed, requires a passing loop close to the middle of the line and a departure siding at each terminal.

4.4.3 Operate 2 train sets of 80 cars and 2 locomotives. Required car fleet is 168 ore cars and 5 Locomotives (1 spare/exchange locomotive and 8 cars) (3,280 kW). One locomotive at each end of the train.

4.4.4 It is assumed that BIM will start off operating shorter trains during the ramp-up period to solve all operating challenges, potential distributed power test trains, crew training and to allow for ballast and formation consolidation before the full train configuration is implemented.

4.5 Design Train Length

- The train design length is 900 m (80 x 10.56 (including stretch) + 2 x 22.7).

4.6 Other Trains

4.6.1 Only ore trains are considered for the optimized rail system proposed and other trains will only be considered during potential future upgrading phases.

4.7 Passing Tracks and Tracks at Terminals

4.7.1 *Passing Loops*

4.7.1.1 The RTC modeling concluded the location of a passing loop close to the 56 km chainage, based on running times of the loaded and empty trains.

4.7.1.2 The mid-way passing loop could be fit between 55,886 km and 56,947 km, providing a clearance of 900 m, fit for maximum 80 car train length. The switches need to be installed on tangent track and not inside vertical curves.

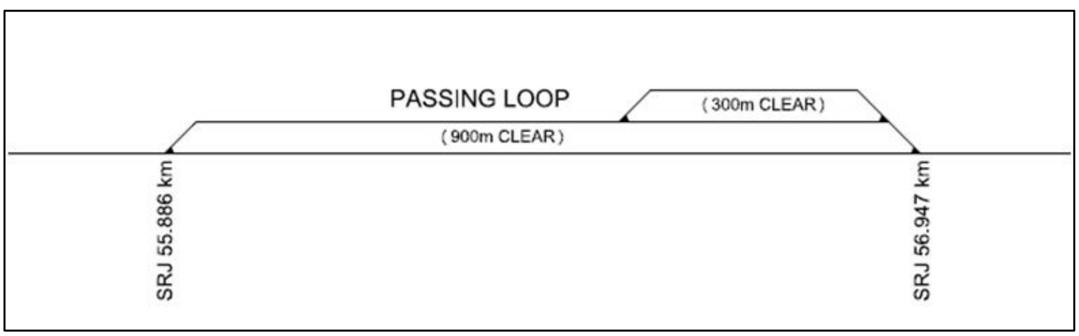

Figure 4-1: Midway Passing Loop and Backtrack

4.7.2 *Mine Side Track Layout*

4.7.2.1 The Mine side track facilities have been rationalized and are represented in Figure 4-2 below:

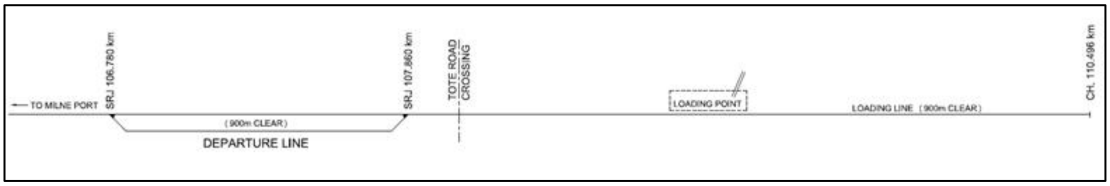

Figure 4-2: Mine Track Diagram

4.7.2.2 The mainline runs past the front-end loader loading bank into a dead-end.

4.7.2.3 A siding of 900m clearance is also required, located in the vicinity where the freight siding was recommended initially.

4.7.2.4 The loading bank operations are based on 3 front-end loaders in the Static and Dynamic analysis.

4.7.3 *Port Side Track Layout*

4.7.3.1 The port side terminal and yard layout have been optimized and is presented in Figure 4-3 below:

4.7.3.2 The mainline will run straight into the elevated area adjacent to the quarry (Q1), through the off-loading facility into a dead-end. Clearances on both sides of the dumper must allow for 900m maximum train lengths, incorporating the tippler run-around section for empty train returns. The run-around section will tie back to the mainline in front of the dumper but will also run straight into a departure siding with 900 m clearance to allow a newly arrived loaded train to position in front of the tippler with an empty train waiting in the siding for inspection before departure back to the mine and for shunting movements if bad order cars need to be exchanged etc. Daily service and provisioning will be done by mobile units to the stationary train on the departure siding in order to enable the locomotives to be provisioned while still coupled to the empty cars.

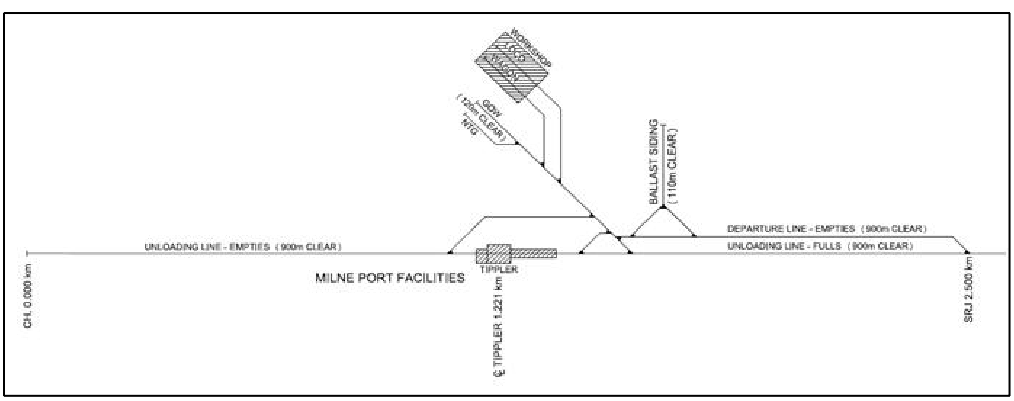

Figure 4-3: Port Side Track Diagram

4.7.3.3 An additional gather will tie onto the departure siding with four spurs that will go into the Locomotive and car maintenance facilities, for bad-order cars and good order cars for car exchange. Space for a second potential future line adjacent to the dumper empty car spur is provided as a shunting spur that could take a full train length for shunting and operational flexibility in future.

4.7.3.4 Provision for a ballast siding into the quarry area has been allowed for with another connection back to the departures siding that could serve as a triangle for cars and locomotives to be rotated for change of direction of travel and in support of wheel wear management.

4.7.3.5 The cycle time through the port terminal, including all these activities, has the most prominent impact on the train plan.

4.8 Hi-Rail Refuges

4.8.1 Track maintenance personnel and on-track maintenance machinery, must clear the line to let trains pass to minimize train operations interference and delays.

4.8.2 All track-bound equipment use the passing loop back track or the sidings at the terminals for this purpose. However, vehicles used for regular inspection and daily light maintenance are utility vehicles equipped with road/rail functionality, or referred to as “Hi-Rail” equipment.

4.8.3 These vehicles can clear the track at any location provided with a level surface at rail level of approximately 4 m wide, typically at level-crossings or purpose made refuges.

4.8.4 The locations for such refuges or level crossings should be carefully planned with the rail operations and maintenance contractor and will typically be at not more than 10 km intervals where geometric conditions are practical and safe and can coincide with normal level crossings at grade such as the access roads or track maintenance access roads as well as the Tote Road level crossings.

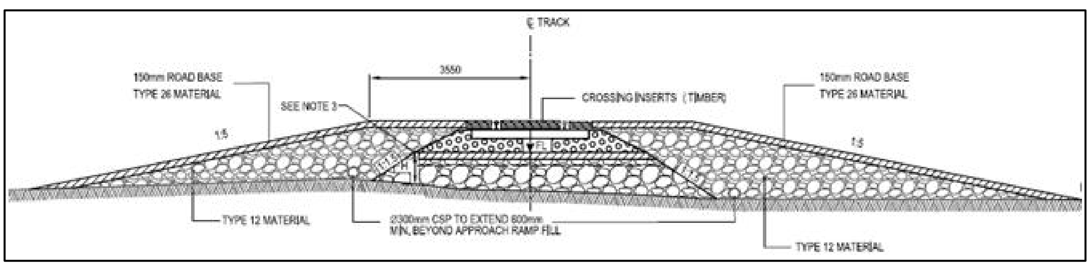

Figure 4-4: Typical Arrangement for Level Crossing

5. Rail Alignment

5.1 General

5.1.1 The design criteria relevant to the rail alignment has been based on design criteria related to heavy haul railway operations and support infrastructure.

5.1.2 The basic objective is to have the gradients as flat as possible and the radii as large as possible. In some locations this is not possible due to the topography and the geotechnical considerations.

5.1.3 The emphasis for the optimizing actions was on an alignment that promotes operational safety and low maintenance, applying minimum design standards for optimizing purposes. The design speed is 75 km/h for both loaded and unloaded trains and the operating speed is 60 km/h. The commonly used design standard for North America heavy haul industrial track design and upgrades forms the basis of the design standards followed, unless alternative standards are specifically referenced.

5.2 Horizontal Alignment

5.2.1 The rail will predominantly be on an embankment of Type 12 rock fill between 700 mm and 1500 mm thick, above the natural ground level (NGL), measured on the high end of the cross fall under the ballast toe. The 1500 mm thick section had been designed for ice rich soil sections on the alignment.

5.2.2 Unevenness or cross fall in the NGL will be smoothed out with more run of quarry backfill Type 12 of varying thickness.

5.2.3 There will be no benches between topside of the embankment to the toe of the rock fill. There is no shoulder on the sub ballast layer and the ballast shoulder will vary from 300 mm to 600 mm depending on the curve radius for lateral support for the continuously welded track on steel ties.

5.2.4 On these curves where the outside leg of the track gets super elevated the top of formation or top of sub-ballast is widened from the standard 2624 mm to accommodate the wider ballast shoulder as well as the effect of the super elevation.

5.2.5 *Tote Road Interface*

5.2.5.1 Road accidents on the Tote Road should be prevented from having an impact on rail operations and vice versa.

5.2.5.2 For the optimized preliminary design the rail centerline will be off-set at 15 m from the Tote road centerline where the track and the road are at the same grade. Where the track embankment height increases or where the track is lower than the road, each case should be evaluated on its merits to determine the off-set of the embankment toes or cut-line of cuttings to maintain a safety barrier in which safety measures can be installed to keep impact between the two modes isolated.

5.2.5.3 For each locations where the rail alignment interferes with the existing road alignment, more detailed analysis need to be performed to determine whether the rail alignment can be adjusted or whether the road will have to be diverted.

5.2.6 *Curve Radius*

5.2.6.1 The approach for a heavy haul line, or any rail line for that matter, is to install the largest radii possible while still balancing the required earthworks and other design and cost parameters.

Large curves (or straight track) are better for rail/wheel interaction than small radii curves and therefore better for maintenance purposes.

5.2.6.2 The design brief from BIM for the Mary River Expansion Study – Stage II phase railway, was initially that the horizontal alignment should stay alongside the Tote road and as far as possible inside the previously demarcated areas in which the development was scoped for permitting purposes. This brief was still respected during the optimization efforts except for locations where rock is present for cut to fill and where obvious geometric optimizing opportunities can be exploited.

5.2.6.3 The approach is therefore to design for a nominal radius of 500 m as the rule and an absolute minimum of 230 m as an exception for horizontal curves. (60 km/h speed restriction will apply to curves with radii of 230 m, coinciding with the operating speed). The RTC simulation model outputs will be analysed to consider the speed profile and energy consumption in order to adjust the alignment to exploit further optimization opportunities during the Expansion Study – Stage II phase.

5.2.7 *Spiral Curves (Transitioned Curves)*

5.2.7.1 Spiral lengths of horizontal curves (transition curves from tangent track to circular track) are calculated for each radii according to the AREMA manual for spirals and a design speed of 75 km/h, as follows:

Spiral Length (m)	Curve Radii Range (m)
300	230 to 249
270	250 to 274
240	275 to 299
210	300 to 399
180	400 to 424
150	425 to 549
120	550 to 699

5.2.7.2 In areas with difficult topographical challenges and constraints AREMA allows spiral lengths to be compromised to the following:

Spiral Length(m)	Curve Radii Range(m)
150	230 to 274
120	275 to 324
90	325 to 474
60	475 to 949
30	>950

5.2.7.3 These spirals are normally staked in 30 m stations for construction purposes, hence the lengths of multiples of 30.

5.2.7.4 As AREMA bases these calculations amongst others on “passenger comfort” it was already recommended for the pre-feasibility design to follow the adaption of constant transitional curve lengths according to the South African standard for heavy haul rail lines analyzed and proven to be effective over many years for track maintenance and rolling stock behavior purposes. This approach is applied for the optimizing efforts for the rail alignment.

- Spiral Length = 60 m for curve radius R ≤ 300 m.
- Spiral Length = 80 m for curve radius R > 300 m.

5.2.7.5 These spirals are staked in 20 m stations for construction purposes in preparing and shaping the sub-grade, formation and track.

5.2.8 *Minimal Tangent Length*

5.2.8.1 Minimum tangent track between spirals of reverse curves is 20 m in order for the bogies of one car to settle and to prevent them from being on cant applied in opposite grades. Transition curves can be butted in compounded and circular curves on running lines.

5.2.8.2 No spirals are required in yard track.

5.2.8.3 Apply the full applicable super elevation (cant) over the length of the spirals on both ends of the circular curve in order to have the full and constant cant on the circular section of the curve. Cant will be applied for 60 km/h operating speed and less cant based on the actual speed profile, for curves where the train goes slower due to gradients or speed restrictions.

5.3 Vertical Alignment

5.3.1 *Curve Lengths*

5.3.1.1 Vertical curvature will be applied between different grades at a rate of change not more than 0.040m/20m/20m (K=100).

5.3.1.2 Vertical curves are to be avoided in horizontal curves, however if it cannot be avoided and any other design criteria is compromised, vertical curves can be fitted to the circular sections of horizontal curves.

5.3.2 *Ruling Gradient*

5.3.2.1 A ruling grade of 1.5% (1 to 66.7 – 1:66.7) facing loaded ore trains will be designed for. Grades on curves must be compensated to allow for an equivalent lesser gradient in curves.

5.3.2.2 Exceptional Grades: A ruling grade of 3.0% (1:33) facing empty ore trains or loaded general freight- and mixed trains (Fuel, material and equipment) will be designed for as an absolute maximum and as an exception, for grades on inclines/declines less than an ore train length. Grades on curves will be compensated to allow for an equivalent lesser gradient in curves.

5.3.2.3 Exceptional Grades occur at only 3 locations over the entire 110 km mainline or approximately 3 km out of 110 km. The steepest grade in 2 of these locations is compensated to 1:35 due to the horizontal curves of radius 700 m in these same sections.

5.3.2.4 A ruling grade of 2% (1:50) facing empty ore trains or loaded general freight- and mixed trains (Fuel, material and equipment) will be designed for, for grades on inclines/declines more than an ore train length. Where the fill requirements can be enhanced and where the preceding grade is not steeper than 1% (1:100) a grade of 2.2% (1:45) will be allowed for sections longer than an ore train as an absolute maximum.

5.3.2.5 Grades on curves must be compensated to allow for an equivalent lesser gradient in curves in order to compensate for the higher rolling resistance of rail/wheel interaction through curves in relation to the radius of any specific curve.

5.3.2.6 The relatively steep gradients are necessary to adjust to the very challenging topography in the relevant corridor footprint and an effort to minimize the need for extensive excavations in the extreme permafrost conditions of Baffin Island and also to prevent extensive new permitting applications and environmental impact.

5.3.2.7 These gradients fall outside the relevant "range" of gradients normally associated with heavy haul rail operations (refer to Project Benchmarking Memo H352034-3000-224-030-0001), but has been thoroughly analyzed with our in-house traction and adhesion tools to prove sustainability with the optimized alignment as base. Further compromise of gradients to optimize earthworks is not recommended.

5.3.2.8 Allow in general one vertical grade direction change over one ore train length of track and as an exception 2 grade direction changes over one ore train length of track in places where the other vertical- and civil design criteria will be compromised if this exception is not allowed for.

5.3.2.9 The train design length of 900m now makes provision for the maximum number of 80 cars per train with 2 locomotives on RDP.

5.3.2.10 The optimized design based on the pre-feasibility design length of 775 m has not been compromised, as the grade changes per grade allowed also accommodates the 900 m design length.

5.3.2.11 Gradients in other locations:

- Gradients in passing tracks: 0-0.25%.
- Gradients in yard tracks: 0-0.125%.
- Unloading facilities: 0-0.1%.
- Loading facilities and attended trains: 0 – 0.25%

5.3.3 *Grade Compensation*

5.3.3.1 The measure of elevation for a ruling grade (1**:**X) = (20/X)m per 20 m of track; the reduction in elevation for a curve of radius (R) and a ruling grade (1**:**X) = (14/R)m/20m; so the measure of elevation for compensated ruling grade = ((20/X)**-**(14/R))m/20m.
Therefore compensated equivalent ruling grade in such a curve = 1**:** 20/((20/X)**-**(14/R)).

6. Geotechnical Recommendation and Earthworks

Report number H352034-3000-229-230-0001, a summary of the preliminary geotechnical recommendations for the railway embankment design, based on the existing Tote Road geotechnical investigation data, as part of the Mary River Expansion Study – Stage II, served as basis for the preliminary earthworks design criteria for the purpose of the estimation of earthworks quantities for the Mary River Expansion Study – Stage II. These recommendations had been revised for the optimizing exercise subsequent to another site assessment by Hatch that coincided with the VIP workshop. Further optimization and detailing can be considered for the feasibility study as geotechnical drilling and testing are currently conducted on the optimized alignment footprint.

The following paragraphs provide a record of optimizing decisions related to the earthworks.

6.1 Geotechnical Data

6.1.1 The site assessment report and various daily calls are referenced and linked to the cross sections for embankments and excavation on/in ice rich soils, rock and rock plates.

6.2 Embankment Stability

6.2.1 *Sub-grade Properties*

As part of the Tote road upgrade project in 2007/2008, Knight Piesold identified four categories of frost/thaw susceptibility to delineate the road bed foundations and the foundation conditions along the Tote Road.

These views were further enhanced by the site visit and assessment by Hatch and the following typical cross sections were recommended and applied for the MTO's to specific sections on the optimized alignment:

6.2.2 *Recommended Cross Sections for Embankments*

Two standard embankment sections were introduced as per the schematic in Figure 6-1

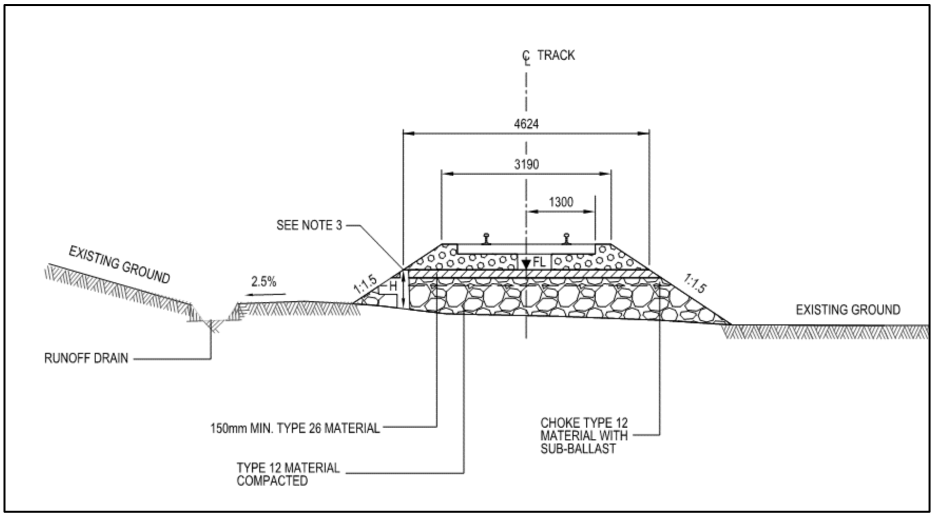

Figure 6-1: Typical Cross Section Embankments

The following observations apply:

6.2.2.1 For radii (R) > 800 m and tangent track the top of formation is 4624 mm, which is the top of sub ballast and base of ballast, therefore no sub ballast shoulder;

6.2.2.2 For 400 m < R ≤ 800 m the top of formation is 4900 mm, which is the top of sub ballast and base of ballast, therefore no sub ballast shoulder. The ballast shoulder is increased to 400 mm to the outside rail of the curve and this outside rail is super elevated between 54 mm and 86 mm, hence the top of sub ballast increases from 4624 mm to 4900 mm to the outside of the curve;

6.2.2.3 For R ≤ 400 m the top of formation is 5100 mm, which is the top of sub ballast and base of ballast, therefore no sub ballast shoulder. The ballast shoulder is increased to 600 mm to the outside rail of the curve and this outside rail is super elevated between 108 mm and 173 mm, hence the top of sub ballast increases form 4624 mm to 5100 mm to the outside of the curve;

6.2.2.4 Material Definition:

- Type 12: Minus 1 m run of quarry rock fill.
- Type 25: Minus 75 mm crushed rock for ballast layer.
- Type 26: Minus 50 mm crushed rock for sub ballast layer and to choke top of Type 12 fill.

6.2.2.5 Minimum Embankment Thickness (H) (Type 12 Plus Sub Ballast):

- Measured under the ballast toe on the high-end of the cross fall.
- H = 700 mm Standard Dimension.
- H = 1500mm on ice rich Permafrost.
- 1800 g/m² non-woven geotextile under Type 12 material on ice rich Silt.

6.2.3 *Recommended Cross Sections for Excavations*

6.2.3.1 Excavation in ice rich permafrost needs to be avoided. In locations where excavation is not avoidable the excavation should be day lighted to the low side of the side slope as illustrated in the schematic in Figure 6-2.

6.2.3.2 In locations where daylighting is not possible the side slope on the other side will be a mirror image of the slope in the figure to a height where it cuts the natural ground level. Snow trap mitigation will need to be detailed for Expansion Study – Stage II phase.

6.2.3.3 The side slopes of 1V:2H of the excavation is covered by a layer of 500 g/m² non-woven geotextile and a 500 mm cover of selected Type 12 material.

6.2.3.4 The layerworks for the embankment is the standard 700 mm under the ballast toe plus 100 mm polystyrene layer for a total of 800 mm from top of sub ballast to top of excavated permafrost.

6.2.3.5 The polystyrene layer is overlain by a 1000 g/m² geotextile for protection.

6.2.3.6 The standard widths of the top of formation apply for tangent track to curves of less than 400m radii i.e 4624, 4900 mm and 5100 mm.

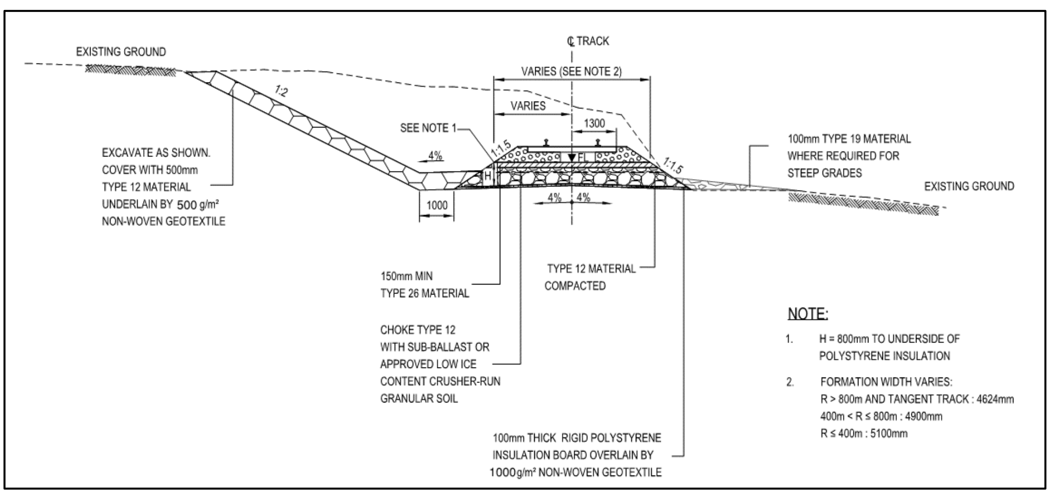

Figure 6-2: Typical Cross Section in Ice Rich Permafrost

6.2.3.7 Excavation in sedimentary bedrock ledges is illustrated in Figure 6-3 below:

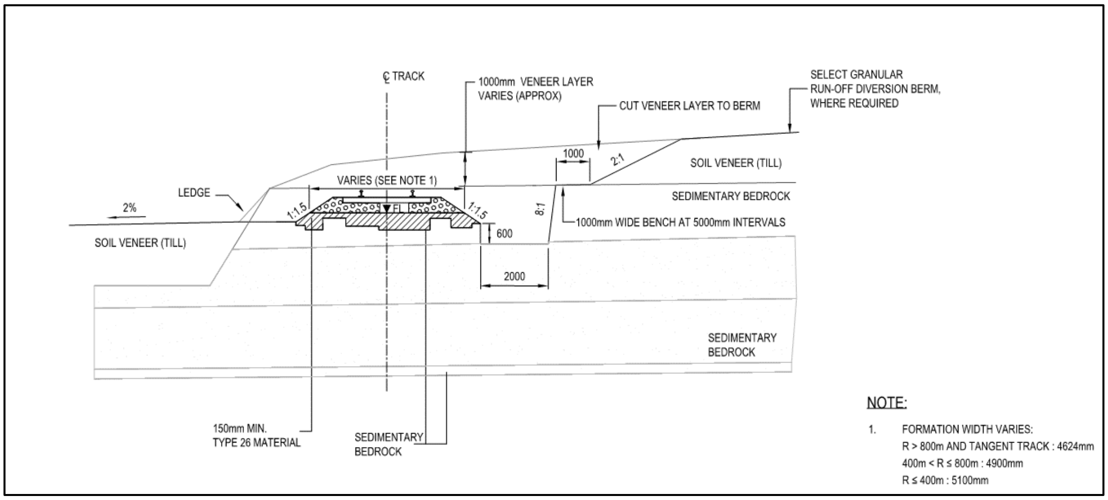

Figure 6-3: Typical Cross Section of Cut in Sedimentary Bedrock Ledges

6.2.3.8 The side slopes of the cut through the sedimentary bedrock is 8V:1H and through the soil veneer (till) 1V:2H.

6.2.3.9 The Type 26 sub ballast thickness is a minimum of 150 mm and the unevenness of the cut in the bedrock is smoothed with sub ballast Type 26.

6.2.3.10 The standard widths of the top of formation apply for tangent track to curves of less than 400m radii i.e 4624, 4900 mm and 5100 mm.

6.2.3.11 Excavation in for cuts in granitic rock is as per Figure 6-4 below:

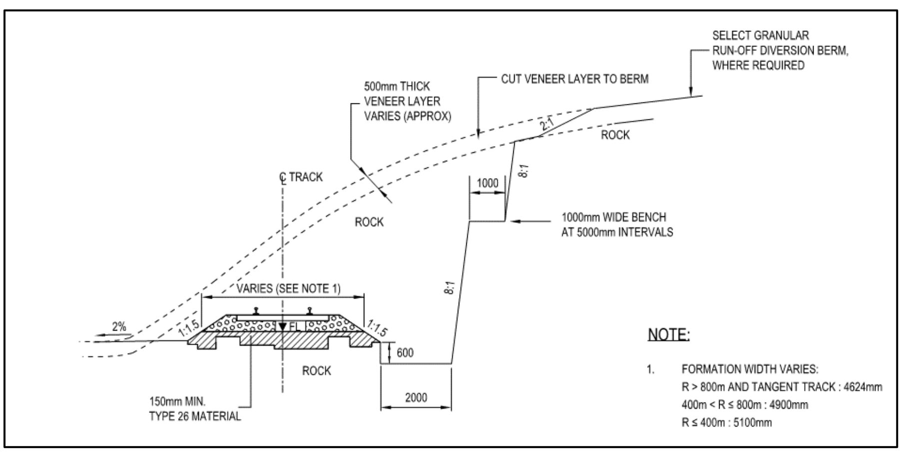

Figure 6-4: Typical Cross Section of Granitic Rock Cut

6.2.3.12 The side slopes of the cut through the granitic rock is 8V:1H and through the soil veneer (till) 1V:2H.

6.2.3.13 The Type 26 sub ballast thickness is a minimum of 150 mm and the unevenness of the cut in the rock is smoothed with sub ballast Type 26.

6.2.3.14 The standard widths of the top of formation apply for tangent track to curves of less than 400m radii i.e 4624, 4900 mm and 5100 mm.

6.2.3.15 A typcial cut-off drain will be required in some instances where there a stream crossing the rail alignment but where the positioning of a drainage culvert is impossible due to the rail alignment being in a cut and the daylighting of such a culvert is imposiosble or cost prohibitive. The figure below illustrates what this typical detail will entail.

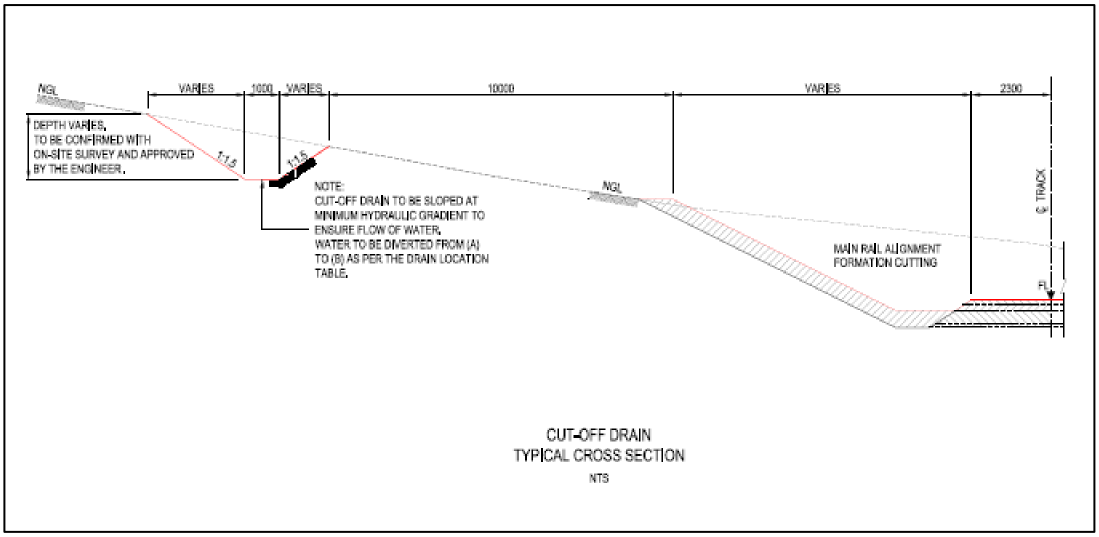

Figure 6-5: Typical Cross for a Cut-off Drain

6.3 Line Sections to Apply Typical Cross Sections

6.3.1 Chainages where to apply the different configurations of the typical cross sections are summarized in Table 6-1 below. The rail chainages in the table offer potential further optimization of better sub grade conditions for the feasibility study and subsequent to the outcome of the geotechnical evaluation currently underway.

Table 6-1: Type of Embankment Section along the Rail Alignment

Chainage			Embankments	Reference	Excavation	Reference	Remarks Sub grade
From km	To km	Length km	Profile for Layer Works	Embankment Type	Profile for Cut	Cut Type	NS = Non Susceptible PS = Potentially Susceptible MS = Moderately Susceptible HS = Highly Susceptible
0	8.9	8.9	700mm Standard or 150 mm minimum	Figure 6-1	Rock Cut	Figure 6-4	NS
8.9	14.2	5.3	700mm Standard or 150 mm minimum	Figure 6-1	Rock Cut	Figure 6-4	NS
14.2	15.2	1	1500mm Permafrost or 800 mm in cuts	Figure 6-1	Permafrost	Figure 6-2	HS
15.2	30	14.8	700mm Standard or 800 mm in cuts	Figure 6-1	Permafrost	Figure 6-2	PS & NS
30	43	13	700mm Standard or 800 mm in cuts	Figure 6-1	Permafrost	Figure 6-2	PS
43	53	10	700mm Standard or 800 mm in cuts	Figure 6-1	Permafrost	Figure 6-2	NS
53	62	9	700mm Standard or 800 mm in cuts	Figure 6-1	Permafrost	Figure 6-2	PS
62	68	6	700mm Standard or 150 mm minimum	Figure 6-1	Ledge Rock Cut	Figure 6-3	NS
68	76	8	700mm Standard or 800 mm in cuts	Figure 6-1	Permafrost	Figure 6-2	PS
76	80	4	1500mm Permafrost or 800 mm in cuts	Figure 6-1	Permafrost	Figure 6-3	MS
80	86.25	6.25	700mm Standard or 800 mm in cuts	Figure 6-1	Permafrost	Figure 6-2	PS
86.25	87.25	1	1500mm Permafrost or 800 mm in cuts	Figure 6-1	Permafrost	Figure 6-2	MS
87.25	89.5	2.25	700mm Standard or 800 mm in cuts	Figure 6-1	Permafrost	Figure 6-2	PS
89.5	92	2.5	700mm Standard or 150 mm minimum	Figure 6-1	Rock Cut	Figure 6-4	NS
92	95.4	3.4	700mm Standard or 800 mm in cuts	Figure 6-1	Permafrost	Figure 6-2	PS
95.4	95.78	0.38	700mm Standard or 150 mm minimum	Figure 6-1	Rock Cut	Figure 6-4	NS
95.78	100	4.22	700mm Standard or 800 mm in cuts	Figure 6-1	Permafrost	Figure 6-2	PS
100	104	4	700mm Standard or 800 mm in cuts	Figure 6-1	Permafrost	Figure 6-2	NS
104	109	5	700mm Standard or 800 mm in cuts	Figure 6-1	Permafrost	Figure 6-2	PS

Note: [1-] The road foundation classifications are approximate. Foundations Classifications were based on report by Knight Piesold and adjusted to rail chainages and inputs from the Hatch site assessment.

6.4 Settlement Considerations

6.4.1 Settlement of embankments in permafrost and thaw circumstances offer a challenge in the embankment design process. The requirement is to define settlement allowances during the design process. Careful construction planning to prioritize high embankments to exploit the early settlement under load before the final layer works is one measure to mitigate settlement disruption, as well as strategies to correct settlement during maintenance interventions.

6.4.2 Preloading of the formation will be managed by considering the use of the formation by construction equipment and road vehicles where appropriate.

6.4.3 Table 6-2 provides a summary of the condition of the sub-grade discussed above and linked to certain line sections. It also indicates the estimated settlement considerations linked to these sections.

Table 6-2: Summary of Embankment Recommendation and Estimated Settlement

Embankment Section	Ground Frost/Thaw Susceptibility	Ground Ice Content	Classification	Thaw Settlement Estimate (mm)	Typical Section
Fill Cut	Non Susceptible	Non to low	Segregated ice is not visible by eye[1]	<20	Figure 6-1
	Potentially Susceptible	Low to Mediate	Segregated ice is visible by eye, less than 25 mm (1") in thickness[1]	20-100	
Fill Cut	Moderately Susceptible	Mediate to High	Ice greater than 25 mm (1") thickness[1]	100-300	Figure 6-1
	Highly Susceptible	Very High	Ice greater than 0.3 m [2]	>300	

Notes:[1]- Classification is based on Unified Soil Classification System of Frozen Soils; [2]- Based on Roujanski et. al. (2010).

6.5 Rock Fill Criteria

6.5.1 The geotechnical recommendation is to use rock fill Type 12 for the embankment support under the sub ballast layer for backfill and to smooth the natural ground level (NGL) or to fill where the NGL has a cross fall. Type 26 is the recommended good crushed and graded stone/rock for the sub ballast layer and a choke layer between sub ballast and the Type 12 rock fill. The grading for Type 25, recommended for ballast, is too fine and an alternative grading is provided, more common for use for heavy haul rail lines.

6.5.2 The following is a summary of the gradations for materials to be used for railway embankment fill in Expansion Study – Stage II stage. Types 12 fill is recommended for use as fill material to be placed over the weak native sub-grade to prepare an appropriate foundation for embankment fill construction. The gradation for Type 12 run of quarry fill is shown in Table 6-3.

Table 6-3: Type 12 Fill - Run of Quarry

Nominal Sieve Size (mm)	Percentage Finer Than (By Weight)
1000	100
600	95 - 100

300	50 - 100
150	0 - 80
19	0 - 30
4.75	0 - 10

6.5.3 Table 6-4 and Table 6-5 summarize materials for ballast and sub-ballast. It should be noted that the grading for ballast had been changed from the Type 25 grading considered by the geotechnical team based on a track design basis. The appropriate “Type” to be confirmed, but ballast is further specified under Section 9.5.1.1.

Table 6-4: Type – Ballast

Nominal Sieve Size (mm)	Percentage Finer Than (By Weight)
73	100
63.0	90 – 100
53.0	40 – 70
37.5	10 – 30
26.5	0 – 5
19.0	0-1
13.2	0

Table 6-5: Type 26 Fill – Sub-ballast

Nominal Sieve Size (mm)	Percentage Finer Than (By Weight)
50	100
13.2	60 – 80
4.75	20 – 45
1.18	0 – 15
0.075	0 – 5

7. Hydrology

7.1 Introduction

7.1.1 The hydraulic design for culverts and bridge structures for the Tote road was based on 1 in 5 years return flood period, whilst normally 1:50 for culverts and 1:100 return floods and intensities for major structures are considered for railway line designs. For this project the design was for 1:200.

7.1.2 The hydrologic analysis for the Tote road had been reviewed refer to document H352034-3000-228-030-0001 titled the In-Principle Review of Previous Tote Road Hydrology Assessments, dated 2016-08-18.

7.1.3 Baffinland Iron Mine requested Knight Piésold to complete an update of previous studies concerning the design peak flows for the region and to incorporate the most resent stream flow data. Refer to Knight Piésold document number NB102-00181/39-A.01.

7.2 Methodology

7.2.1 *Design Peak Flows*

7.2.1.1 In the Hatch memo referenced in 7.1.3 Hatch raised queries with regard to the method used to derive the design peak flows. Following the updated design peak flows as presented in the report referenced in 7.1.4 the following methodology would be adopted by the project for the design of drainage structures.

7.2.1.2 Drainage structure locations will be identified along the proposed rail alignment, some of these structures will be to facilitate cross-drainage and others will be to perform the function of balancing culverts to balance the water that may collect in a low spot from either side of the rail alignment.

7.2.1.3 Catchments will be delineated by the project for all drainage structures, excluding the rail over river bridges which will be delineated by the responsible engineer to be appointed under procurement package CC003.

7.2.1.4 The delineated catchments will be used in conjunction with the formulas presented as output from 7.1.4 to calculate the associated run-off flows for a 1:200 year flood.

7.2.1.5 The flow volumes calculated in 7.1.5.3 will be used to determine the ultimate sizing of the culvert structure in terms of number and size of barrels.

7.2.1.6 Baffinland Iron Mine supplied information concerning which drainage structures are located in fish bearing streams. BIM will also supply stream flow data for fish bearings streams which, have been monitored on site so as to enable the project to determine the 3-day delay for a 1:10 year flood. This information will then be used to size the drainage structures. It is impossible to have stream flow data for every fish bearing stream. Thus the project will use ratios based on the known flow in monitored stream to scale the flow up or down for other fish bearing streams where no stream flow data is available.

7.2.2 *Flood Return Period*

7.2.3 One in one hundred year return period.

7.2.4 *Design Velocities*

7.2.5 Velocities of water flow through culverts less than 3 m/s subcritical flow. Normal culvert, embankment and stream side slopes treatment against erosion will be applied.

7.2.6 For velocities determined as more than 3 m/s and less than 5 m/s applicable treatment to normalize the flow will be recommended for erosion protection and/or fish bearing streams.

7.2.7 For flows higher than 5 m/s special treatment must be considered on a case by case approach.

8. Bridge and Culvert Design Criteria

8.1 Introduction

8.1.1 This section describes the design elements and criteria for the railway bridges and major culvert structures that are to be designed and constructed for the Project.

8.1.2 This section will be a live document that will be revised once outstanding information becomes available. The values and information not yet available is highlighted in the relevant sub sections. Additional geotechnical investigations and drilling work as well as bathymetry data will be obtained in the first and second quarter of 2018.

8.2 Title Block

8.2.1 Each structure will be referred to by a prefix of either BR (for bridges) or CV (for culverts), an ID number indicating the kilometer station and a serial number that identifies multiple structures within the same kilometer of track. E.g. BR-68-1, CV-34-3. Zero km is Port Side and 107km Mine Side.

8.2.2 Where a bridge or culvert is located at a kilometer station, the lower km station will be used.

8.3 References for Design Standards

Design	Design Method	Code
Steel Design	Service load design (working stress design)	Chapter 15 of the Manual for Railway Engineering (MRE), as published by the American Railway Engineering and Maintenance-of-Way Association (AREMA).
Concrete Design	Service Load design (working stress design)	Chapter 8 the Manual for Railway Engineering (MRE) as published by the American Railway Engineering and Maintenance-of-Way Association (AREMA)
Prestressed Concrete Design		Part 17 of Chapter 8 of the Manual for Railway Engineering (MRE) as published by the American Railway Engineering and Maintenance-of-Way Association (AREMA).

Design	Design Method	Code
Seismic design		Chapter 9 the Manual for Railway Engineering (MRE) as published by the American Railway Engineering and Maintenance-of-Way Association (AREMA).

8.3.1 The standards addressed above will be supplemented by the CSA Standard S6 "Canadian Highway Bridge Design Code" (S6). The use of this code and the requirements will be highlighted in the relevant sections below.

8.4 Bridge Geometry

8.4.1 *Design Requirements*

- Number of tracks = 1
- Number of service roads = 0
- Number of walkways = 2 (1 each side of bridge)
- Design life = 20 years

8.4.2 *Datum*

8.4.2.1 The geographical coordinate system used is:

- Name: UTM84-17N
- Description: WGS 1984 UTM, Zone 17 North

8.4.3 *Control Line*

8.4.3.1 The horizontal control line used for the basis of the project is the centre line of track and all transverse dimensions will be taken relative to this control line. The transverse dimension will NOT be taken from the centreline of the structure.

8.4.3.2 The vertical control line used for the basis of the project is the top of the sub-ballast layer.

8.4.4 *Coordinate System*

8.4.4.1 The structures will be dimensioned in ground coordinates and stationing provided in grid coordinates.

8.4.4.2 The conversion between ground and grid coordinates is currently undefined and each structure will be located relative to a single grid point located along the control line at the low station centreline of bearing.

8.4.5 *Span Lengths*

8.4.5.1 The Span length of a bridge is defined by the distance between the bearing centrelines on the foundations and measured along the control centreline. Span lengths are provided in metres. Standard span lengths has been considered for similar girder type bridges.

8.4.5.2 For fabrication purposes, “Girder Lengths” are specified at temperatures of 20°C.

8.4.5.3 “Span Lengths” are set according to bearings being centred at a temperature of -15°C.

8.4.5.4 As measurements are being taken between foundation units, not along the superstructure, the “Span Lengths” are equally correct at any temperature.

8.4.5.5 The following relationship therefore results:

8.4.5.6 Span Length= Girder Length × (1- (20 + 15) × 12e-6) = 0.99958 × Girder Length.

8.4.5.7 A minimum allowance of 20 mm will be provided on each Girder Length in order to allow for the temperature difference as well as grid to ground conversions.

8.4.6 *Horizontal and Vertical Clearance from Obstructions*

8.4.6.1 For each single track structure, the minimum clear width of the ballast zone is 3.600 m, as measured at the top of concrete/steel deck level. The side walls of the ballast pan will be sloped outwards at a slope of 2V:1H.

8.4.6.2 Minimum clearance box required for trains is as follows:

Width (Horizontal):

- For plan curvature up to 3 degrees (R ≥ 600m): 5715 mm:

  This value is based on the AREMA clearance box width of 5486 mm plus an allowance of 78.2 mm per degree of curvature, in accordance with Table 28-1-1 in Part 1 of Chapter 28 of the 2009 edition of the Manual for Railway Engineering (MRE) as published by the American Railway Engineering and Maintenance-of-Way Association (AREMA), at a maximum curvature of 3 degrees. Structure may intrude into a triangle at the bottom corners. The triangle is 1219.2 mm high by 914 mm wide at the base. See sketch below.

- For tangent track: 5486 mm:

  An allowance is defined by the distance of the obstruction to the curved tangent track. This increase is given per degree of curvature. The allowance will be applied if the tangent track is curved within 24.384 m of the obstruction. At the bottom corner’s, structure may intrude into a triangle that is 1219 mm high by 914 mm wide at the base. This is in accordance with Part 1 of Chapter 28 of the 2009 edition of the Manual for Railway Engineering (MRE) as published by the American Railway Engineering and Maintenance-of-Way Association (AREMA). See sketch below.

Height (Vertical):

- For plan curvature up to 3 degrees (R ≥ 600 m) and tangent track the height clearance is required to be 7010 mm from top of rail.

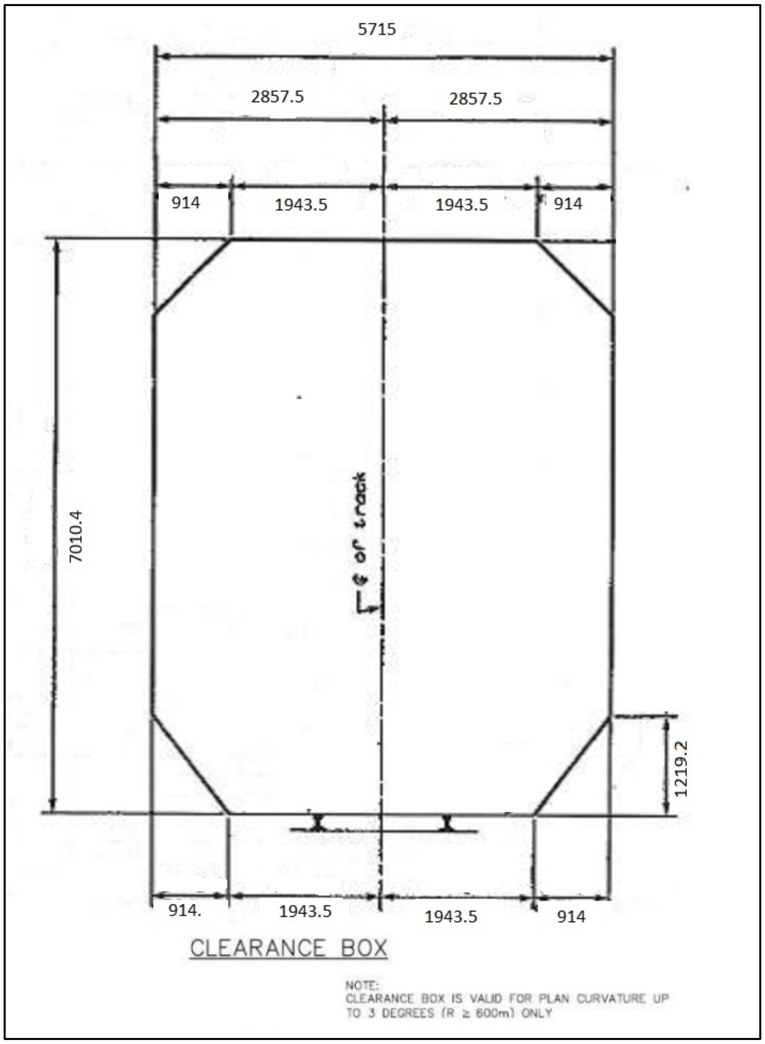

Figure 8-1: Clearance Box for Plan Curvature up to 3 Degrees (R ≥ 600 m)

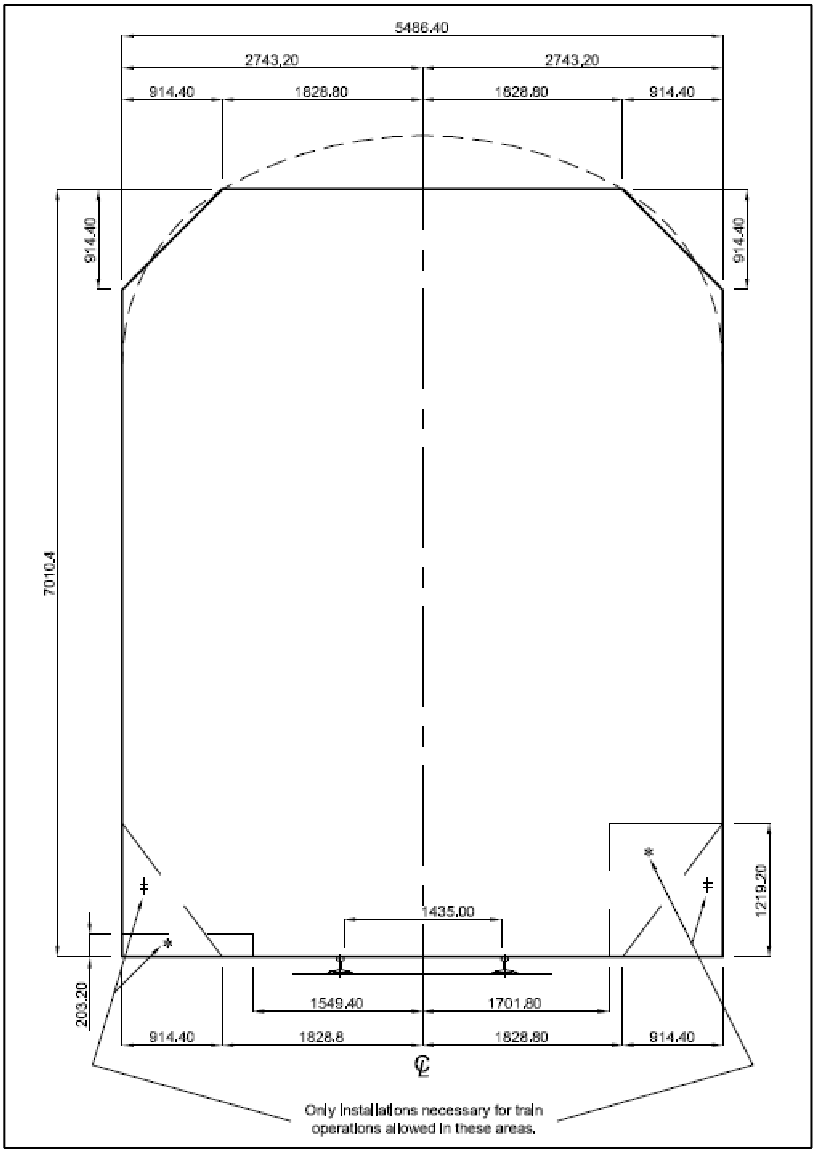

Figure 8-2: Clearance Box for Tangent Track

8.4.7 *Vertical Clearance of Water Crossings*

8.4.7.1 The freeboard of the bridge is defined as the open space from the soffit of the bridge to the top of the water level at a given flow. The minimum allowable freeboard will be 0.30 meters.

8.4.7.2 For the purpose of this the design the following freeboard must be maintained for water crossings:

- All Streams:
  - 0.30 meters above 1 in 200 year flow elevation (High water level).
  - 0.60 meters above the 1 in 25 years flow elevation.
- Navigable streams only:
  - 1.5 meters above the average annual high water elevation (Normal Water Level), unless noted otherwise.

8.4.8 *Walkways*

8.4.8.1 Where required on bridges for maintenance access, walkways will be provided on both sides of the structures. Walkways will have a minimum width of 700 mm.

8.4.8.2 Guardrails will be provided on the exterior side of the walkway. The guardrails may not be inside of the required clearance box. The guardrail height will be 1050 mm above the walking surface of the walkway.

8.4.8.3 There will be no permanent fixtures inside of the clearance box. Refuge bays will be provided, where pedestrians on the walkway would be located inside the clearance box, at a maximum spacing of 45 meters.

8.4.9 *Fixity*

The fixity on the spans will be as follows:

- One end fixed translationary (X, Y, Z).
- One end will be fixed transversely (Y).

8.5 Bridge Design Parameters and Loading

8.5.1 *Ballasted Deck*

8.5.1.1 Bridges will be assessed on a case by case basis as whether the bridge will have a ballasted deck or open deck.

The criteria basis for this will be:

- Environmental Constraints
- Axle Loading

- Bridge Strength
- Settlement of piles due to permafrost and alignment of track.

8.5.1.2 Elevations will be set based on an assumed ballast depth of 478 mm below base of rail for wooden ties and the ties will extend as far as the extension of the guardrails, and as such also serve as a transition section between the steel ties on the mainline and the hardwood sleepers on the bridges.

8.5.1.3 For the design of the bridge, the load due to ballast will be based on a depth of 750 mm (approximately 1.5 x design depth from below base of rail), allowance includes for a maintenance tamp. Ballast pans and ballast retaining structures will be designed for a ballast depth of 750 mm.

8.5.1.4 Drainage from the ballast pan will be designed to accommodate and contain any liquid spill that occurs in the vicinity of the bridge. Expansion joints will be designed to contain any liquid spill that occurs in the vicinity of the bridge. The flow of the liquid will be able to be contained.

8.5.2 *Vertical Displacements and Camber*

8.5.2.1 The allowable vertical displacements under live load and impact will be less than:

- Span / 800

8.5.2.2 Spans must be cambered as defined in AREMA Chapter 15 Part 1 Article 1.2.10. All structures must be cambered for dead load. All cambering of spans must be subject to the Contractor's designer's discretion.

8.5.3 *Lateral/Longitudinal Displacements*

8.5.3.1 The allowable lateral displacement within a span shall be less than:

- For tangential track

  $0.028L^2$

- For curved sections

  $0.066L^2$

Where:

The resulting deflection is in mm.

L = span length (m).

The allowable lateral displacement at a pier shall be less than:

- For tangential track

  $0.028D^2$

- For curved sections

  $0.066D^2$

Where:

The resulting deflection is in mm.

D = sum of the two span lengths adjacent to the pier (m).

The allowable longitudinal displacement of the superstructure shall be less than:

- 50 mm for load combinations including seismic loads
- 28 mm for all other load combinations.

Note: for load combinations including seismic loads, the allowable deflections are for serviceability level.

8.5.4 *Live Load*

8.5.4.1 The defined live load model in MRE Clause 15-1.3.3 is Cooper E-80. For the purposes of the design of the structures for this project, the live load will be based on Cooper E-90 (Cooper E-80 + 12.5%).

8.5.4.2 The impact loading shall be applied in accordance with MRE Clause 15-1.3.3.

8.5.4.3 The alternate live load on the 4 axles shown in MRE Figure 15-1-3 shall also be checked.

8.5.4.4 MRE Clause 15-1.3.4 shall be used to distribute the live loads between the load-carrying members.

8.5.4.5 In accordance with MRE Clause 15-1.3.3 pattern loading will be used on multi span bridges to achieve the greatest live load stress. For single span bridges the greatest live load stress will be determined by applying different scenarios of the Cooper E-100 and alternative live load on 4 axles.

8.5.5 *Centrifugal Force*

8.5.5.1 Centrifugal forces shall be applied in accordance with MRE Clause 15-1.3.6 to structures located on curves.

8.5.5.2 The design speed of 75 km/h shall be assumed when applying the equations.

8.5.6 *Fatigue Stress Cycles*

8.5.6.1 MRE Clause 15-1.3.13 shall be used to design the steel structures for fatigue resistance.

8.5.6.2 All elements shall be designed for more than 2,000,000 stress cycles.

8.5.7 *Braking and Traction Forces*

8.5.7.1 Longitudinal forces shall be determined in accordance with MRE Clause 15-1.3.12.

8.5.8 *Bearing Friction Forces*

8.5.8.1 The longitudinal forces due to bearing friction will be based on an assumed coefficient of friction of 15%.

8.5.9 *Walkway Loads*

8.5.9.1 For design purposes, any area extending beyond the required clearance box shall be considered to be walkway.

8.5.9.2 Walkway load = 5.0 kPa.

8.5.10 *Snow Loads*

8.5.10.1 The ground snow load in the area is approximately 2.0 kPa in accordance with the 2005 National Building Code of Canada.

8.5.10.2 A snow load of 3 kPa will applied to all structures. The additional 1 kPa is to account for any unforeseen weather and for any uncertainty in the National Building Code of Canada.

8.5.11 *Snow and Walkway Combination*

8.5.11.1 Snow and walkway loading will not be considered to occur simultaneously.

8.5.11.2 Snow and walkway load cases will be considered as follows:

a) 5.0 kPa over the walkway areas (any areas outside the clearance box width) in combination with train loads.

b) 3.0 kPa over the entire width of the bridge, not in combination with train loads.

8.5.11.3 The above indicates that load case a) will govern the design. Thus explicit consideration of snow load is not required.

8.5.12 *Ice Accretion Loads*

8.5.12.1 S6 Figure A.3.1.4 is used for to determine the ice accretion load.

8.5.12.2 The figure indicates that 12 mm of ice thickness is required. A safety of 1.25 is used on the value.

8.5.12.3 Ice thickness = 15 mm.

8.5.12.4 Ice load = 15 mm $\times$ 9.81 kN/m^3 = 0.15 kN/m$^{2.}$

8.5.12.5 Ice accretion load will be considered a dead load for the purpose of load combinations.

8.5.13 *Wind Load on Structure*

8.5.13.1 Wing load on structures will be determined in accordance with MRE Clause 15-1.3.8.

8.5.14 *Wind Load on Live Load*

8.5.14.1 Wind load on live load shall be determined in accordance with MRE Clause 15-1.3.7 (a).

8.6 Other Lateral Forces

Any other additional forces that result from equipment and maintenance shall be determined and applied in accordance with MRE Clause 15-1.3.9.

8.6.1 *Temperature Range*

8.6.1.1 CSA S6 Figure A3.1.1:

- Maximum mean daily temperature = 10°C

8.6.1.2 CSA S6 Figure A3.1.2:

- Minimum mean daily temperature = -35°C

8.6.1.3 Two types of superstructures are provided below in accordance with CSA S6 Clause 3.9.3.

8.6.1.4 Type A: steel or aluminum beam, box, or deck truss systems with steel decks and truss systems that are above the deck.

8.6.1.5 Type B: steel or aluminum beam, box, or deck truss systems with concrete decks.

8.6.1.6 <u>For a Type ‘A’ superstructure:</u>

- Maximum effective temperature: 10°C + 25°C = 35°C
- Minimum effective temperature: -35°C – 15°C = -50°C

8.6.1.7 CSA S6 Figure A3.1.1:

- Assumed structure depth = 1 m
- Reduction to maximum effective temperature = 3.5°C
- Increase to minimum effective temperature = 5.5°C
- Maximum Temperature = 35°C – 3.5°C = 31.5°C ≈ +35°C
- Minimum Temperature = -50°C + 5.5°C = -44.5°C ≈ -45°C
- Range = 35°C + 45°C = 80°C

8.6.1.8 For a Type ‘B’ superstructure:

- Maximum effective temperature: 10°C + 20°C = 30°C
- Minimum effective temperature: -35°C – 5°C = -40°C

8.6.1.9 CSA S6 Figure 3.5:

- Assumed structure depth = 1.5 m
- Reduction to maximum effective temperature = 3.5°C
- Increase to minimum effective temperature = 5.5°C
- Maximum Temperature = 30°C – 3.5°C = 26.5°C ≈ +30°C
- Minimum Temperature = -40°C + 5.5°C = -35.5°C ≈ -35°C
- Range = 30°C + 35°C = 65°C
- The thermal coefficient of steel = 12×10^{-6}/°C
- The thermal coefficient of concrete = 10×10^{-6}/°C

8.6.1.10 The design temperatures above will be used for the structural design of the bridges according to the type classification.

8.6.1.11 The material requirements will be governed by the site Climatic Data. This information indicates that the average temperature is -15ºC and will be used as the temperature that the bearings are centred at.

8.6.2 *Earth Pressure*

8.6.2.1 The active pressure will be determined using the following parameters:

- Unit weight for soil = 20.0 kN/m^3
- 'at rest' coefficient = 0.50

8.6.2.2 The above is to be confirmed with the geotechnical engineer during the project.

8.7 In Stream Ice Loads

8.7.1 The requirement of ice loading on the structure will be determined during the project based on hydrological information.

8.7.2 Where in stream ice loads are required, these shall be determined in accordance with CSA S6 clause 13.2.

8.8 Stream Forces

8.8.1 Stream forces will be calculated by the following formula:

$P_a = K \times V_a^2$

P_a = average stream pressure (kPa)

V_a = average stream velocity (m/s)

K = drag constant:

= 0.725 for square-ended pier

= 0.360 for semi-circular pier

= 0.400 for a wedge-shaped nose <90°

8.8.2 Forces will be distributed to the pier assuming a triangular pressure distribution of $2P_a$ at water surface and 0 at riverbed.

8.9 Seismic Effects

8.9.1 *General*

8.9.1.1 Seismic analysis will be carried out using a linear elastic analysis. Response spectra will be based on MRE Clause 1.4.4.3.

8.9.1.2 The peak ground acceleration (PGA) proposed value is 0.4g and is to be confirmed from the following website:

http://earthquakescanada.nrcan.gc.ca/hazard/interpolator/

8.9.1.3 MRE Clause 9-1. The Site Coefficient (MRE Clause 9-1.4.4.1) shall be taken as 1.0 for all locations, subject to confirmation by the geotechnical engineers.

8.9.2 *Load Combinations for Structural Check – Concrete Elements*

8.9.2.1 *Service Load Design*

8.9.2.2 The load combinations contained in the table below will be checked. The last column of the table indicates the allowable multiplier to be applied to the working stresses for each combination depending on the specified code.

8.9.2.3 The table below indicates the group loading combination for SERVICE LOAD DESIGN.

8.9.2.4 Groups I-VIII taken directly from MRE Clause 8-2.2.4 Table 8-2-4.

8.9.2.5 Group IX is adapted from a combination specified in MRE Clause 9-1.4.6, this specifies requirements for load factor design (LFD) only. The combination has been determined by comparison with other working stress combinations specified in MRE Chapter 8 and with load combination specified in MRE Clause 8-1.4.6 for steel structures.

8.9.2.6 Group IX only applies to the "Serviceability" seismic load case. For other seismic load cases, yielding is assumed to occur and these checks not based on material stresses but are based on displacement demands.

Table 8-1: Group Loading Combination – Service Load Design (MRE Clause 8-2.2.4 Table 8-2-4)

Group	D+	LL+I	LL Min	LF	CF	WL	WU	WLL	ICE	EQ	%
I	1	1			1						100
II	1					1					125
III	1	1		1	1	0,5		1			125
IV	1	1			1						125
V	1					1					140
VI	1	1		1	1	0,5		1			140
VII	1	1			1				1		140
VIII	1					1			1		150
IX	1									1	150

Note:
D+ includes D (dead load), E (earth pressure), B (buoyancy) , SF (stream force) and the weight of accreted ice.
LL+I = train loads + impact + 5.0 kPa walkway loads outside of clearance box.
LL Min = Minimum live load per MRE 15-1.3.10 "Stability Check".
LF = longitudinal force (braking and traction) + bearing friction effects
CF = centrifugal force
WL = wind on loaded structure
WU = wind on unloaded stricture
WLL = wind on live load
ICE = ice loads (down drag and impact – not accretion)
EQ = seismic loads

8.9.2.7 *Load Factor Design*

- The load combinations contained in the table below will be checked.
- The table below indicates the group loading combination for LOAD FACTOR DESIGN.
- The load factors provided below are only intended for designing structural members by the load factor design concept. The actual loads should not be increased by these factors when designing for foundations, checking foundation stability.

Table 8-2: Group Loading Combination Load Factor Design (MRE Clause 8-2.2.4 Table 8-2-5)

Group	D+	LL+I	LL Min	LF	CF	WL	WU	WLL	ICE	EQ
I	1.4	2.33			1.4					
IA	1.8	1.8			1.8					
II	1.4					1.4				
III	1.4	1,4		1.4	1.4	0.5		1.4		
IV	1.4	1.4			1.4					
V	1.4					1.4				
VI	1.4	1,4		1.4	1.4	0.5		1.4		
VII	1									1
VIII	1.4	1.4							1.4	
IX	1.2					1.2			1.2	

Note:

D+ includes D (dead load), E (earth pressure), B (buoyancy) , SF (stream force) and the weight of accreted ice.
LL+I = train loads + impact + 5.0 kPa walkway loads outside of clearance box.
LL Min = Minimum live load per MRE 15-1.3.10 “Stability Check”.
LF = longitudinal force (braking and traction) + bearing friction effects
CF = centrifugal force
WL = wind on loaded structure
WU = wind on unloaded stricture
WLL = wind on live load
ICE = ice loads (down drag and impact – not accretion)
EQ = seismic loads

8.10 Load Combinations for Structural Check – Steel Elements

8.10.1 *General*

8.10.1.1 The load combinations contained in the table below will be checked.

8.10.1.2 The last column of the table indicates the allowable multiplier to be applied to the working stresses for each combination depending on the specified code.

8.10.1.3 The table below indicates the load combinations with Groups I-III taken from Chapter 15.

8.10.1.4 Group II applies to only to the members which are subjected to wind load only.

8.10.1.5 Group IX is taken from MRE Chapter 9 with consistency being maintained with the concrete load combination in the previous section with regard to the naming.

8.10.1.6 Group IX applies only to the "Serviceability" seismic load case. For other seismic load cases, yielding is assumed to occur and these checks not based on material stresses but are based on displacement demands.

Table 8-3: Group Loading Combination (MRE Chapter 15)

Group	D+	LL+I	LL Min	LF	CF	WL	WU	WLL	ICE	EQ	%
I	1	1			1						100
IA	1		1		1						100
II							1				100
III	1	1		1	1	1		1	1		125*
IIIA	1						1		1		125*
IX	1									1	150*

*The specified increase in allowable stress shall not be applied to floor beam hangers or bolts.

Notes:

D+ includes D (dead load), E (earth pressure), B (buoyancy) , SF (stream force) and the weight of accreted ice.
LL+I = train loads + impact + 5.0 kPa walkway loads outside of clearance box.
LL Min = Minimum live load per MRE 15-1.3.10 "Stability Check". Walkway load not included.
LF = longitudinal force (braking and traction) + bearing friction effects
CF = centrifugal force
WL = wind on loaded structure
WU = wind on unloaded structure
WLL = wind on live load
ICE = ice loads (down drag and impact – not accretion)
EQ = seismic loads

8.10.2 *Bearing Replacement*

8.10.2.1 The structure will be designed taking into account the bearing replacement or shimming. Jacking points on the structure will be indicated. This will avoid the future requirements for additional foundations or support frames.

8.10.2.2 The jacking points will be designed for dead load only.

8.10.3 *Utilities*

8.10.3.1 Where required, ducts shall be installed on the bridges for the passage of utilities. Ducts will be surface mounted. The size, location and number of, will be determined during the project.

8.11 Bridge Materials

8.11.1 *Concrete*

8.11.1.1 Cast in-situ concrete will be avoided where possible due to the constraints on construction. However, if the design requirement does not allow for steel or precast concrete, cast insitu shall be used.

8.11.1.2 The following shall apply:

Cast in-situ Concrete Design:	28-day compressive strength of 35Mpa
	Sika Grout Arctic 100 material is to be used or
	Air entrapment design is to be used

8.11.1.3 Precast reinforced concrete design: 28-day compressive strength of 45 MPa.

8.11.2 *Concrete Protection for Reinforcement*

8.11.2.1 The minimum clear cover for reinforcement shall be as described below:

- Cast against/permanently exposed to earth: 75 mm
- All other locations: 50 mm

8.11.3 *Structural Steel*

8.11.3.1 All exposed structural steel is to be atmospheric corrosion resistant (weathering steel) Grade 350AT, Category 4 or approved equivalent and shall conform to CSA Standard G40.1.

8.11.4 *Corrosion Allowance*

8.11.4.1 A corrosion allowance of 1.5 mm (1/16'') shall be deducted from the nominal thickness for sheet products only.

8.11.5 *Bolts*

8.11.5.1 All bolts will be 7/8'' diameter (22 mm) type A325 (weathering steel).

8.11.6 *Joints*

8.11.6.1 Integral abutments with no joints will be considered for bridges with spans less than 50 m.

8.11.6.2 Where integral abutment joints are not possible, standard expansion joints will be designed.

8.11.7 *Bearings*

8.11.7.1 Bearings shall be self-lubricating bearings.

8.11.7.2 The coefficient of friction at expansion locations is assumed to be 15% for the design. No additional factor of safety is required on the 15%.

8.11.7.3 The friction forces due to temperature movements are assumed to arise from dead load only. Live load is not included.

8.11.7.4 If self-lubricating spherical bearings are selected then the friction forces will arise as a result of live load rotation.

8.11.7.5 For multi-span bridges, the worst loading case will arise when a single span is loaded. This is due to the bearings on adjacent span at any pier acting in different directions. For this load case, the 15% coefficient of friction will be used in combination with the total dead load and live load reaction.

8.11.8 *Waterproofing*

8.11.8.1 No waterproofing membrane will be used.

8.11.8.2 For all steel deck plates that are susceptible to crevice corrosion will be galvanised.

8.12 Bridge Geotechnical Parameters

8.12.1 *Ad Freeze Piles*

8.12.1.1 Geotechnical parameters relating to the foundations will be completed when further investigations and details become available.

8.12.1.2 The proposal for the adfreeze piles is to incorporate a welded steel grade beam as a pile cap rather that a concrete pile cap.

8.13 Other Bridge Design Considerations

8.13.1 *Guard Rails*

8.13.1.1 Guard rails shall be provided on all tracks installed on bridges and shall extend 20 m beyond either side of the structure.

8.13.2 *Fish Passage*

8.13.2.1 The bridge crossings will be assessed to determine if the crossing is over a fish habitat. Where bridges are crossing over fish habitats, the environmental recommendations and hydraulic report will provide the requirements.

8.13.3 *Scour Protection*

8.13.3.1 Scour protection will be determined on a case by case basis and will be determined by the hydraulic report.

8.14 Bridge Options

8.14.1 The rail girder bridge that has been considered for the structure:

- Through Plate Girder (TPG)

8.14.2 The rail bridge deck that has been considered for the structure:

- Ballasted Deck that comprises of a concrete deck or steel deck to contain the ballast.

8.15 Culvert Geometry

- The hydrology in terms of flows, peak flows and intensities for the related catchment areas for each river or stream, the new rail alignment will cross, had been reviewed and determined for 1 in 200 year return periods. This will guide bridge and culvert basic hydraulic sizing and the necessary adjustments (over compensation) to accommodate the uncertainties associated with arctic hydrology and the influence of ice and snow on the hydraulics.
- The Expansion Study – Stage II costing are based on using galvanised corrugated steel pipes pending further investigation to use pre-fabricated concrete box culverts. Pre-fabricated box culverts and culvert bottom slabs are normally up to 3 tonnes per unit, requiring mechanical handling through all the transport mode changes in the logistics chain from manufacturer to installation on site. The trade-off in culvert unit choice can be concluded once the hydraulics had been completed and the material take-off for culverts are detailed, and priced by the contractors during the next phase of the project. It is noted that box culverts are seen as environmentally more friendly bridging fish bearing water ways.

8.15.1 *Dimensions*

8.15.1.1 Culvert diameter or size will be standardized to maximum 4 standard sizes that will either be used as single or multiple culvert combinations for each water way or run-off path where culverts need to be installed. Single pipe culverts will be favored where possible. Dimensions will vary depending on:

- Peak flow volumes.
- The hydraulic gradient of the stream crossing at the track location.
- The proximity to the Tote road culvert in the same stream or run-off path, implying potential downstream mitigating protection of the rail formation for back damming.
- Minimum cover over the culvert and support bedding under the culvert; and
- Fish passage considerations.

8.15.1.2 The four standard sizes ø900 mm, ø1200 mm, ø1500 mm and ø1800 mm will then be installed as single or multiple culverts rounded up to the next full size to determine number of pipes or pre-fabricated units required per location. For grade crossings and caribou crossings ø600 mm will be used to ensure there is drainage underneath crossings of the rail alignment.

8.15.2 *Vertical Clearance*

8.15.2.1 The vertical clearance for culverts shall be determined by considering the 5 dimension drivers above, the upstream storage conditions and the potential damming effect in closer proximity to the Tote road culverts for the water course, by providing mitigating protection for the rail formation on the downstream side with geotextile or anti-seepage walls.

8.15.2.2 The risk of overtopping shall be assessed for the design criteria employed with the purpose to mitigate storm water damage to the rail embankment by anti-seep walls or membranes on both sides or appropriate other measures where required.

8.16 Culvert Design Rational

8.16.1 *General*

8.16.1.1 Culvert design shall consider the following:

- Prevent water accumulation on the sides of embankments.
- Divert water and ice away from the toe of the embankment.
- Provide cut-off drains or berms for dispersed flow and accumulate through appropriate culvert in the proximity.
- Provide appropriate embankment protection where required.
- The culvert shall be sloped in the direction of flow at the same grade as the water path grade, such that the centre of inlet- and the centre of outlet is as close as possible to the centre of the water path and the direction/orientation of the water path.
- Provide appropriate inlet and outlet protection and treatment, linked to the water flow velocity to prevent piping through the embankment and erosion of the water path sides and the embankment.
- The water shall be channelled with a down chute at such low spots in cuttings into the drop inlet or calming pond.
- Provide culvert barrel treatment, scour holes, wing walls and drop inlets where grades are too steep and water velocity >5 m/s.
- Provide oversized culvert with weirs, cut-off collars both ends and natural stones inside culverts where water velocity <5, but >4 m/s.
- Provide wing walls both ends where water velocity is <4, but >3 m/s.
- Provide basic inlet and outlet protection where water flow velocity is subcritical (<3 m/s).

8.16.2 *Typical Culvert Sections*

8.16.2.1 The culvert dimension considerations in 8.15.1 will guide culvert sizing. Culvert bedding, support, cover and backfill measures are as important. Differential settlement under the embankment weight and train loading as per 8.5.4 and 8.5.5 needs to be prevented. The following Figures provide the basics for culvert configurations and are excerpts of drawings H352034-3000-220-294-0001 and H352034-3000-220-294-0002.

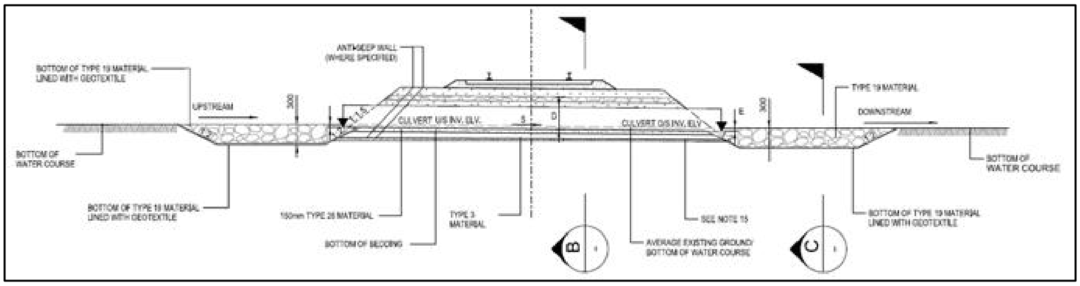

Figure 8-3: Culvert Section with Erosion Protection

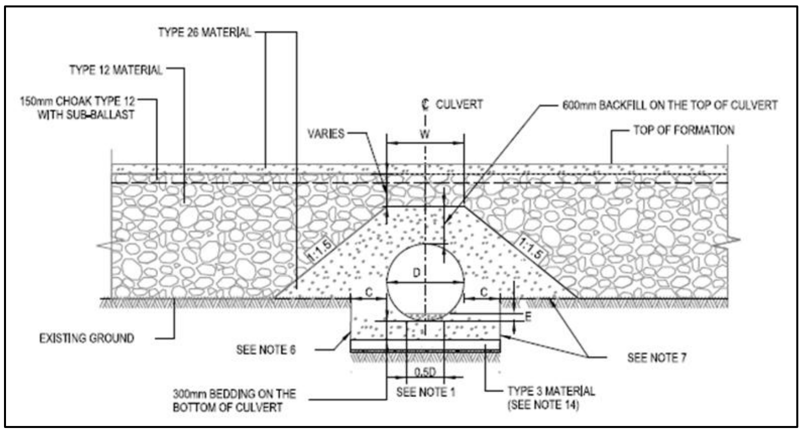

Figure 8-4: Single Pipe Culvert with Minimum Backfill Requirements

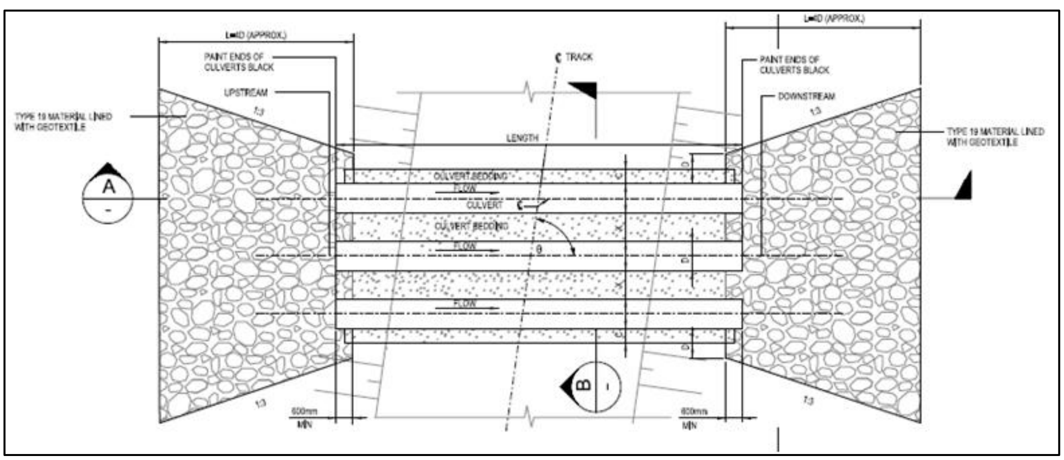

Figure 8-5: Plan – Multiple Pipe Culvert with Erosion Protection

8.16.3 *Requirements for Fish Bearing Crossings*

8.16.3.1 The following criteria shall apply to fish bearing streams to ensure the protection of fish habitats where culverts need to be installed:

- Identify culverts located in fish bearing crossings.
- Design to assist in minimum disruption of fish migration or movement with reference to over sizing, 20% of diameter below natural stream grade (Figure 8-6), light and appropriate measures to control water velocity through culvert.
- In multiple culvert configurations provide at least in a single culvert the fish passage promoting measures.
- Fish bearing culverts will be assessed on a case by case basis to install appropriate fish passing promoting measures where required.

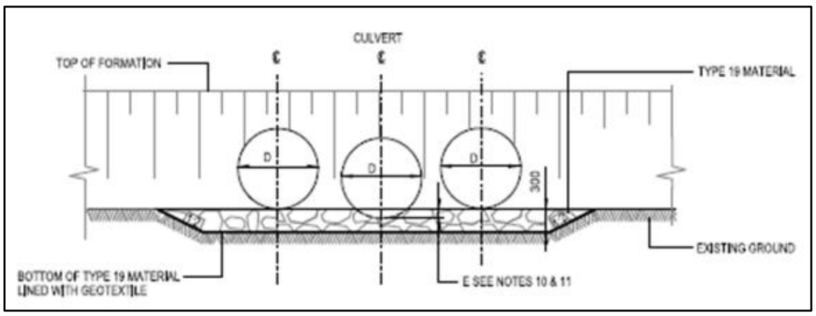

Figure 8-6: Multiple Pipe Culvert with Fish Passing

9. Track

The track design standards have been carried over from document "FULL DESIGN BRIEF 2-04-2012", the Steensby Report, being the property of BIM and reviewed to be a good application of the North American Standards by Consultants experienced in North American and Canadian railway design. A few adjustments have been made which will be highlighted where applicable. Further adaption to minimum standards has been followed to optimize the rail design. A steel tie system will be installed for the optimized approach but the criteria for a wood tie system is included for reference purposes.

9.1 Design Standards

9.1.1 The operating conditions described in Section 4, guide and dictate what standards and procedures is required to provide the infrastructure to support sustainable capacity delivery- and operations for the rail system.

9.1.2 The design of the components is mainly based on AREMA standards and codes of practice and shall conform to CN standards for Class 3 track and the standards and guidelines set forth by the Canadian Transportation Commission (CTC). In the absence of a suitable AREMA standard, other international standards (i.e. UIC, etc.), may be used.

9.1.3 A full list of all the codes and procedures to consider is provided as Section 2 of this document.

9.2 Track Structure Design Conditions

9.2.1 *Train Loading*

9.2.1.1 The train loadings (design speeds and axle loads) on the track structure associated with the railway are summarized as follows:

Maximum design speed	:	All trains both directions; 75 km/h (loaded and empty)
Annual Traffic	:	Iron Ore Traffic (Dry) 12 Mtpa; (Humid)12.24 Mtpa
Axle Load	:	Ore Train* 32.5 tonnes (all trains)

9.2.2 *Sub-grade Loading*

9.2.2.1 The track structure shall be designed to dissipate train loads through the track structure to produce a maximum loading on the sub-grade of 170 kPa as per Chapter 16 – Section 10.3.2.1 of AREMA.

9.2.3 *Key Track Structure Parameters*

9.2.3.1 The track structure required for the described heavy haul operation can be configured as follows:

- Rail 136 lb RE (67.4 kg/m))
- Welded/jointed Welded mostly with possible jointed track in yards and sidings.
- Ties Timber (178 mm x 229 mm x 2.6 m).
- Tie spacing (mm) 540
- Fastenings Pandrol "e"-clips with 18" Victor tie plates; welded shoulders for steel ties.
- Screw spikes Pandrol "e"-clips with welded rail seat.
- Ballast depth (mm) 300
- Ballast + tie depth (mm) 478
- Ballast shoulder width (mm) tangent/curves 300/350
- Ballast shoulder slope 1V : 1.5H
- Sub-ballast cross-slope 0.00% (Top) 0.00% (Bottom)
- Minimum sub-ballast shoulder width is 0 mm
- Typical cross-sections for main track, siding and yard tracks are shown in the sections below, Figure 9-1 and Figure 9-2 (Drawing H352034-3000-220-294-0003).

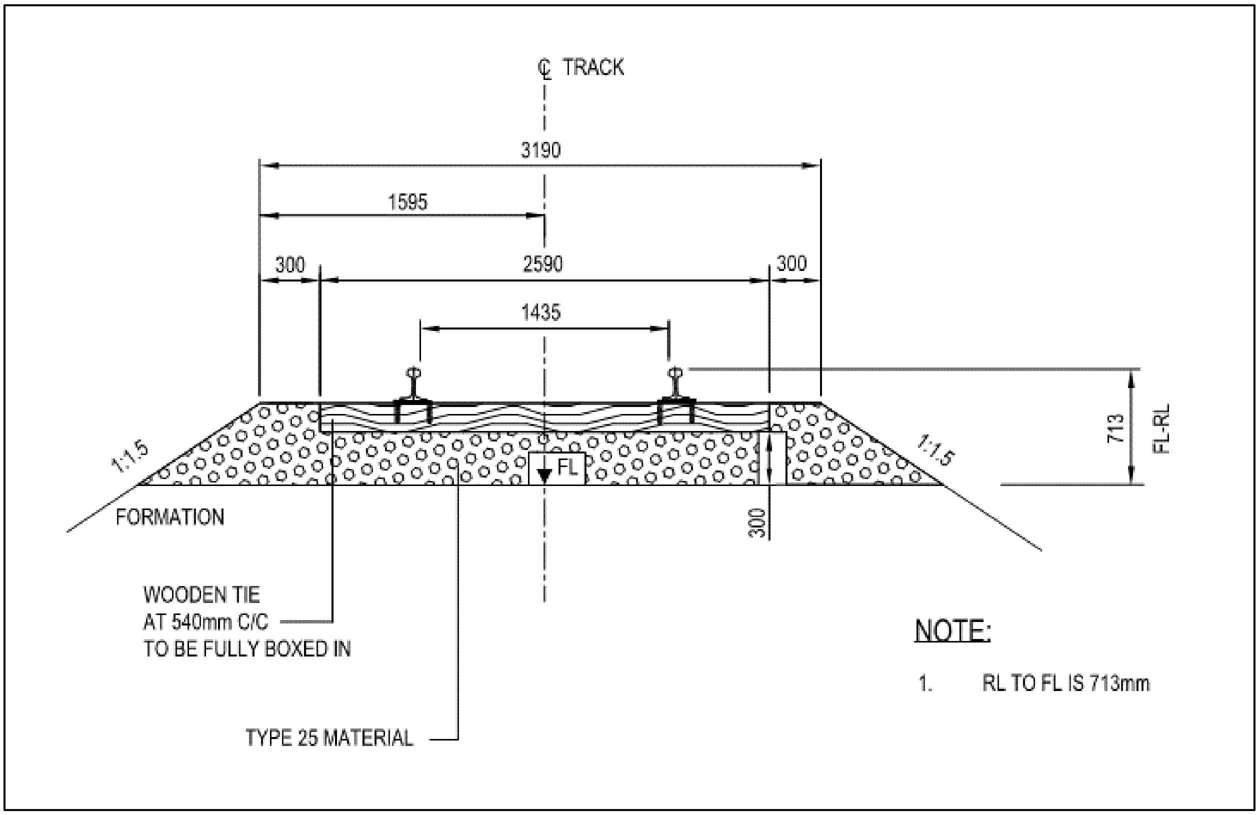

Figure 9-1: Typical Cross Section – Superstructure

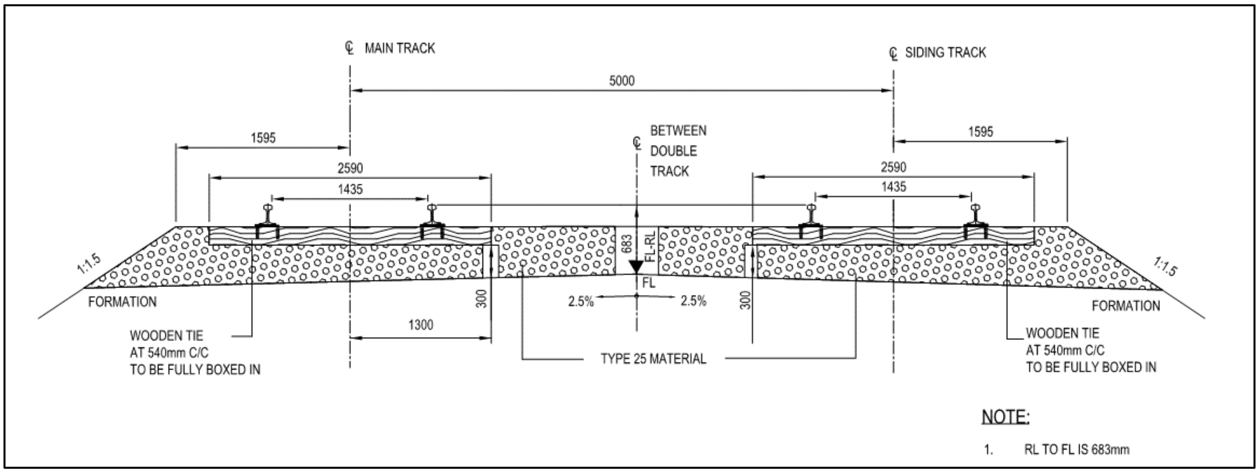

Figure 9-2: Typical Cross Section – Double Track in Sidings – Superstructure

9.3 Rail

9.3.1 *General*

9.3.1.1 Selection of a rail section for the Baffinland Iron Mines Railway System between Mary River and Milne Port is based on the following criteria:

- Design axle loads.
- Annual tonnage.
- Alignment curvature and gradient.
- Maximum Train design speeds.
- Extreme climate conditions.
- Type of rolling stock.
- Maintenance requirements are somehow compromised with the absence of sub ballast shoulder.
- Ease of welding.

9.3.2 *Rail Dimensions and Tolerances*

9.3.2.1 The rail shall be 136 RE profile for the entire network in accordance with AREMA, Chapter 4.

9.3.2.2 The rail shall be purchased in minimum lengths of 24 m (80 ft.) to support a modular panel installation concept.

9.3.3 *Steel Quality*

9.3.3.1 AREMA, Manual for Railway Engineering, Volume 1, Chapter 4, Sections 2.1.4.1 and 2.1.4.2 list two types of steel, namely, standard chemistry and low alloy chemistry. In addition, the respective tables identify the chemical composition, hardness and tensile properties. With respect to hardness the standard chemistry rail lists two types; standard and high strength rail, while the low alloy chemistry lists three types; standard, intermediate and high.

9.3.3.2 The rail shall be 136RE; AHH grade with minimum yield strength of 130,000 psi, for both mainline track and yard track. The low alloy steel is being recommended on the basis of improved welding characteristics, improved wear characteristics at weld joint areas and superior resistance to wear (longer life).

9.3.3.3 All rails shall be rolled using clean regular carbon steel with an emphasis on the cleanliness of the steel and reduction of inclusions in the rail during the manufacturing process. Premium steel has not been considered due to its predisposition to brittle fracture during extreme cold weather.

9.3.3.4 A major criterion in the selection of a Contractor shall be their ability to roll rails using clean steel and guarantee the durability and cleanliness of the steel in sub -50°C temperatures.

9.3.4 *Rail End Drilling and Hardening*

9.3.4.1 Rail for use in continuously welded sections shall be supplied undrilled.

9.3.4.2 Rail for use in jointed track shall be drilled to accommodate a 90 mm long, 6-hole joint bar (fishplate). Jointed rail shall only be used in yards and sidings and as such end hardening is not required.

9.4 Ties

9.4.1 *Yards, Mainline and Sidings*

9.4.1.1 All ties shall be untreated hardwood no 1 ties.

9.4.2 *Spacing Tolerance*

9.4.2.1 The tolerance on the tie spacing shall be +/- 10 mm along the mainline and +/- 15 mm in yards and along sidings with no cumulative tolerance over any distance (if in one crib the tie spacing is above the nominal spacing the adjacent crib shall not be above nominal to facilitate continuous action tamping).

9.4.2.2 Tie spacing in the yards and mainline is 540 mm.

9.5 Fastenings

9.5.1 *Steel Ties*

9.5.1.1 Fastenings Pandrol “e”-clips with 18” Victor tie plates (hardwood) for curves with radii <875m with screw spikes.

9.5.1.2 “AREMA” tie plates for curves with radii >875m with cut spikes.

9.6 Ballast

9.6.1 Ballast shall be composed of crushed rock or a material of comparable character and shall be in accordance with AREMA, Chapter 1, Part 2. The ballast material shall be a hard, dense, strong and angular material with a durable particle structure providing sharp corners and cubicle fragments with a minimum of flat and elongated particles. It shall be free from clay, shale or an excess dust or other undesirable substances or materials. The ballast must have high wear and abrasive qualities to withstand the impact of traffic loads and track maintenance by heavy tamping machines without excessive degradation. The ballast must also provide high resistance to temperature change, chemical attack, low absorption properties and should be free of cementing properties.

9.6.2 Testing procedures will be in accordance with the AREMA, Chapter 1, Section 2.8 and conform to ASTM specifications and associated testing procedure, the ballast requirements are prescribed by the code and the Ballast Grading Requirements (AREMA size No. 4) or as in Figure 9-1 below:

Table 9-1: Ballast Crushed Stone Grading

Nominal Sieve Size (mm)	Percentage Finer Than (By Weight)
73	100
63.0	90 – 100
53.0	40 – 70
37.5	10 – 30
26.5	0 – 5
19.0	0-1
13.2	0

Table 9-2: Ballast Physical Specification

Laboratory Test	Standard	Values
Los Angeles Abrasion Test (LAA)	ASTM C 535-69	< 35% weight loss
Mill Abrasion Test (MA)	Non-standard test	<5% weight loss
LLA + 5(MA)	–	<50%
Degraded Aggregate Cement Value (CV)	Non-standard test	<(1.0 +0.2xMA)
Bulk Specific Gravity	ASTM C127	>2.6
Magnesium soundness test	ASTM C88-76 x 5 cycles	≤8% weight loss
Water Absorption	-	≤1.5%

9.7 Turnouts

9.7.1 *General*

9.7.1.1 Turnout for use on the rail system shall be referred to under the designation relating to the "frog (crossing) number" as described on pages 6-35 and 6-36 in Section 6.5 – Turnouts of the Practical Guide to Railway Engineering, AREMA 2003. Without limiting their completeness, the turnouts shall consist of the following components:

- Switch and crossing assemblies.
- All special and running rails.
- All rail braces, stretcher bars, castings, check rails, other track material, track appurtenances and miscellaneous items required to make the turnout installation complete.
- A complete set of steel turnout ties.

9.7.1.2 The design of the turnouts shall conform to the most recent edition of AREMA Plans and Specifications. They shall be designed to support the operating conditions set forth in the Operating Requirements Section.

9.7.1.3 No. 9 shall conform to the 136 RE rail profile. AREMA standards permit 32 km/h operating speeds through the diverted track for No. 9 lateral turnouts. Operating speed on the mainline is 60 km/h to a maximum of 75km/h as the design speed.

9.7.2 *Turnout Ties*

9.7.2.1 Track ties for all turnouts within the yard shall be steel ties in accordance with an AREMA No. 9 turnout.

9.7.2.2 Track ties along mainline turnouts shall be steel ties in accordance with an AREMA No. 9 turnout.

9.7.3 *Main Line*

9.7.3.1 The No.9 turnout shall have the geometry conforming to AREMA Plan No. 910-41 with 5,030mm (16 feet 6 inches) straight Samson switch points for standard gauge track. The ties shall be hardwood ties with fastenings designed for this turnout. The tie spacing and lengths shall be in accordance with AREMA specifications.

9.7.4 *Yards and Backtracks*

9.7.4.1 The No. 9 turnout shall have the geometry conforming to AREMA Plan No. 910-41 with 5,030mm (16 feet 6 inches) straight Samson switch points for standard gauge track. The ties shall be hardwood ties and fastenings. The tie spacing and lengths shall be in accordance with AREMA Plan No.912-58 as described in the AREMA, Portfolio of Trackwork Plans for the No. 9 Switches, latest edition.

9.7.5 *Snow Elimination*

9.7.5.1 All mainline and yard turnouts shall be equipped with automatic cold air blowers to ensure that no snow settles between the switch points and the stock rails.

9.8 Joints

9.8.1 *Standard Joint Bars*

9.8.1.1 Joint bars shall be toeless and conform to the profile presented in AREMA, Chapter 4, Part 3, Fig. 4-3-3 for 136RE rail section with the following bolt hole properties:

- Oval shaped with 1-5/16” diameter.
- Track bolts: 1 1/8” x 5 7/8” oval shape.

9.8.1.2 Rail drilling, bar punching and bolts shall be in accordance with AREMA, Chapter 4, Part 3, Table 4-3-1. All nuts and bolts shall be manufactured in accordance with AREMA, Chapter 4, Section 3.5.

9.8.2 *Insulated Joints*

9.8.2.1 Insulated joints are not considered as the signaling and control systems will be radio order controlled for a dark territory systems approach.

9.8.3 *Welded Joints*

9.8.3.1 If the modular installation concept is used the panels will be continuously welded with an on-track butt welding machine. The process shall conform to the requirements of AREMA, Chapter 4, Section 3.1.12. All welds for CWR shall be electric flash-butt welds.

9.8.3.2 Aluminothermic welds may be used where space does not permit flash-butt welding and for closure welds when de-stressing rails. Aluminothermic rail welds shall be made using full preheat welding kits (molds, charges, etc.), designed for 136RE rail with the metallurgical properties described in the applicable sections

9.9 Other Track Materials

9.9.1 *Guard Rails*

9.9.1.1 Guard rails shall be provided on all tracks installed on bridges and shall extend 20 m beyond either side of the structure. They shall also be provided in locations such as running in close proximity to sensitive water bodies.

9.9.1.2 Guard rails shall be designed in accordance with AREMA, Chapter 7, Section 3.6.2. They shall consist of 2 additional rails located inside the running rails. All guard rails shall be fastened using 12" tie plates for 5 ½" rail base width as per AREMA, Chapter 5, Part 1, Section 1.3, Figure 5-1-4 and standard spikes. It is not required for guard rails to have the same section as the running rails and may be second hand rail with the same base of rail dimension.

9.9.2 *Derails*

9.9.2.1 Derails shall be installed wherever the possibility exists that equipment left standing on tracks, other than main tracks or sidings may be moved by wind, or gravity, or both, so as to obstruct a main track or siding. Derails shall be installed on both ends of tracks where unattended locomotives are regularly stored.

9.9.2.2 The sliding derail shall be the preferred derail, as it provides derailing protection for all types of cars and units that are stored on sidings or backtracks regardless of the grades involved.

9.9.2.3 The model, size and hand of derail shall be selected to match the specific rail section height. A right hand or left hand derail shall be used where derailing protection is required (a right hand derail is one which derails to the right when looking in the direction of the movement to be controlled).

9.9.3 *Stop Blocks (Bumping Posts)*

9.9.3.1 Bumping posts shall be provided at the ends of all dead end tracks. All bumping posts shall be steel fabricated triangle units compatible with 136RE rail sections. In addition, they shall be equipped with a strengthening "middle rail" and a shock-free cushion head.

9.10 Track Signs

9.10.1 The design of the line shall make provision for appropriate way-side signs required for the safe operation of trains. Signs shall be provided for:

- Whistle posts.
- Kilometer and half kilometer point markers.
- Permissible running speeds.

- Bridge structure and major river identification.
- Station (siding) names.
- Registered clearance and bridge markers.
- Snow and flangers.
- Derails.
- Yard limits.
- Level crossings (Skidoo crossing and animal crossing signs); and
- Other miscellaneous signs required for safe operation.

9.10.2 Way-side signs shall be provided in English and Inuktituk. The design of all signs shall follow the guidelines in AREMA, Chapter 1, Part 7.

9.10.3 Optimization and appropriate elimination of track signs will be pursued further in the feasibility study.

9.11 Crossings

9.11.1 Crossings and Refuges (Set-offs)

9.11.1.1 At various locations along the rail line, refuges or set-offs and vehicle crossings are required to accommodate the entrance and exit of track maintenance vehicles. All set-offs shall be constructed using a set of 205 mm (8 in) x 205 mm (8 in) wood planks fastened to the ties using suitable hook bolts. A minimum of 76 mm (3”) shall be maintained between the gauge face of the rail and the nearest wood plank to ensure the wheel flange of rail cars will not be impeded.

9.11.1.2 The track structure shall remain the same as the typical cross-section shown in the cross section drawings and Figure 4-4 in Section 4 above. Road base Type 26 fill material shall be used as an approach material and shall be graded flush with the timber planks between the rails on top of the ties.

9.11.1.3 Where crossings are required in yards, wooden track ties shall be substituted for the ties in the standard yard track structure.

9.11.2 Animal Crossings

9.11.2.1 To assist the caribou in crossing over the track the following typical detail illustrates the proposed crossing. A total of 11 crossings has been included in the design and the final locations will be confirmed by BIM.

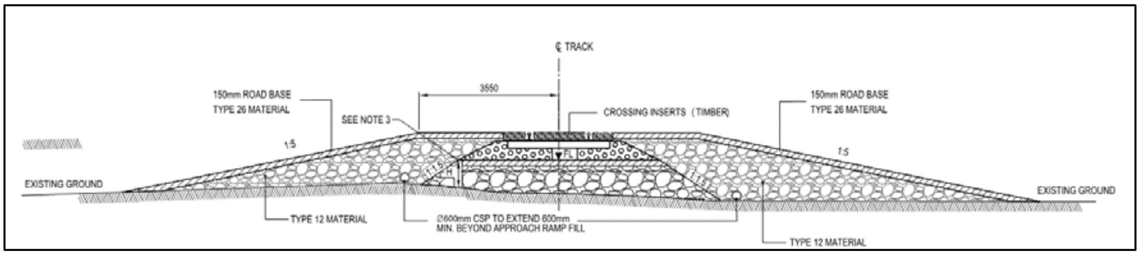

Figure 9-3: Typical Cross Section – Caribou Crossing

9.12 Clearances

9.12.1 *Clearance Diagrams*

9.12.1.1 The clearance enveloped developed is based on Transport Canada's *Standards Respecting Railway Clearances* (TC E-5) and the general clearance envelope outlined in AREMA, Chapter 28, Section 1.2, Figure 28-1-1.

9.12.1.2 The TC E-5 also requires a lateral allowance for track curvature of 25.4 mm per degree of curvature.

Table 9-3: Lateral Clearance Requirements for Curved Track

Curve Radius (m)	Curve Radius (degrees)	Additional Lateral Clearance (mm)
1746	1	25.4
873	2	50.8
582	3	76.2
436	4	101.6
349	5	127
291	6	152.4
249	7	177.8
218	8	203.2

9.12.2 *Track Spacing*

9.12.2.1 The design of all tracks shall respect the track spacing defined in Table 9-4.

Table 9-4: Track Spacing

Facilities	Minimum Track Spacing - TCE-5(m)	Design Spacing (m)
Tangent Tracks between Mainline and Sidings	4.27	5.00
Yard Tracks	4.11	≥ 5.0 (Purpose made)
Parallel Ladder Tracks	5.49	5.50

9.12.2.2 The minimum distance between track centers shall be increased by 50.8 mm (2”) per degree of curvature. A 5.0 m track spacing shall be used to provide an allowance for curves up to 4 degrees (R=436 m). If a siding curve adjacent to a mainline track exceeds 4 degrees then an additional track spacing of 50.8 mm per degree is required.

9.12.3 *Right-of-Way Fencing*

9.12.3.1 The railway right-of-way shall not be fenced and neither the yards and terminals.

9.13 Track Construction

9.13.1 The specific requirements shall be in accordance with AREMA, Manual of Railway Engineering, Volume 1, Chapter 5, Part 4 and Part 5. These shall be developed and detailed in the specifications. The requirements shall consider the current, most appropriate construction practices and methods that are expected of an international contractor. The use of heavy automatic mechanized machinery will be required. It is expected that bidders will be provided an opportunity to propose alternate methods to construct the track structure that meets the requirements at the most economic cost.

9.14 Track Maintenance

9.14.1 *Track Maintenance Conditions*

9.14.1.1 Sub ballast shoulders have been scaled down to zero for the optimizing exercise. In certain areas particularly with high embankments, long term slow settlement is anticipated due to ice creep. These locations will need to be revisit during the Mary River Expansion Study – Stage II in order to consider wider sub ballast shoulders to suit.

9.14.2 *Maintenance of Way Vehicles*

9.14.2.1 All track maintenance vehicles must be equipped for cold-weather conditions including supplemental heating (portable heaters) and storage for arctic survival equipment. A list of the maintenance of way (MoW) vehicles required is shown in the Operating Plan.

9.14.3 *Maintenance Bases and Sidings*

9.14.3.1 Infrastructure maintenance teams shall be based at both Mary River and Milne Port, the principal shop of MoW equipment shall be in the Consolidated Maintenance Facility at Milne.

9.14.3.2 The main line siding is provided with a back track for MoW use. Siding location will still be confirmed

10. Rolling Stock

10.1 Locomotives

10.1.1 The locomotives must be diesel-electric locomotives and be able to operate in the harsh and extreme cold environment. Locomotives that are successfully operated under these extreme cold conditions are the EMD SD70 ACEM and the General Electric (GE AC4400) locomotives. The new AC traction motor configuration provides more optimized energy consumption and will be the preferred locomotives for this application.

10.1.2 The locomotives to be standard gauge configuration in order to run on 1435 mm gauge. The locomotives to be equipped with dynamic braking capability as well as distributed power (cable and radio control capability) in order to run multiple locomotives on the train. Each locomotive to be connected with the back to the train and cab facing forward, as there is no balloon at the port or the mine sites for the train to turn around. The locomotives need to be equipped with F-type couplers that can absorb the maximum pull and compression force of 1600 kN. The locomotives to be equipped with airbrake braking system.

10.1.3 The locomotive must have a co-co bogie configuration as the axle loading on the perway will be designed for 32.5 tonnes per axle loading, so typical 198 metric tonnes and 33 tonnes axle loads.

10.1.4 The locomotives must be equipped with an onboard toilet facility.

10.2 Cars

10.2.1 The ore cars to be of standard gauge configuration with 1435 mm gauge and the open top gondola type car that can be tipped by means of a rotary tippler. The cars must be coupled by means of a rotating coupler on each side of the car. This will enable the off-loading of a single car per cycle through the single cell rotary tippler.

10.2.2 The cars must be equipped with an air-brake braking system and the drawbar and coupler configuration must be the F-type coupler.

10.2.3 The ore cars will be designed to accommodate a maximum loaded axle load of 32.4 tonnes per axle and must be equipped with self-steering bogies.

10.2.4 The car must have a tare weight of 22 metric tonnes.

10.2.5 The cars must fit within the minimum rail structure gauge tolerances at a width of 5750 mm. This value is based on the AREMA clearance box width of 5486 mm plus an allowance of 80 mm per degree of track curvature at a maximum curvature of 3 degrees. At the bottom corners, structure may intrude into a triangle that is 1220 mm high by 915 mm wide at the base.

10.2.6 Height: 7010 mm from top of rail.

10.2.7 The rail structure clearance gauge for both locomotives and cars are indicated by the drawing below:

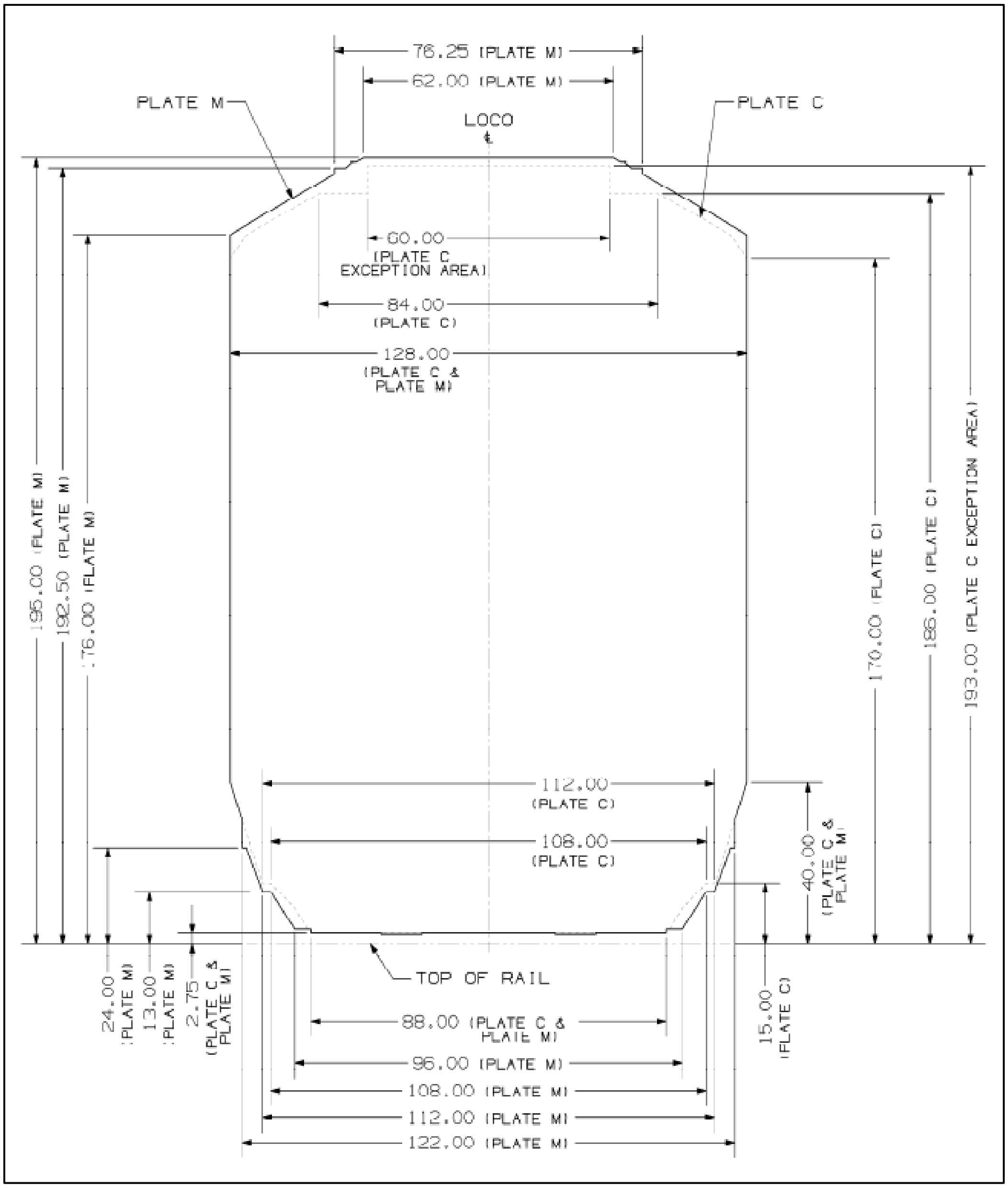

Figure 10-1: Structure Gauge Plate M

11. Rolling Stock Facilities

11.1 Functional Design Criteria for Diesel-Electric Locomotive Depot

11.1.1 The new locomotive maintenance depot facility will be located at the port of Milne and must be designed to perform all maintenance activities on the diesel-electric locomotives that will be used for the main line operation as well as for the shunt mobile located at the maintenance facility. The original designed facilities have been scaled down on floor space for the optimized operations, office requirements and other amenities have been planned to be modular prefabricated units.

11.2 Main Workshop Facility for Diesel-Electric Locomotives

11.2.1 The facility must provide for minor and major repairs which must include for A, B and C shedding that will include but not be limited to the following activities:

- Unscheduled repairs.
- Scheduled repairs.
- Unscheduled maintenance.
- Scheduled maintenance.
- Component exchange (Blower motors, traction motors, compressors, radiators, turbo charger, alternator, electronic control cards, valves, cables etc.) Repair of these components will be by OEM's).
- Wheel cutting.
- Minor engine repairs.
- Fuelling.
- Sanding.
- Attend to driver trip report faults.
- Oil top-up on sub-systems.
- Electronic cards/modules exchange.
- Toilet servicing.

11.2.2 The locomotive maintenance facility must be fully enclosed in a maintenance building/shed and one locomotive must be able to be serviced in the facility at any given time. The servicing line must be equipped with a pit that will allow maintenance staff to enter underneath the locomotive when stationary on the rail line inside the workshop. Access stairs to be provided at both ends of the pit and adequate lighting to be provided inside the pits.

11.2.3 Mobile scissor jack platforms will be provided to allow maintenance staff to obtain access to both sides of the locomotives and perform maintenance activities. The scissor jack platforms must also be able to lift small components (max. 500 kg) that must be installed on the locomotive. Further consideration to fixed working platforms will be given during the feasibility phase.

11.2.4 One overhead crane with a capacity of 45 tonnes must be provided to traverse the locomotive area and 10t for the car workshop area and move heavy components within the depot. A forklift with lifting capacity of 15 ton will be used for other lifting activities inside the workshop.

11.2.5 The locomotive inspection platforms and pit areas will be equipped with 380V and 220V power connections as well as compressed air sockets for electrical and pneumatic maintenance tools being used by the maintenance staff.

11.2.6 The pits will be designed to allow for easy construction as well as allow the cleaning of the locomotive below deck equipment and bogies during inspection cycles. The floor design allows for the drainage and collection of effluent from the pit area which will then be treated on site. Adequate light to be provided inside the pits in order for staff to perform inspections. These lights must be waterproof and adhere to IP65 standards.

11.2.7 The locomotive maintenance facility must be able to maintain the dedicated locomotive fleet of 5 mainline diesel-electric locomotives and one shunt mobile.

11.2.8 The facility must have adequate space for storage of locomotive components in the prescribed manner and this facility must form part of the main shed structure.

11.2.9 Office provision must also be made to accommodate the required staff levels at the depot and must link to the main shed structure.

11.2.10 The locomotive daily servicing and provisioning will take place on the departure siding by means of mobile fueling, sanding and maintenance equipment.

11.3 Main Workshop Facility for Iron Ore Cars

11.3.1 The requirement for car maintenance on the dedicated gondola type fleet is that all maintenance activities will be conducted at the new Milne car maintenance depot.

11.3.2 All scheduled and unscheduled work will be conducted at this new facility.

11.3.3 The maintenance cycle of the iron ore car fleet is based on a 2 year lifting cycle which is derived from the annual kilometres travelled and the associated hollow wear on the wheel sets.

11.3.4 Designs of the car maintenance workshop have been scaled down to accommodate two ore cars per cycle in the workshop.

11.3.5 The following ore car maintenance facility functional design criteria was used in the design of the facility:

- Light repairs.
- Scheduled maintenance.
- Unscheduled maintenance.
- The facility must be able to handle two ore cars in the enclosed area.

- The maintenance facility must be located such that quick turnaround time of cars to be serviced can be achieved.
- Calculations for workshops are based on 365 working days per year.
- Working of day time shifts only.
- Wheel set changes are required at 4 mm hollow wear limit.
- Maintenance on ore car components are based on an exchange principle and sub component repairs are send away for repairs.
- The ore car maintenance facility must be able to maintain the dedicated ore car fleet of 168 cars.
- The facility must be designed to handle the 2, 4, 6, 8 year maintenance cycles for liftings on the cars and equipment must be able to conduct all these scheduled liftings in the depot.
- The depot must be equipped with lifting jacks that can conduct body and bogie lifts inside the main structure of the depot.
- A separate bogie repair area adjacent to the lifting line must be provided to conduct all maintenance on bogie frames, wheels, sub-assemblies, brake systems, couplers, draw gear and body repairs.
- Provision must be made for full brake system testing after the lifting process and must be conducted by means of a single car brake testing system.
- Provision must also be made in the maintenance depot for a wheel lathe that will be required to cut and profile car wheels of the ore car fleet. The locomotive wheel cuts will be performed by means of a portable wheel lathe which will not require a body lift of the locomotive,
- The facility must have adequate space for storage of car components in the prescribed manner and the facility must be linked to the main shed structure.
- Office provision must also be made to accommodate the required staff levels at the depot and must be linked to the man shed structure.
- Provision must be made for store of the following items: oil, rubber pipe, cleaning agents, small parts, coupler and draw gear, bearings, brake valves, knuckles, seals, gas bottles, lubricants and filters and must be linked to the main shed structure.

11.3.6 The following activities will be conducted at the ore car maintenance facility:

- Scheduled repair.
- Unscheduled repair.
- Body repairs.
- Bogie repairs.
- Wheel cutting and re-profiling.
- Bearing replacements.

- Bogie frame repairs and alignment.
- Draw gear replacement.
- Brake system component replacement.
- Body Painting and Stencilling.

11.4 Rolling Stock Maintenance Facility Stores and Offices

11.4.1 The rolling stock maintenance workshop is designed as a single building that provides space for the locomotive repair and car repair. Stores and offices have been moved adjacent to the workshop in modular format for the optimizing process.

11.4.2 The stores for both locomotive and ore car spares are located on the ground floor of the workshop facility and offices are housed adjacent to the workshop. The stores layout is designed with separate areas for locomotives and cars. Provision must be made for parts received- and dispatch counters with the actual stores located in-between. Space allowance must be made based on the spares requirements of the cars and locomotives.

11.4.3 The bigger component store is equipped with wider doors to allow the delivery and collection of heavy parts by means of a forklift directly from the workshop area. An open area store for larger and heavier components is allowed for. The smaller store areas must be equipped with shelving to increase storage space of the smaller components. The store for small parts provides access for individuals only with no need for access for forklifts.

11.4.4 Allowance must also be made for a dark and ventilated store room required for all the rubber pipes and seals. Provision must also be made for a locomotive battery store with battery recharging equipment and with suitable ventilation.

11.4.5 Provision is made for two compressor rooms that house a compressor for the car brake testing bays and a separate compressor that will supply air to the rest of the car and locomotive workshop areas. A separate gas and cleaning agent store must be provided and these are all situated outside the main building, some 25 m away from the main maintenance building. A run-off water collection treatment facility must be provided for the effluent generated inside the workshop area and must be disposed after treatment.

12. Design Criteria Summary

12.1 This Section is a high level tabular summary of the design criteria covered in the preceding Sections of this design rational for the major elements of the optimized track, supporting infrastructure, operations and rolling stock for the railway between Mary River Mine and Milne Port associated with the Expansion Study – Stage II upgrades.

12.2 The tables also provide cross reference to the section numbers where these criteria are discussed.

Table 12-1: General Design

Item	Element	Design Criteria	Section
1.	Project Language	Canadian English	1.5
2.	Rail Classification	Standard Gauge- heavy Haul Railway	1.6
3.	Design Context	Mainly AREMA based, and all codes specified	1.7
4.	Units of Measure	International System (SI)	1.10

Table 12-2: Site Conditions

Item	Element	Design Criteria	Section
1.	Site Conditions	Defined Table 3.1	3.2
2.	Design Base	Standard Specification (H349000-S003120)	3.2

Table 12-3: Operations

Item	Element	Design Criteria	Section
1.	Ore Traffic	12 Mtpa (12.24 Mtpa – wet (2%moisture))	4.1.3
2.	Locomotive Axle Load	33 tonnes	4.2
3.	Car Axle Payload - Initially	30 tonnes	4.2
4.	Maximum Car Axle Load	32.5 tonnes	4.2
5.	Train Design Speed	75 km/h	4.3
6.	Operating Speed	60 km/h	4.3
7.	Locomotives per Train	2	4.4.2
8.	Cars per Train	80	4.4.2
9.	Train Design Length (80)	900 m	4.5
12.	Gross Weight Loaded (72)	9750 tonnes	4.5
13.	Gross Weight Empty (72)	1974 tonnes	4.5
14.	Net Weight (72)	7776 tonnes	4.5
15.	Trainloads per day (72)	6 Loads/day	4.5

Table 12-4: Alignment

Item	Element	Design Criteria	Section
	Horizontal Alignment		**5.2**
1.	Minimum off-set from Tote Road	15 m	5.2.1
2.	Curve Radius Target	≥ 1000 m	5.2.2
3.	Curve Radius Minimum Target	500 m	5.2.2
4.	Curve Radius Absolute Minimum	230 m	5.2.2
5.	Transition Curves R > 300 m	80 m	5.2.3
6.	Transition Curves R ≤ 300 m	60 m	5.2.3
7.	Tangent Length between Reverse Curves	20 m	5.2.4
	Vertical Alignment		**5.3**
1.	Vertical Curve rate of Change	0.040 m/20 m/20 m; K=100	5.3.1
2.	Ruling Gradient facing Loaded	1.5% (1:67)	5.3.2
3.	Ruling Gradient facing Empty	2.0% (1:50)	5.3.2
4.	Exceptional facing Empty < 775 m	3.0% (1:33)	5.3.2
5.	Allowed Facing Empty > 775; G>1% to follow	2.2% (1:45)	5.3.2
6.	Grade Compensation for G=1:X in Radius (R)	1: 20/((20/X)-(14/R)).	5.3.3
7.	Gradients in Passing Track	0 to 0.25%	5.3.2.11
8.	Exceptional facing Empty < 775 m	0 to 0.125%	5.5.2.5
9.	Allowed Facing Empty > 775; G>1% to follow	0 to 0.1%	5.5.2.6

Table 12-5: Earthworks

Item	Element	Design Criteria	Section
	Embankments		**6.2**
1.	Typical Side Slopes	1V:1.5H	6.2.1
2.	Sub Ballast Layer 150 mm	Type 26 Crushed Rock	6.2.2
4.	2nd Layer 550 mm in Non-Susceptible & Potentially Susceptible to Ice soils, choked with Type 26	Type 12 run of quarry rock fill	6.2.2
5.	2nd Layer 1350mm in Moderately Susceptible & Highly Susceptible to Ice soils, choked with Type 26	Type 12 run of quarry rock fill	6.2.2
6.	Geotextile below 1350 mm layer	1800 g/m² Stiff Woven	6.2.2
	Sub-grade Cuttings		**6.2.3**
1.	Cut side slopes in rock	1V:8H	6.2.3
2.	Cut side slopes ice rich soils	1V:2H (for pre feasibility)	6.2.3
3.	Layer Work, Geotextiles and Polystyrene Insulation	Section 6.2.2	6.2.2
4.	Grading Layer Works	Table 6-3 to 6-5	6.5
5.	Recovery of cut frozen ground for fills	Cut to spoil for FS	

Table 12-6: Hydrology

Item	Element	Design Criteria	Section
1.	Design Peak Flows	Extrapolated from Tote study	7.2.1
2.	Flood Return Period	200 years	7.2.2
3.	Design Flows	Q100: V = 3m/sec	7.2.3

Table 12-7: Bridges and Culverts

Item	Element	Design Criteria	Section
1.	The design Criteria for Bridges and Culverts are already in concise summarized format and very comprehensive in the Section indicated		8

Table 12-8: Track

Item	Element	Design Criteria	Section
	Track Superstructure – Rail		**9.3**
1.	Mainline, sidings and yards	136 RE	9.3.2
2.	Mainline Joints	Welded	9.3.2
3.	Yard & Siding Joints	Jointed and Welded	9.3.2
4.	Mainline Ties	Untreated Hardwood Ties	9.4.1
5.	Yard & Siding Ties	Untreated Hardwood Ties	9.4.1
6.	Mainline Tie Spacing	540 mm	9.4.1
7.	Yard & Siding Tie Spacing	540 mm	9.4.3
8.	Curves < R400m Tie Spacing	540 mm	9.4.3
9.	Mainline, sidings and yards Fastenings	Pandrol “e”-clips	9.5.1
10.	Mainline Turnouts	AREMA No. 9	9.7
11.	Yard Turnouts	AREMA No. 9	9.7.4
	Ballast		**9.6**
1.	Ballast Shoulder General	300 mm	9.6
2.	Ballast Shoulder on outside of Curves < 350m	600 mm if LWR	9.6
3.	Ballast Volume	1600 m³/km	9.6
4.	Sub Ballast Depth	150 mm	9.6
5.	Ballast cover between Sub Ballast & Tie	300 mm	9.6
6.	Ballast +Tie Height	312 mm	9.6
7.	Ballast Shoulder Slope	1:2	9.6
8.	Ballast Grading & Properties	Table 9-1 and 9-2	9.6

Table 12-9: Yards and Sidings

Item	Element	Design Criteria	Section
	Milne Tippler Yard		**4.7.3**
1.	Loading Lines	Part of Mainline km's	4.7.3
2.	Departure Loop	900 m	4.7.3
3.	Loco Run-around Loop	347 m	4.7.3
4.	Loco Workshop Spur	390 m	4.7.3
5.	Car Workshop Spur	215 m	4.7.3
6.	Bad Order Car Spur	205 m	4.7.3
7.	Good Order Car Spur	160 m	4.7.3
8.	Quarry Spur and Y	400 m	4.7.3
9.	Cross Over	120 m	4.7.3
	Passing Loop (km's 56.017 to 57.490)		**4.7.1**
1.	Siding	900 m	4.7.1
2.	Back Track	350 m	4.7.1
	Mary River Mine Yard		**4.7.2**
1.	Loading Line right through to Stop Block	Part of Mainline km's	4.7.2
2.	Departure Siding	900 m	4.7.2

Table 12-10: Rolling Stock

Item	Element	Design Criteria	Section
	Locomotives		**10.1**
1.	Fleet Size	4+1 for exchange	4.4.2
2.	Locomotive Type	Diesel Electric	10.1.1
3.	Traction	AC Traction Motors	10.1.1
4.	Horsepower	3,280 kW	10.1.2
5.	Special Specifications	Extreme Cold Weather	10.1.2
6.	Co-Co	6 axles	10.1.3
7.	Minimum Axle load	32 tonnes/axle	10.1.3
8.	Maximum Axle load	33 tonnes/axle	10.1.3
9.	Maximum Length	23 m	10.1.3
10.	Vehicle Gauge	"Plate M" AAR S-2028	10.1.1
11.	Loco Wheel track Gauge	Standard 1,435 mm	10.1.1
	Ore Cars		**10.2**
1.	Fleet Size	180	4.4.2
2.	Car Tare Weight	22 tonnes	10.2.3
3.	Maximum Payload @ 32.5 t/axle	108 tonnes	10.2.3
4.	Coupler to Coupler Length	10.5 m (10.65m incl. Stretch)	10.2.4
5.	Car Width	3.2 m	10.2.4
6.	Maximum Car Height	7.01 m from top of rail	10.2.4

Table 12-11: Rolling Stock Facilities

Item	Element	Design Criteria	Section
	Locomotive Service (in line servicing in the yards)		**11.2**
1.	• Re-Fueling • Sanding • Provisioning and Hygiene • Lubrication • Daily Service Tasks • Attend to driver trip report faults • Oil top-up on sub-systems • Electronic cards/modules exchange • Windscreen replacement • Windscreen wipers replacement	Mobile equipment & provisioning done on departure siding.	11.2.10
	Locomotive Maintenance Facility		**11.2**
2.	• Unscheduled repairs • Scheduled repairs • Unscheduled maintenance • Scheduled maintenance • Component exchange (Blower motors, traction motors, compressors, radiators, turbo charger, alternator etc.). • Wheel cutting • Engine repairs	1 track extended outside workshop;1 locomotive	11.2.1
	Car Maintenance Facility		**11.3**
3.	• Scheduled repair • Unscheduled repair • Body repairs • Bogie repairs • Wheel cutting and re-profiling • Bearing replacements • Bogie frame repairs • Draw gear replacement • Brake system component replacement • Body Painting and Stencilling.	1 track 2 cars	11.3.6
	Stores and Offices		**11.4**
4.	• Loco and Car shops under one roof • Stores accommodated inside the building and modular offices outside and linked to workshop	2 track bays, parts exchange and repair and other facilities integrated	1.4.1 to 11.4.5